



**Roskilde
University**

Unformalized Problems

For Problem Solving in Physics I and Problem Solving in Physics II

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UNFORMALIZED PROBLEMS

For Problem Solving in Physics I

and Problem Solving in Physics II

Jens Højgaard Jensen
February 2016

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UNFORMALIZED PROBLEMS for Problem Solving in Physics I and Problem Solving in Physics II

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This text contains English versions of the so-called unformalized problems (Breddeopgaver) in physics used at RUC. The first part of the text is a minor collection of 68 practice problems from the beginning of the so-called Breddekursus in 1976. The second part collects the exam problems from 1976 – February 2016; in February 2016 there were 672 such problems.

As of September 1, 2007, the Breddekursus has been split into two courses Fysisk Problemløsning I (Problem Solving in Physics I) and Fysisk Problemløsning II (Problem Solving in Physics II). As of 2015 each of these courses covers 10 ECTS points. In the fall of 2010, Problem Solving in Physics I was taught for the first time in English.

The purpose of these courses is, popularly speaking, to train the students to think like a physicist. Secondly, the purpose is to strengthen and broaden the students' knowledge and understanding of physical phenomena and theories within classical and modern physics.

These problem solving courses deviate crucially from physics courses taught at other universities in Denmark and, for that matter, in the rest of the world. The instruction is based on this collection of problems as well as a regular physics text book, but with a focus on the collection of problems. Moreover, the problems at the course exam are not posed with sharply defined and delimited problem formulations.

Rather, an exam problem is a somewhat openly formulated question, so that the formalization of the problem as a step towards a solution is a crucial part of the answer.

An appendix is a reprinted article giving further explanation of the aim of the courses and the related type of problems.

The majority of the problems have been translated by Martin Niss from the Danish version.

Jens Højgaard Jensen, February 2016

UNFORMALIZED PROBLEMS
for
Problem Solving in Physics I
and
Problem Solving in Physics II

1976 — 2016

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Preface

This collection of unformalized problems (so-called Breddeopgaver, literally “broad problems”) contains a minor collection of practice problems as well as exam problems from 1976 – January 2016.

Up to and including 2007, the exam problems are from the so-called Breddekursus in physics at RUC. The minor collection has been developed to give a starting point for this course. The Breddekursus initiated the specialized studies in physics after two years of basic studies. The course took one year with instruction 2 half days per week and had a size equivalent to 18 ECTS points. The test consisted of two written, closed-book tests of 4 hours’ duration with a 48 hours interval in between.

As of September 1, 2007, a new study regulation for the specialized studies in physics became effective, so that the syllabus of the Breddekursus is divided into two courses:

Fysisk Problemløsning I (Problem Solving in Physics I) and
Fysisk Problemløsning II (Problem Solving in Physics II)

Each of these courses covered 7.5 ECTS points. In 2015 yet another study regulation meant that the two courses were expanded to 10 ECTS points each; the syllabus of Problem Solving in Physics I was supplemented by some tools from the mathematical toolkit and Problem Solving in Physics II now includes more electrodynamics. Both course ends with a written, closed-book, 4 hours test.

In the fall of 2010, Problem Solving in Physics I was taught for the first time in English. Problem Solving in Physics I is part of the bachelor study and can be taken either at the second year of the basic studies or at the third year of the bachelor study after the basic studies. The course focuses on the solving of problems taken from the physics syllabi of Danish high schools and the basic studies course “Classical Mechanics” enlarged with additional mechanics, hydrodynamics, thermodynamics and relativity.

Whereas Problem Solving in Physics I is thus placed at the beginning of the physics education, Problem Solving in Physics II is conceived as “the crowning glory” towards the end of the Master’s study, where the combined theory that has been learned during the total physics education can be brought into play. The course focuses on problem solving of problems taken from the syllabus of the bachelor degree in physics enlarged with electrodynamics, optics, quantum physics, statistical physics, atomic physics, nuclear physics, particle physics, and solid-state physics and astrophysics.

For Problem Solving in Physics I it is assumed that the participants have the qualifications corresponding to A levels in both mathematics and physics

from a Danish high school supplemented with at least the courses “Calculus” and “Classical Mechanics” at the Basic Studies in Natural Sciences program.

For Problem Solving in Physics II it is assumed that the participants have the qualifications corresponding to a least a bachelor degree from RUC with physics as one of the two disciplines.

The purpose of both Problem Solving in Physics I and Problem Solving in Physics II, is, popularly speaking, to train the students to think like a physicist. Secondly, the purpose is to strengthen and broaden the students’ knowledge and understanding of the said broad collection of phenomena and theories within classical and modern physics.

The instruction in the Problem Solving in Physics I and Problem Solving in Physics II takes place in the spring semester and the fall semester, respectively. The instruction consists of a mixture of review lessons, problem solving and discussions. Due to the amount of material covered, the courses are quite demanding in terms of homework. These problem solving courses, as well as the previous Breddekursus, deviate crucially from physics courses taught at other universities in Denmark and, for that matter, in the rest of the world. The instruction is based on this collection of problems as well as a regular physics text book, but with a focus on the collection of problems. Moreover, the problems at the course exams are not posed with sharply defined and delimited problem formulations. Rather, an exam problem is a somewhat openly formulated question, so that the formalization of the problem as a step towards a solution is a crucial part of the answer. This aspect of the problems combined with the fact that they are demanding in terms of insight into the fundamental concepts and phenomena from a wide range of classical and modern areas of physics, give the courses a central position within the specialized studies in physics.

Jens Højgaard Jensen has, through the years, been the recurrent teacher of the course and has produced a little less than half of the problems in this collection. In addition, through the years, Lasse Rasmussen, Aage Bonde Kræmer, Karin Beyer, Albert Chr. Paulsen, Tage E. Christensen, Bent C. Jørgensen, Poul Winther Andersen and Martin Niss have taught the course as well as produced problems for it. Moreover, changing part-time lecturers have taught the section on astrophysics of the course and have contributed to the problems on this topic.

In the previous Breddekursus, the exam problems covered the entire syllabus and were a mixture of more manageable and more challenging problems. The list below indicates, by page number and number, a subset of the exam problems that, in terms of level of difficulty and syllabus, are within the scope of Problem Solving in Physics I:

1.1, 1.3, 1.4, 1.5, 1.6, 2.8, 2.10, 3.12, 3.15, 4.17, 5.18, 5.19, 5.21, 6.24, 6.26, 7.29, 7.32, 7.33, 8.35, 8.38, 9.39, 9.41, 9.42, 9.43, 11.49, 11.53, 11.54, 12.55, 12.57, 12.60, 13.62, 13.64, 13.65, 15.1, 15.4, 15.6, 17.2, 17.5, 18.6, 19.1, 19.4, 19.6, 20.8, 21.2, 21.4, 21.6, 21.7, 22.8, 23.1, 24.4, 26.1, 27.4, 27.5, 27.7, 28.2, 31.1, 33.8, 34.3, 35.7, 36.2, 36.4, 37.8, 38.1, 40.2, 40.4, 42.1, 42.4, 43.7, 45.1, 46.5, 47.7, 48.1, 49.4, 50.7, 51.8, 53.2, 54.6, 54.7, 54.8, 55.2, 56.3, 56.4, 58.6, 60.2, 62.6, 65.1, 66.3, 69.7, 69.8, 70.1, 71.2, 76.1, 76.2, 77.4, 80.2, 80.3, 81.4, 82.2, 83.3, 84.7, 84.8, 85.1, 87.6, 88.7, 89. 1, 90.6, 90.7, 91.2, 92.5, 92.6, 93.8, 94.2, 95.4, 96.6, 97.8, 98.2, 99.5, 99.6, 101.1, 101.2, 102.6, 102.8, 103.1, 103.3, 104.4, 104.6, 105.8, 106.1, 107.4, 107.5, 107.7, 107.8, 108.1, 108.2, 108.4, 109.6, 109.7, 109.8, 111.3, 112.7, 114.4, 114.5, 115.7, 116.1, 117.4, 117.5, 119.5, 120.1, 122.1, 122.3, 123.5, 124.1, 124.2, 125.4, 126.1, 131.3, 131.4, 132.4, 133.3, 133.4, 133.5, 134.4, 136.2, 136.3, 137.5, 138.2, 139.4, 141.1, 141.2, 142.4, 143.1, 143.2, 144.4, 144.5, 145.1, 145.3, 146.5, 147.1, 147.2, 149.3, 149.4, 150.1, 150.2, 151.1, 151.2, 151.4, 151.5, 152.2, 152.3, 152.5, 153.1, 153.3, 154.3, 154.5, 155.1, 156.1, 156.4, 157.1, 157.2, 158.4, 159.1, 159.3, 159.5, 160.1, 160.4, 161.1, 161.2, 161.3, 161.5, 162.2, 162.4, 163.1, 163.4, 164.3, 165.5, 166.1, 166.2, 166.3, 167.4, 168.1, 170.1, 170.2, 170.3, 171.5, 172.1, 172.2, 174.1, 174.2, 174.3, 174.4, 174.5, 175.1, 175.3, 177.1, 178.5, 179.1, 179.4, 180.2, 180.3, 181.4, 181.5, 182.1, 182.3, 182.5, 183.1, 183.4, 183.5, 184.1, 184.3, 185.1, 185.2, 187.2, 188.5, 189.1, 189.3, 189.4, 189.5, 190.1, 190.4, 191.5, 192.1, 192.2, 192.3, 193.2, 194.4, 194.5, 195.1, 195.3, 194.4, 195.5, 197.1, 200.3, 202.1

1. When drilling oil, pumps are usually not necessary as the pressure in the oil in itself is sufficient to press the oil to the surface.

How big is the pressure?

Justify your answer.

2. Why is there a bang when a fighter plane breaks through the sound barrier?

3. We assume that, roughly speaking, the universe has a uniform density of stars. How does the amount of light that we receive from stars that are a certain distance away from the Earth depend on the stars' distance to the Earth?

How would the night sky look if there were stars at arbitrary large distances?

Justify your answers.

4. A power station gets its cooling water from the sea.

What is the ratio between the station's capacity during summer and during winter, if the sea temperature goes from 15°C to 0°C , and the temperature of the kettle is kept at 180°C ? Justify your answer.

5. The folks at CERN observe some phenomena when two proton beams with opposite momenta collide and the energy of the protons is about 30 GeV .

How much energy would be required of the protons in the proton beam in order to observe the corresponding phenomena in collisions with hydrogen at rest in the laboratory?

Justify your answer.

6. Why is high voltage used in the transportation of electricity over large distances?

7. What is the maximum momentum of an electron bound in an atom?

In principle, what is the smallest size of an atom?

Justify your answer.

8. As is well-known, a helicopter has an extra vertically rotating propeller at its tail.

What is the reason for this?

Justify your answer.

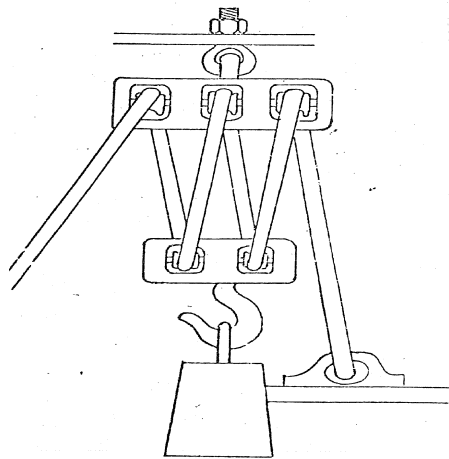
9. Positrons and electrons can for a short time period form a system, positronium, with stationary states analogous to the revolution of the electron around the proton in the hydrogen atom. Radiation with characteristic wavelengths corresponding to the transitions between these states can be observed experimentally.

Where in the spectrum is this radiation?

Justify your answer.

10. What force is required to lift the plumb bob of the sketched pulley arrangement compared to the force required to lift the bob using a single pulley?

Justify your answer.



11. What is the heat capacity of a gas consisting of N atoms?
What is the heat capacity of a solid material consisting of N atoms?
What role do the electrons play for the size of the heat capacity?
Justify your answers.

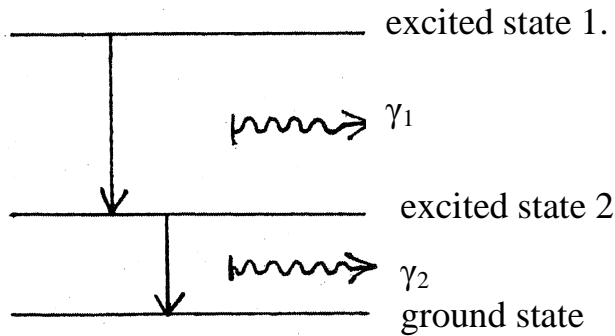
12. A man is standing on the edge of a wharf and is close to fall backwards. By making a rotating movement with his arms, he gets back in upright position. In which of the two possible ways is he rotating his arms?
Justify your answer.

13. When a conducting metal band is placed in a magnetic field perpendicular to the band, a voltage difference between the two sides of the band appears. What is the cause of this so-called Hall effect, and how large is the voltage difference?
Justify your answer.

14. Sketch a method for the determination of the radius of a star when its total radiance and surface temperature (i.e. spectral type) are known.

15. What numerical quantities need to be known in order to calculate the velocity of falling raindrops?
Which fall fastest: Large or small drops?
Justify your answers.

16. Some excited nuclei often decay to another excited state, which then decay to the ground state (see the figure.) The net result of these decays is two photons (light quanta) with different energies that can be detected.



A so-called coincidence measurement registers only the cases where the second photon is emitted within a very short time after the first one. What is the least possible variation of energy of the registered photons?

17. A piece of rock is to be dragged horizontally along the ground using a rope, tied around the piece. Determine the angle that the direction of pull should make with the direction of motion to make the pull force as small as possible.

18. When cosmic rays interact with the Earth's atmosphere, unstable elementary particles are generated. They move with the velocity V towards the Earth. The decay time of similar particles at rest is T .

What decay time is observed when the said particles are observed from the Earth?

Justify your answer.

19. A sun oven essentially consists of a large mirror or a lens that focuses the sun rays on the material to be heated.

What is the maximum temperature obtainable with a sun oven?

Justify your answer.

20. An electromagnet is driven by an alternating current so that the magnetic field changes direction concurrently with the current. A copper ring is placed with its opening turned towards one of the magnet's poles.

What is the impact on the ring of the electromagnet?

Justify your answer.

21. For the driver's license test, the driver needs to know that the braking distance is proportional to the square of the velocity.

Argue for the usefulness of this rule.

22. The Earth is constantly hit by electrons emitted by the Sun.

Where do most of them enter the atmosphere?

Justify your answer.

23. The dissociation energies for the molecules O_2 and N_2 are 5.05 eV and 7.37 eV, respectively.

What do these facts imply for the radiation that can hit the Earth?

24. A heat pump is used to heat a house. The pump functions approximately as an ideal Carnot process operating between the ground outside the house at a temperature of 5°C and a hot-water tank inside the house at a temperature of 60°C . Heat is conducted from the hot-water tank via a central heating device to the living room that has a temperature of 20°C .

What is the ratio of heat delivered to the living room and the energy used to operate the heat pump?

Justify your answer.

25. Photos of the Sun show that the central parts of the disc of the Sun shines much brighter than the edge or limb.

Explain this so-called limb darkening.

What is the effect of the presence of the Sun's atmosphere for the phenomenon?

26. What is the relation between wave speed and wavelength for the waves in the Atlantic Ocean?

Justify your answer based on a dimensional analysis.

27. A neon tube functions in the following way: Electrons, which are accelerated by a voltage drop along the tube, collide with neon atoms. This excites the latter, so that light is emitted when the neon atoms decay to their ground state.

Explain the fact that it is possible to hold a neon tube without burning oneself, in contrast to the case for an ordinary light bulb.

28. The tidal waves of the Earth contain a lot of energy that may be used for practical purposes. What is the origin of this energy?

29. A satellite orbiting the Earth is equipped with an air conditioning system that ensures that the composition and the pressure of the air within the satellite are like those at the surface of the Earth.

Can a candle burn in the satellite?

Justify your answer.

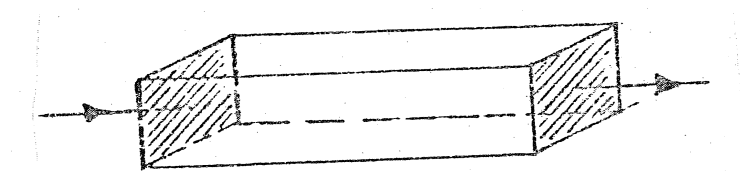
30. At what distance is it no longer possible to discern the two lights of a car?

31. Sketch a method that can be used to study whether the inert gases are monatomic.

32. A container with insulating side faces and conducting terminal surface is filled with liquid or gas containing free ions.

What resistance is met by an electric current through the container, if the frictional resistance of the ions is assumed to be proportional to their velocity?

Justify your answer.



33. Is it more petrol efficient to use a somewhat high compression ratio than a low one in a petrol engine?

Justify your answer.

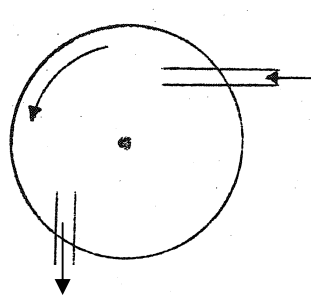
34. Is it possible to determine whether the Sun has an atmosphere as well the possible composition of it based on observations done on the Earth?
Justify your answer.

35. A fire hose is lead around a corner and firemen are placed on each side of the corner. When water is flowing in the hose the firemen have to use force to strain the hose from straighten out.
How much force do they have to apply?
Justify your answer.

36. Is it reasonable to envisage the neutron as composed of an electron and proton kept together by electrostatic forces?
Justify your answer.

37. How many times hotter is white-hot iron compared to red-hot iron?
Justify your answer.

38. The figure below is a schematic diagram of a water turbine.



How large is the torque delivered by the turbine?
Justify your answer.

39. Attempts have been made to order all cars to drive with roughly the same velocity at selected road spots.

How does the capacity of the road depend on this velocity?

40. A light beam is split into two beams, which are then brought to interfere. What is the ratio of the light intensities between at an interference maximum and an interference minimum when the ratio of the intensities of the two beams is 100?

Justify your answer.

41. An electron and positron annihilate with the emission of two or more light quanta.

Why not only a single light quantum?

42. How should one hold a floor mop in order to move it by pressing along the shaft?

Justify your answer.

43. Why is an air plane wing more curved on the top side than the underside?

44. A beam of parallel electrons is shut through a hole.

What is the least possible angular dispersion of the beam after the passage through the hole?

Justify your answer.

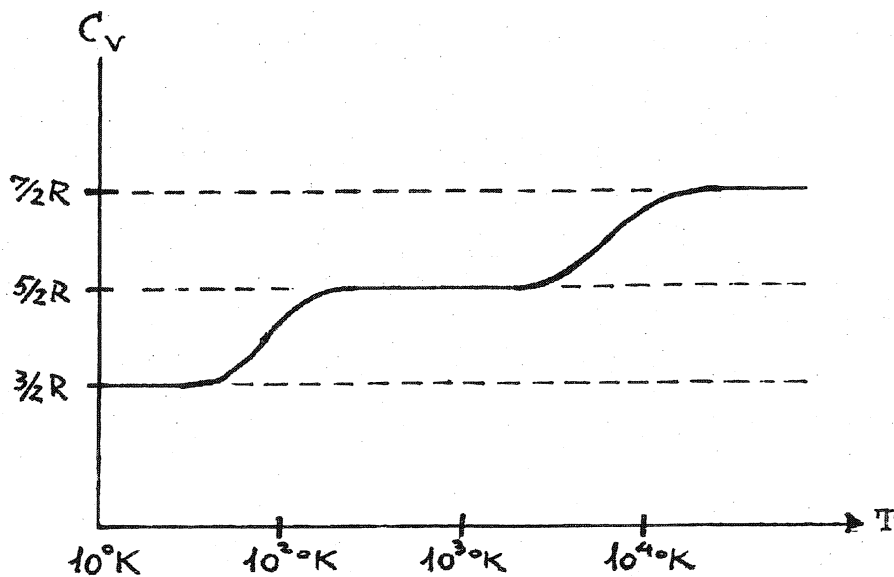
45. How can we observe whether distant stars move relative to the Earth?

Justify your answer.

46. How large is the energy content in a charged capacitor?
Justify your answer.

47. Does the temperature increase or decrease in the central parts of a star as most of the hydrogen is converted to helium?
Justify your answer.

48. The graph shows the heat capacity of a hydrogen gas as a function of temperature. Like the hydrogen molecule, the deuterium molecule is diatomic with the same chemical configuration. The mass of deuterium, however, is roughly twice the mass of hydrogen.
Draw the equivalent graph for deuterium indicating qualitative differences and similarities between the two gases at different temperatures.
Justify the sketch.



49. A train consists of 40 similar wagons and one locomotive, weighing 5 times as much as each wagon. The locomotive pulls the wagons with the force F . How large is the force by which wagons numbers 30 and 31 pull at each other? Justify your answer.

50. If a magnetic needle is placed parallel to an electric wire and the current is switched on, it is well-known that it will deflect according to the right-hand rule.

Explain how the magnetic needle knows the difference between right and left.

51. Charged particles (such as protons and alpha particles) need to have kinetic energies of the order of MeV to penetrate nuclei. The binding energy for electrons in atoms is of the order of eV.

Can this information be used to estimate the ratio between radii of nuclei and atoms?

Justify your answer.

52. What forces should be taken into account when setting up the conditions for mechanical equilibrium of a star's atmosphere?

Justify your answer.

53. What is the period of revolution of a satellite revolving around the Earth?

Justify your answer.

54. Is it possible to say something about the ratio of the frequencies of high and deep notes based on the physical dimensions of tweeters and woofers (high and low frequency loudspeakers, respectively)?

55. What is the least velocity that a rocket needs at the surface of the Earth to be sufficiently large to allow the object to move out of the gravitational field of the Earth?

Justify your answer.

56. Stars are thought to originate from cold hydrogen clouds in the universe that have condensed due to gravitational forces.

How can it then be explained that the stars obtain sufficiently high temperatures in the center to start fusion processes?

57. Estimate an upper bound on the power that a windmill can deliver.

Justify what you are doing.

58. An alternating current transformer consists of two coils with different numbers of turns that are wound around a common iron core.

What is the ratio of the voltage delivered to the transformer to the voltage obtained from the transformer?

Justify your answer.

59. Experiments with emission of γ quanta from nuclei followed by absorption in similar nuclei give different results when the source and absorber is placed vertically above each other and when they are in the same horizontal plane.

Explain this fact.

60. What is the shape of the surface of a liquid in a centrifuge?

Justify your answer.

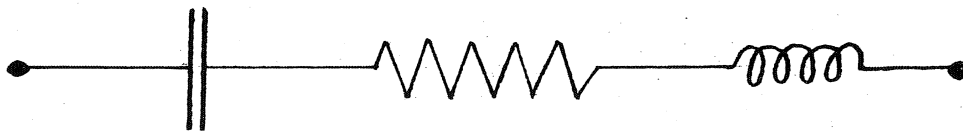
61. Why are we talking about an energy crisis when energy is conserved?
Justify your answer.

62. A π^+ meson (rest energy 140 MeV) decays to a muon (μ^+ with rest energy 105 MeV) and an neutrino (ν_μ with zero mass); schematically

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

How large is the momentum of the muon in the rest system of the π^+ meson?

63. At what oscillation frequency (for the voltage) will the following impedance act like a purely ohmic resistance?



Justify your answer.

64. A car drives at velocity V . All the windows in the car are closed and the car is draught tight. When the driver opens the ventilation window, he feels that he has swallow to balance a pressure difference.

Does the pressure in the car decrease or increase when the ventilation window is opened?

Justify your answer.

65. When an orchestra tunes instruments, the musicians make sure that the instruments play the same note in the same way, i.e. with the same frequency. How does it sound (besides off-key) when two instruments that are almost but not quite in tune are compared?

Justify your answer.

66. Judged from its color and calculated mass, α Centauri A must look a lot like the Sun. Measurements shows that here on the Earth the light intensity of the Sun is 10^{11} times that of α Centauri A.

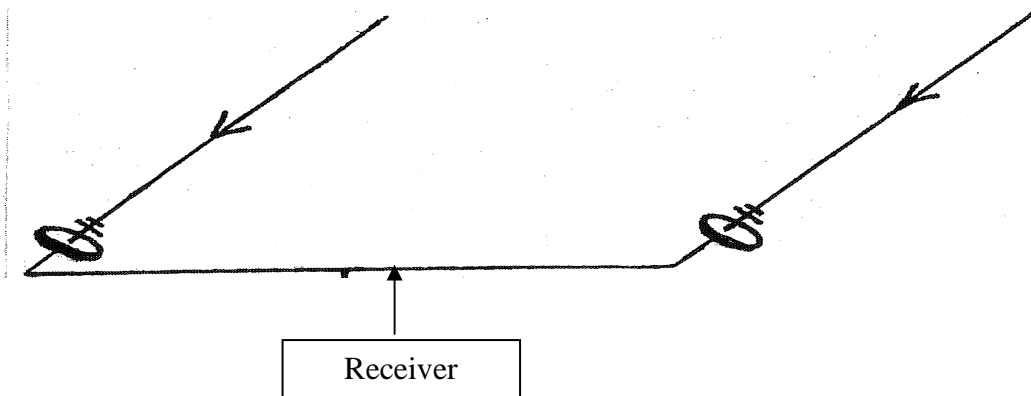
What is the distance to α Centauri A relative to the Sun?

Justify your answer.

67. Radio astronomers use the arrangement sketched in the figure. It is possible to regulate the relative distance between the radio telescopes as well as change the common orientation of the antennas. The received signals are transmitted via wires of equal length to a single receiver placed in the middle of the arrangement.

What distance between the two antennas for a given orientation gives the largest possible resulting signal in the receiver when operating at a particular wavelength?

Justify your answer.



68. Why are antennas for car radios placed outside the car?

Written, 4-hour test in first module physics

To be held: July 12, 1976, 9.00-13.00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. With how large an incline should a curve of a high way be constructed?

Justify your answer.

2. The iron atom weighs about 1% less than the sum of the masses of its constituents. Explain this fact.

3. Colored rings can sometimes be observed in oil films on materials.

How thick are these films?

Is the blue ring the innermost or the outermost ring?

4. A person is alternately at the center and at the periphery of a merry-go-round.

What is the ratio of the angular velocities in the two situations?

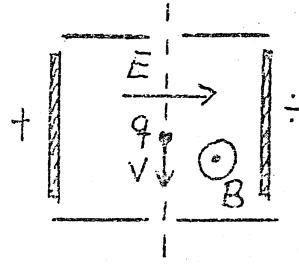
5. Why are the presence of electrons and their movements not taken into account when the heat capacity of a NaCl crystal is calculated?

6. In a particular winter month, a solar heating system linked to a house can sustain a temperature of 30°C in a hot-water tank connected to the heating system. A heat pump, used to heat the house, functions approximately as an ideal Carnot process between this hot-water tank and a hot-water tank at a temperature of 55°C inside the house. If the solar heating system was not present, the heat pump could operate by using the ground outside the house at temperature of 5°C and the hot-water tank inside the house at a temperature of 60°C .

What is the ratio of the energy amounts used to operate the heat pump with or without the solar heating system in the mentioned winter month?

Justify your answer.

7. Charged particles are shut through an electric and a magnetic field as shown.



Only particles of a particular velocity get through. How large is that velocity?
Justify your answer.

8. What is the ratio of typical temperatures of burning garden bonfires to typical temperatures of exploding hydrogen bombs?
Justify your answer.

Written, 4-hour test in first module physics

To be held: July 16, 1976, 9.30-13.30

NO AIDS ALLOWED

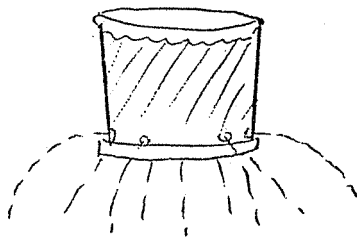
Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. A charged particle moves in circular trajectory in a magnetic field.

What is the angular frequency?

Justify your answer.

2. A primitive sprinkling arrangement consists of a bucket with holes in and along the bottom as shown in the figure.



The bucket is continuously filled to the rim with water and is permanently hung up at a certain height above the place to be sprinkled. How large is the area that gets sprinkled? Justify your answer.

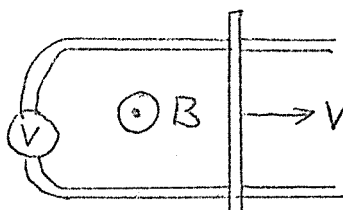
3. Sketch the heat capacity, C_V , as a function of temperature for a diatomic gas. Justify the sketch.

4. Estimate, based on the uncertainty relation, the least possible kinetic energy of the nucleons in a nucleus of a given nuclear radius.

5. What is the ratio of the force needed to pull out horizontally the two topmost boards in a pile of boards to the force needed to pull out the second board from the top while the topmost board is held fixed in its place? Justify your answer.

6. How does the pressure in the atmosphere decrease with the height?
Justify your answer.

7. A metal bar rolls with velocity v on some subjacent metal tracks as shown in the figure



The arrangement is placed in a magnetic field as shown.
What does the voltmeter show?

8. Why do television antennas on roofs look the way they do?
What is the order of magnitude of the wavelength for the television waves?
Justify your answers.

Written, 4-hour test in first module physics

To be held: January 12, 1977, 9.30-13.30

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. How far away from the front of a house with an inclined roof is there a risk of getting hit by a lump of ice falling from the roof?

Justify your answer.

2. A particular star has dust particles in its vicinity that are at absolute rest relative to the star. Estimate the size of these particles.

3. In high precision measurements of the diameter of thin strings, the string is placed between two plane glass plates in a microscope as shown in the figure.



If the plates are illuminated perpendicularly by monochromatic light, light and dark lines can be observed on the area between the plates' mutual touching point and the string.

How is the thickness of the string determined?

Justify your answer.

4. Explain how a rocket motor works in space devoid of air.

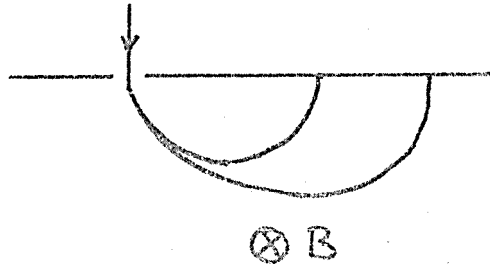
5. Crystals with a large conductivity (metals) are always opaque to light.

Explain this fact.

6. What is the relation between electricity consumption and temperature for a deep freezer if we assume that the motor of the freezer works as an ideal Carnot process between the interior of the freezer and its environment?

Justify your answer.

7. A mass spectrograph separates the different ions in an ion beam of known velocity by using a magnetic field as shown in the figure.



How do the positions of the pick-up points for the different kinds of ions depend on their properties? Justify your answer.

8. Many experiments require the transportation of unstable particles of a given lifetime (at rest) over a certain distance through a vacuum tube at high velocities.

How large a fraction of particles survive the transportation through the tube? Justify your answer.

Written, 4-hour test in first module physics

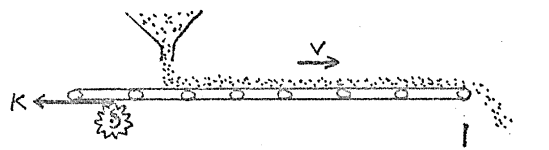
To be held: January 14, 1977, 9.30-13.30

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. How does the self-inductance coefficient of a coil depend on the number of turns?

2. A conveyor belt functions as shown in the figure.



How large a force does the motor have to exert on the belt? Justify your answer.

3. Electrons have a magnetic moment which in the presence of a magnetic field points either in the same direction as the magnetic field or the opposite direction, so that the energy associated with the interaction between magnetic field and the electrons can only assume two values.

How does the magnetization of an electron gas vary as a function of temperature? Justify your answer.

4. Can a free electron absorb or emit a light quantum?

Justify your answer.

5. For those materials which are used in atom bombs because they have a certain density of nuclei that can easily undergo fission, the explosion does not happen until a certain critical amount of the material is brought together in a lump. Explain this fact.

6. Upon arrival in a cold house, the electric heating elements are turned on.

What is the change in the temperature of the house as a function of time?

Justify your answer.

7. For speed detection, the police uses a radar signal reflected by the controlled car.

What is the relation between the relative frequency shift for the reflected signal and the velocity of the car?

8. How does the speed of sound in a solid material depend on the constants of the material? Justify your answer based on a dimensional analysis.

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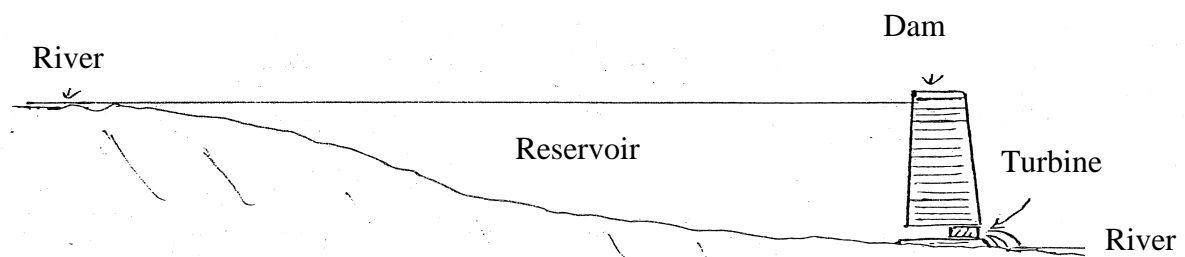
Written, 4-hour test in first module physics

To be held: June 14, 1977

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. A hydroelectric plant is constructed so that water flows from a dammed reservoir through a tube with a built-in turbine to a lower outlet.



Estimate an upper bound on the power of the plant if it runs continually.

2. Under certain circumstances a so-called “muon-atom” can be generated when an electron of an atom is replaced by a captured negative muon with mass 207 times that of the electron.

How are the binding energy and size of a hydrogen atom changed if its electron is replaced by a muon?

Justify your answers.

3. According to the media, there are now satellites in orbit with cameras that can distinguish objects with a size of $1/4$ m.

What is the least possible size of the lens if the satellite is at a height of 300 km? Justify your answer.

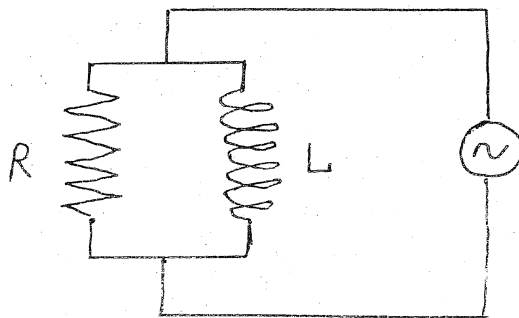
4. In a Van de Graff accelerator electrons are accelerated by traversing a constant, homogeneous electrical field. The electrons are first at rest and then reach relativistic velocities.

What is the final velocity of an electron in an accelerator of a given length? Justify your answer.

5. In a photometric, binary star the two components cannot be distinguish optically, but they move in such a way that the plane of the relative motion contains the direction towards the Earth.

Sketch the observed light intensity as a function of time for such a binary star and justify the sketch.

6. What is the impedance of the following alternating current circuit?



Justify your answer.

7. Water at a particular temperature is poured into an ice cube tray, which is then put into a freezer.

Estimate the electricity consumption of making ice cube from the water.

Justify your answer.

8. A radioactive preparation contains a certain concentration of a substance that by radioactive decay is transformed into another element. This element is also unstable and is transformed by a new decay.

State the ratio of the concentrations of the two unstable substances when the concentration of the “intermediate” substance can be considered constant.

Roskilde University

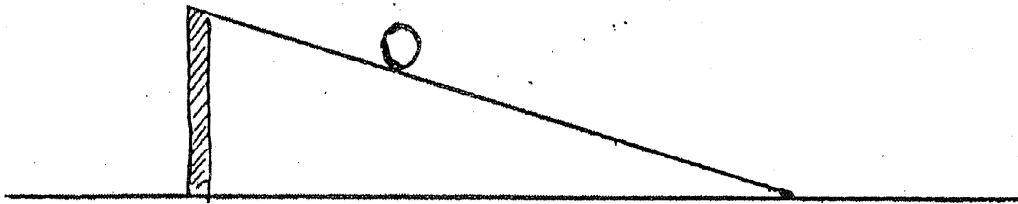
Written, 4-hour test in first module physics

To be held: June 17, 1977

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. A cylinder shaped barrel rolls down a ramp. It starts at rest at the top.



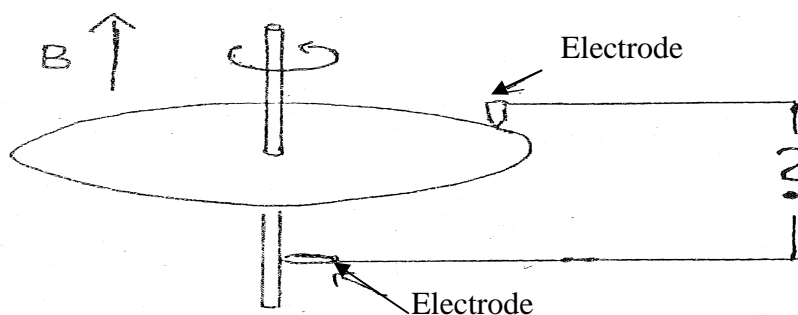
Does it get to the bottom fastest if it is massive or hollow?
Justify your answer.

2. In many applications (e.g. radio tubes) a filament is used as an electron source.

How does the number of produced electrons depend on the temperature of the filament (an approximate expression that contains the dominating temperature dependence is sufficient)?

Justify your answer.

3. A primitive direct current generator can be built from a conducting metal disk that rotates about its axis of symmetry in a fixed homogenous, magnetic field parallel to the axis of rotation.



How large is the electromotive force, i.e. the voltage difference between center and edge of the disk?

Justify your answer.

4. As is well known, the orbital planes of all the planets are roughly coincident. Give a physical explanation for the cause of this fact.

5. A photon is scattered elastically on an atom (the atom is in its ground state before and after the scattering) so that the photon's direction of motion after the scattering forms a certain angle with the original direction.

How does the change of frequency (the difference between the frequency of the original and the scattered photon) depend on the scattering angle?

Justify your answer.

6. If the light of a distant light source is observed through a small slit (small compared to the size of pupil), one does not see a clear image of the slit, but rather a system of bright and dark stripes.

Explain this phenomenon.

7. Sometimes it happens that a region of the Earth becomes warmer than its surroundings, e.g. land relative to the sea on a hot summer day.

Does a relative high or low pressure arise at the warmest place?

Justify your answer.

8. A capacitor with variable capacity (e.g., a rotating plate capacitor) is charged with a certain charge. Then work must be done (by turning the knob) to change the capacity.

How does this work depend on the change of capacity?

Justify your answer.

Written exam in first module physics, Breadth module

Tuesday January 10, 1978 – 4 hours

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. What is the age of the universe?

Give two justified estimates.

2. A ventilation system is designed to renew the air in a room every fifteen minute.

Estimate the dependency of the electricity consumption on the size of the room and the size of the opening of the exhaust device.

3. It is possible to find naturally occurring radioactive elements that decay through chains of other unstable substances, until the chain ends at a stable substance. As an idealized chain we can look at element A, which through emission of an alpha-particle (helium nucleus) transforms into substance B that by emission of yet another alpha-particle becomes a stable substance. Let A have a half-life of 10^6 years and B a half-life of 1 hour.

How much helium is produced per year per mole of A?

Justify your answer.

4. A capacitor is charged by a battery of a given EMF through a fixed ohmic resistance.

How does the current depend on time if the capacitor is uncharged when the current is turned on?

Justify your answer.

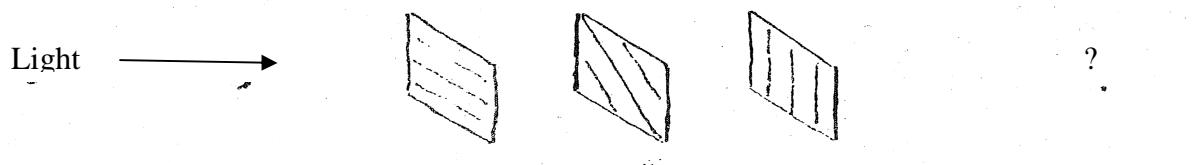
5. Newton's theorem states: If two balls of the same mass collide and one of them is at rest before the collision, then after the collision they will move with velocities that are perpendicular to each other. (Here one neglects possible rotations of the balls; thus this is not exactly true for billiard.)

Is the corresponding angle larger or smaller than 90° if the collision happens at relativistic velocities?

Justify your answer.

6. If the center of the Sun radiates as a perfect black body with temperature $2 \cdot 10^7$ K, what is the wavelength of the radiation that has maximum intensity in the center of the Sun?

7. A Polaroid absorber (such as the glass in Polaroid sunglasses) allows only light that is linearly polarized in a certain direction to pass. We place three such absorbers one after another as shown in the figure, where the hatching shows the allowed direction of polarization.



That is, number 2 is turned 45° relative to 1 and number 3 is turned 45° relative to number 2 and 90° relative to 1.

What is the reduction of the intensity of a beam of unpolarized light passing through this set up?

Justify your answer.

8. It turns out that for rather large groups of crystals the ratio of the heat of fusion (per mole) to the melting point (absolute temperature) is roughly the same for the entire group even though both quantities vary a lot.

What does this tell us about the entropy difference between the solid and liquid state of the substances in the group?

Justify your answer.

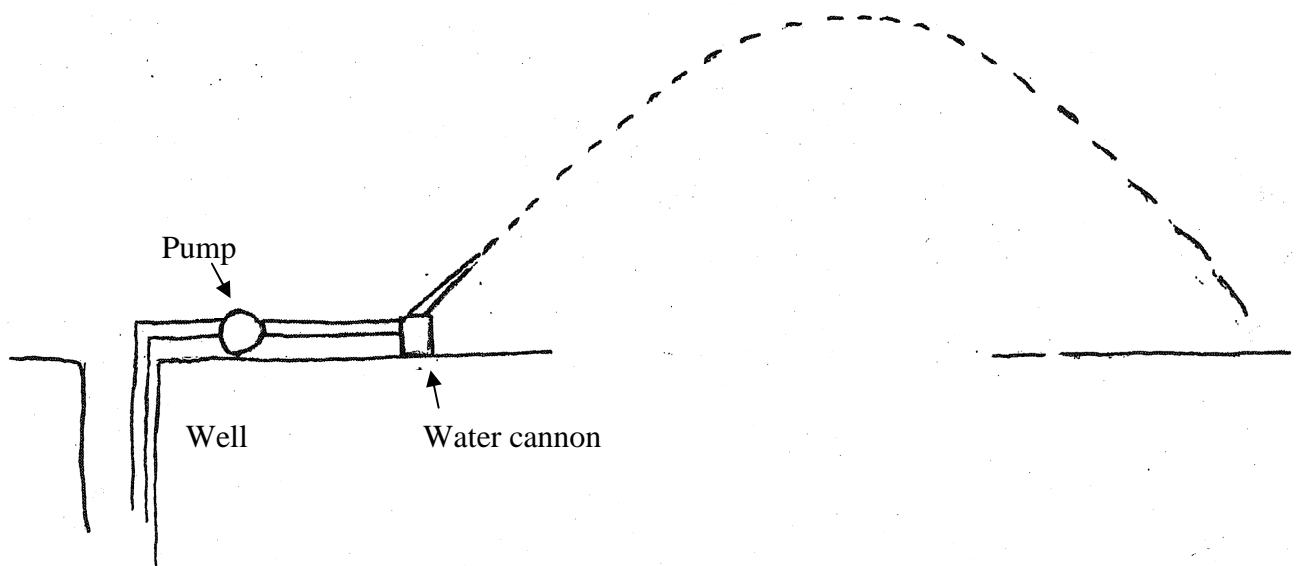
Written exam in physics first module, Breadth course

Thursday, January 12, 1978

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. A so-called water cannon is used for irrigation of fields. It is driven by a pump whose constant pressure gives an outflow velocity that allows a circle of radius 10 m to be irrigated by the cannon.



Estimate the energy consumption per tons distributed water if the water also has to be pumped up from 5 m below the ground.

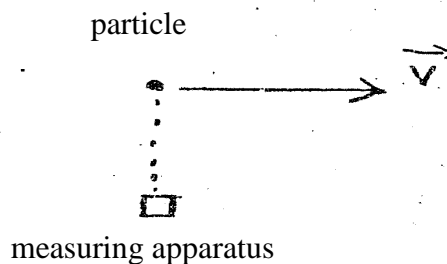
2. Due to the interaction between the magnetic moments of the electrons and the nucleus (the moments are proportional to the respective spins) the stationary states of the atoms are split into several closely spaced energy levels (the hyperfine splitting).

How many hyperfine levels does the ground state of hydrogen split into?
Justify your answer.

3. If the bolometric magnitude of the Sun increases 2.5 magnitudes then by how much will the solar constant and the surface temperature of the Sun change? (Under the assumption that the distance between the Earth and the Sun does not change.)

4. A charged particle moves at a relativistic velocity relative to a measuring apparatus.

What magnitude of the electrical field will the apparatus measure in the moment that the particle passes at a given distance?



5. In a strip light, the light emission is due to the transition between discrete atomic states. The spectrum is thus a line spectrum.

What is the observed line width (at least) if the gas in the strip light has a particular temperature?

Justify your answer.

6. Estimate the magnification of an astronomic telescope that is required in order to use the angular resolution capacity of the objective optimally.

7. An unstable nucleus A of spin 1 (in units of \hbar) decays to another nucleus B of spin 0 and an α -particle (helium nucleus), that also has spin 0. Thus

$$A \rightarrow B + \alpha$$

A substance with a certain concentration of A nuclei is placed in a strong magnetic field; the field will polarize partially these nuclei. The spin will thus have a tendency to align parallel to the magnetic field.

Will we observe more or less alpha-particles emitted in the direction of the magnetic field compared to the same direction in the unpolarized case?

Justify your answer.

8. What quantities determine the acceleration capacity of a car and how does the acceleration depend on these?

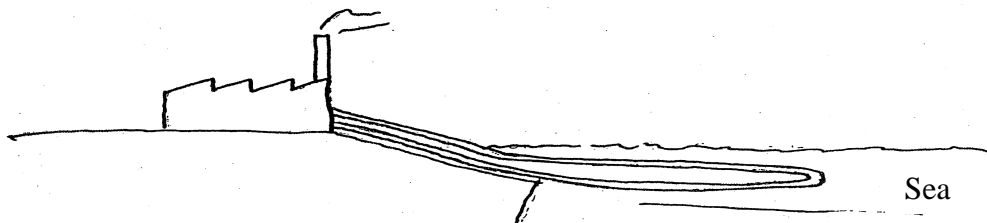
Written exam in physics first module – Breadth course

Monday, February 13, 1978

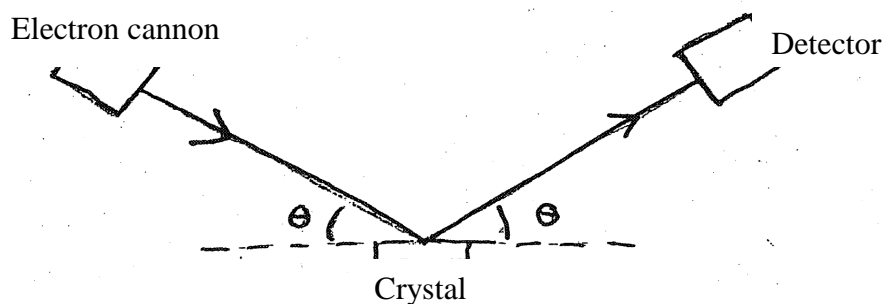
NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. The cooling system of a factory facility uses cooling water that flows at a constant velocity in a closed circuit from the factory through a pipe to the sea and back to the factory. How does the temperature of the cooling water in the part of the pipe emerged in the sea depend on the position in this part of the pipe? Justify your answer.



2. Electrons of fixed momentum are scattered on a cubic crystal (the Davisson-Germer experiment). The set up is such that the scattered electrons are detected if the angle of incidence is the same as the angle of scattering measured relative to the crystal plane. For what angles will there be a relative maximum in the intensity of the scattered electrons? Justify your answer.

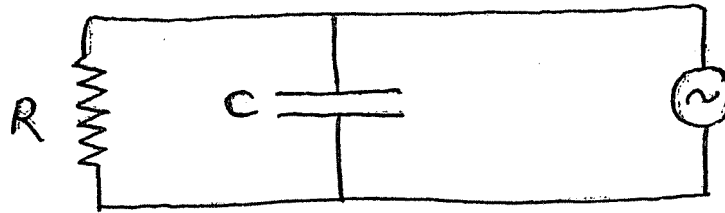


3. A single-cylinder, four strokes, explosion engine can steadily perform work; the magnitude of the work per cycle depend on the number of revolutions. How large a moment of inertia of the flywheel is at least required?

Justify your answer. (Inspired by the engines of old fishing vessels.)

4. Outline the fundamental steps that are used when determining the distance scale of the universe.

5. Find the impedance of the following alternating current circuit.



6. In a strong telescope, a luminous star can be seen even in the day sky. Based on this, estimate the ratio of the intensity of sunlight scattered in the atmosphere to the apparent luminosity of the star.

7. An electron and a positron of equally sized but oppositely directed momenta collide and annihilate. What momentum is at least required in order to create a proton and antiproton in the process?
Justify your answer.

$$e^- \xrightarrow{p} \quad \xleftarrow{-p} e^+$$

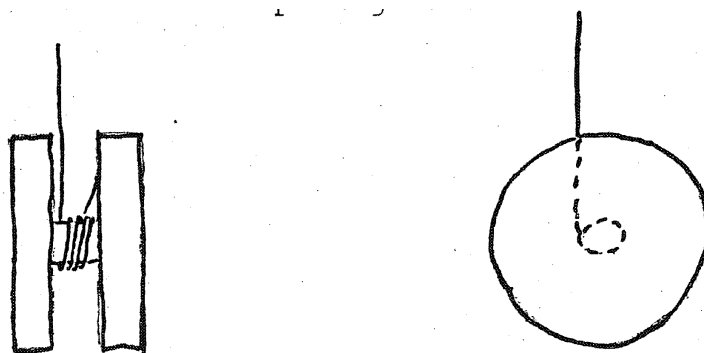
8. A chemical process occurs by the mixing of two gases, whose molecules can then react with each other. How does the reaction rate depend on the temperature of the gas?
Justify your answer.

Written exam in physics module 1, Breadth module
Wednesday, February 15, 1978

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. What is (roughly) the temperature of the filament in a light bulb, when the lamp is turned on? Justify your answer.
2. The average life time of K^+ mesons can be determined by making a beam of mesons with a certain energy and then measure the average distance that they travel before they decay. What is the relation between average life time and time of flight when the mesons have energy of 1 GeV? K-mesons have rest energy of $\frac{1}{2}$ GeV. Justify your answer.
3. Geological and paleontological facts indicate that the radiation of the Sun has been roughly constant for the last 1 billion years or so. Explain how this is possible.
4. A yo-yo consists of two circular disks connected by an axis about which a string is wound up as shown schematically in the figure.



How large is the vertical velocity of the yo-yo if it is released at rest and it has fallen freely from a given height?

(The upper end of the string is of course held fixed.)

5. The solar constant corresponds approximately to an energy flow of $\frac{1}{2}$ kW/m at the surface of the Earth. Does this imply that it is necessary to take into account whether the scale pan is hit by sunlight when using a precision scale to weight with a precision of $1\mu\text{g}=10^{-9}$ kg? Justify your answer.
6. In a colliding beam experiment, two electrons collide with equally sized, but oppositely directed momenta, i.e. in the center of gravity system. From

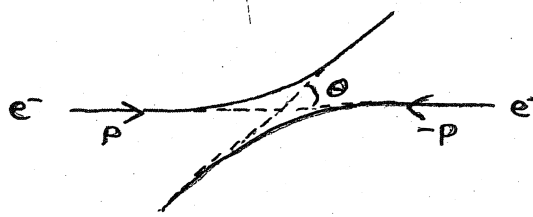
calculations or detailed analyses it is known that the probability that electron number 1 is deflected by an angle of θ is:

$$P(\theta) = |A(\theta)|^2,$$

where A is a known function of θ .

What is the probability that a detector placed at a certain angle relative to the direction of the beam will register an electron in this experiment?

Justify your answer.



7. What is the torque on a compass needle placed parallel to a long straight conductor and at a fixed distance from it?

Justify your answer.

8. How much energy is it possible to obtain from one kilo of antiprotons (if they were available) by letting them annihilate with one kilo of hydrogen? Use this result or another piece of knowledge to estimate the energy content of one kg pure uranium 235 that through fission frees an amount of energy of about 200 MeV per atom.

Written exam in physics first module (Breadth module) 4 hours

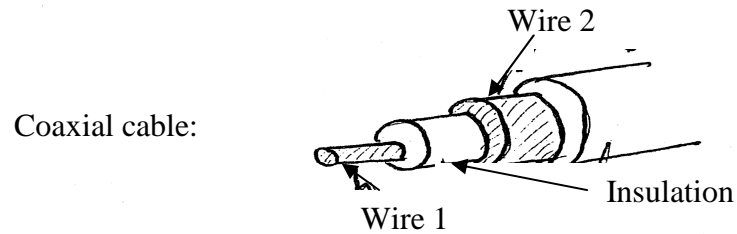
To be held: June 12, 1978

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. Who is hurt most by falling down from a table, a child or adult? Justify your answer.
2. Often, one burn oneself when removing a frying pan or saucepan with a metal handle from the fire. How does the temperature at the end of such a metal handle depend on its length and thickness? Justify your answer.
3. How large are the average values of, respectively, the square of the velocity, $\langle v^2 \rangle$ and the square of the distance from the average position $\langle x^2 \rangle$ at absolute zero of an atom that is bounded to perform a oscillating motion of a specific frequency? Justify your answer.
4. Describe briefly and justify some methods for the determination of galaxy masses.
5. Air planes above a television receiver often disturb the image in such a way that the light intensity oscillates regularly. Explain this fact. Are slow or fast air planes the worst? (The frequency of television waves are of the order of 10^8 Hz)
6. Biochemists use ultra centrifuges to determine the molecular masses of macromolecules. The molecules are dissolved in water; when centrifuging, the molecules move in the water away from the axis of rotation. At a certain distance from the axis the approximately uniform velocity of the molecules is measured by a light interference technique. How are the masses of the molecules calculated from the quantities appearing in the measurement? Justify your answer.

7. What is the magnitude of the magnetic field around a coaxial cable where direct currents of equal magnitudes but opposite directions flow in the two wires? Justify your answer.



8. A metal rod immersed in a saline solution, where the cations are the ions of the metal, can function as one half of a battery. What determines the voltage difference that arises between the metal rod and the saline solution? Justify your answer.

Written exam in physics, first module, 4-hours

To be held: June 20, 1978

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. It takes about a day to defrost a roast from the freezer on the kitchen table. How long time does it take in the fridge? Justify your answer.

2. One can imagine the following cases of circulating wind: counterclockwise around low pressure areas, clockwise around low pressure areas, counterclockwise around high pressure areas, clockwise around high pressure areas. Which cases are physically possible at, respectively, the southern and northern hemisphere? Justify your answer.

3. What does it say about the magnetic state of a substance if constructive interference is observed with x-ray scattering for precisely every other of the values of the scattering angles for which constructive interference is observed with neutron scattering at the same wavelength?

4. The entrance road to a high way crosses the high way. Estimate the impact for traffic security if the entrance road crosses above or below the high way. Justify your answer.

5. In radio programs with direct transmission of telephone conversations with listeners a ringing tone can sometimes be heard and the listener is often asked to turn down the radio. Why is that? Justify your answer.

6. What prevents a gravitational collapse of the Sun? Justify your answer.

7. Since 1962 the usual atomic mass unit, amu, has been fixed by letting the atomic mass of carbon-12, $^{12}_6\text{C}$, be equal to 12 amu by definition. Why are the atomic masses measured in this unit closer to integers than a unit based on the mass of hydrogen, ^1_1H ? Justify your answer.

8. When the electronics industry produces integrated circuits, the desired pattern is projected down from a large template onto the circuit matrix (area about 1 mm²) using photo active ink on the matrix. Estimate a least thickness of the conductive pathways in integrated circuits. Justify your answer.

Roskilde University

First written test in the breadth module of physics

To be held Friday, June 6, 1980, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. What is the advantage of cycling rather than running or walking? Justify your answer.

2. Water can short-circuit electrical fittings. Can ice? Justify your answer.

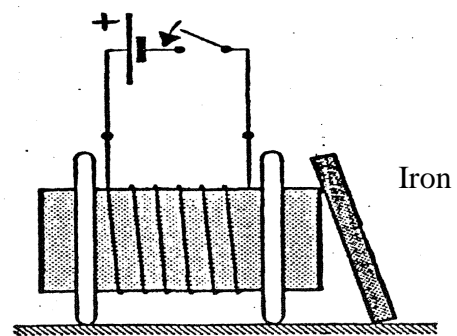
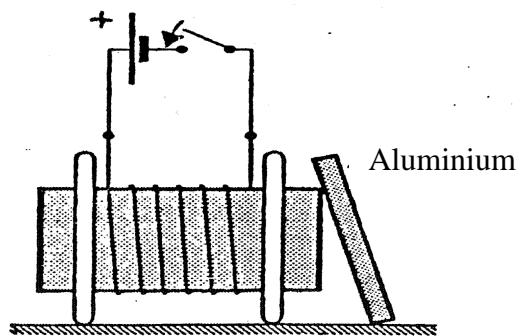
3. A patented product consists of a deep freezer combined with a water heater so that the external condenser of the freezer is placed in an insulated water tank. It is claimed that in regularly use the product can heat 150 l water from a water work to 50°C per day. Estimate the saved energy relative to the case of an uncombined freezer and an electrical heater that heats an equal amount of water.

4. A garden fountain is driven by an electromotor of 40 watt. How high can it send a jet of water of a given cross-section? Justify your answer.

5. An aluminium disk and an iron disk are placed next to an electromagnet, as shown in the figure.

What happens in the two cases when the current is turned on?

Justify your answer



6. What is the ratio between the number of hydrogen atoms in the ground state ($n=1$) and in the first excited state ($n=2$) at the surface of the Sun? Justify your answer

7. Two manned space ships move in uniform relative motion. Do circumstances exist that lead to agreement between the two crews about the coincidence of two events?

Justify your answer.

8. By studying material from meteorites (meteor stones), scientists try to estimate the length of the time interval, “lapse time”, from the end of the last supernova explosion (where the heavy elements were formed) to the formation of the planetary system (and the meteorites).

By counting the number of crystal defects, which are assumed to originate from spontaneous fission of very long lived isotopes, a ratio of the number of fissions of Pu^{244} to the number of U^{238} nuclei since the formation of the stone has been found.

State how this can be used to find the lapse-time, when the age of the meteorite is known by other means and when one has an estimate of the relative frequency of the different isotopes at the beginning of lapse time.

Roskilde University

Second written test in the breadth module of physics

To be held Monday, June 9, 1980, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. For gasses, one distinguishes between the heat capacity c_p at constant pressure and the heat capacity c_v at constant volume. Which of the two quantities is smallest? How large is the difference for an ideal gas? Justify your answers.

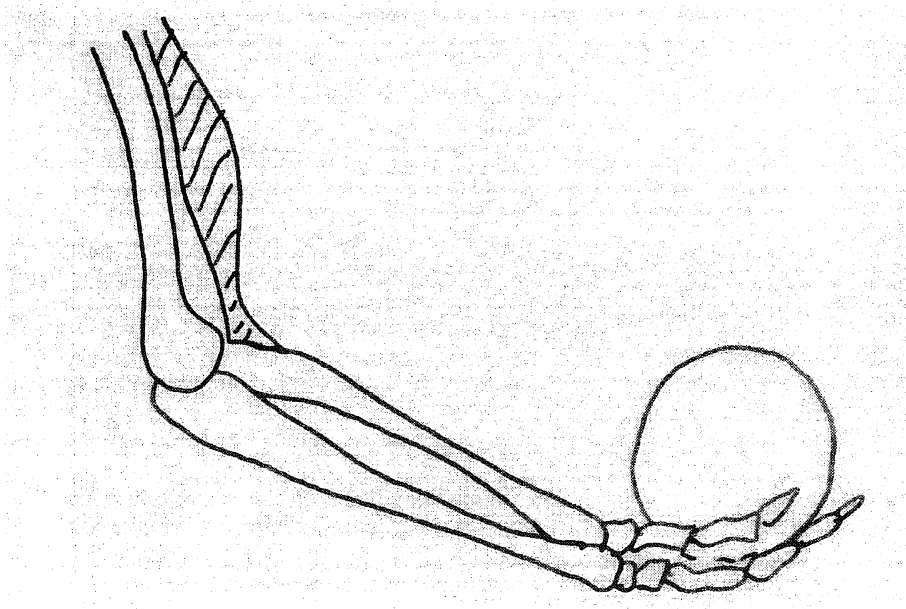
2. Sketch a simple electrical network that can be seen as an analogy to a particle that performs damped harmonic oscillations. Discuss the meaning of each of the components and justify the analogy.

3. How large is the radius of the helium ion, He^+ , relative to the radius of the hydrogen atom? Justify your answer.

4. Spectacle lenses and other optical instruments are often coated with a thin film in order to reduce reflection. How should the film be chosen to obtain the best result?

Justify your answer.

5. The figure shows an arm holding an object.



What is the strain on the elbow joint?

Justify your answer.

6. The motion of the electrons in a current-carrying conductor gives rise to a magnetic field in the vicinity of the conductor. Why not also an electrical field?

Justify your answer.

7. A toy consists of a plastic disk, almost with the form of an inverted plate. The disk is thrown horizontally in such a way that it at the same time is put in rotation around its axis of symmetry – and land surprisingly far away. Give an explanation of the motion of the disk.

8. A star is observed in a telescope with a mirror diameter of 50 cm or 500 cm. In both cases the star is pictured as a small disk of angular diameter of about $1''$. Explain this fact.

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First written test in the breadth module of physics

To be held Friday, January 9, 1981, 09:00-13:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. In a not quite new dormitory building, a significant heat loss through the exterior walls and appurtenant windows of the rooms is noted. It is contemplated to cover the walls with insulating sheets and replace the old-fashioned window glass with insulating glass.

The k-values for the different materials are assumed to have the following values in units of $W/(m^2 \text{ } ^\circ C)$:

Old (one-layer) glass	7
Wall of light weight concrete	1.4
Two-layer insulating glass	2.5
Insulating sheet (2.5 cm Rockwool)	1.6

(The k-value for a layer of material is the thermal conductivity divided by the thickness of the material.)

By covering the walls, how much can the heat loss be reduced relative to the original situation?

Which of the two measures matters most?

Justify your answers.

2. What is the focal length of a shaving mirror?

Justify your answer

3. Sirius is a binary star consisting of a main sequence star Sirius A of mass $2.2 M_{\odot}$ and a white dwarf Sirius B of mass $0.9 M_{\odot}$. Argue in favor of assuming that Sirius B has shed half of its mass at one point in the past.

4. As is well-known, a rotating spinning top can be brought to “stand” on a smooth surface for a while without tilting. In the end it “staggers” around in a characteristic way before coming to a halt. Explain these phenomena.

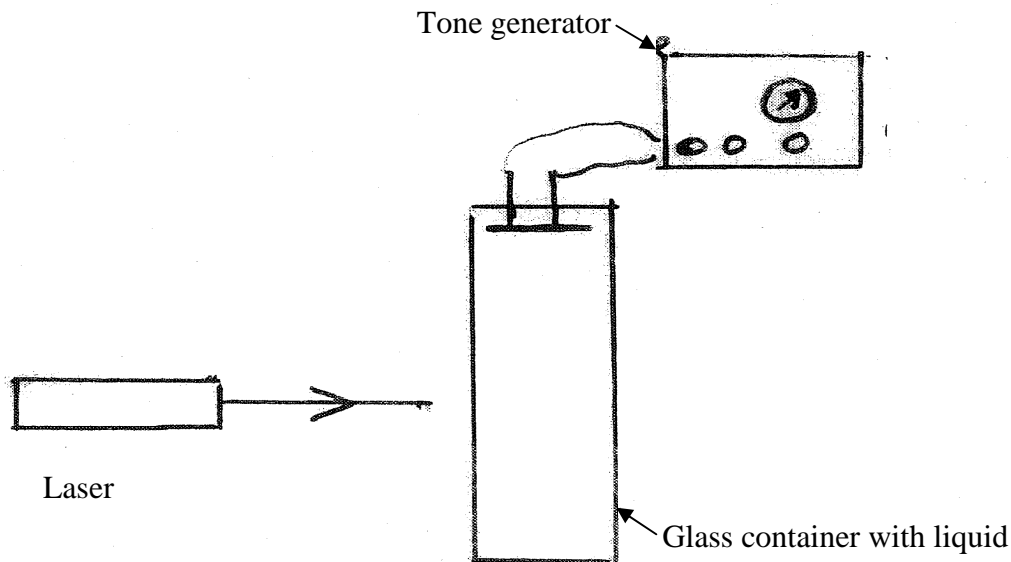
5. Is there a relation between the appearance and the semiconductor properties of different pure semiconductor crystals? What is the relation? Discuss the appearance when the crystals are observed in ordinary light and in infra red light.

Justify your answer.

6. A star is moving away from the Earth. Between the Earth and the star there is a thin gas cloud moving in direction towards the Earth. Show on a sketch how these facts influence the observed spectrum in the vicinity of the H_{β} line of hydrogen ($\lambda=486 \text{ nm}$).

Justify your answers.

7. For the determination of the speed of light in a certain liquid, a method studies laser light after it has passed a glass container filled with the liquid in which standing waves are created using a tone generator (see the figure)



Describe how the sketched method works. What would be a realistic frequency area for the tone generator?

Justify your answer.

8. A chunk of ice with a 10-kroner coin on top is brought to float in a glass of water. What is the water level in the glass after the ice has melted compared to the water level before the melting?

What happens in the corresponding experiment with the coin replaced by a wooden block on top of the chunk of ice?

Justify your answers.

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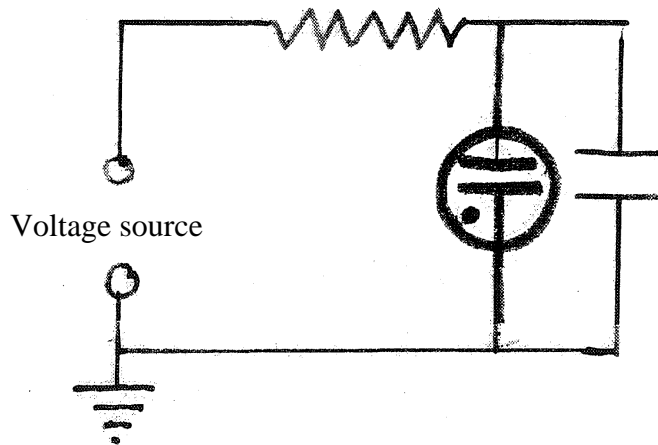
Second written test in the breadth module of physics

To be held Monday, January 12, 1981, 09:00-13:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1.



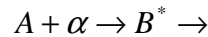
The figure shows a circuit consisting of a direct voltage source, a resistance, a capacitor and a glow lamp. The glow lamp is a discharge tube that has infinitely large resistance when no current is flowing and a very small resistance when it is turned on. It turns on when a characteristic ignition voltage is applied to it and it turns off at a characteristic turn-off voltage that is smaller than the ignition voltage.

The circuit can be used to produce a flashing light. How is that? How does the flash frequency depend on the quantities appearing in the problem?

Justify your answers.

2. It is well-known that the surface of water (e.g., of a lake) becomes darker when it is rippled by a gust of wind. Why?
Justify your answer.

3. When a foil containing nuclei of a substance A is bombarded with α particles, radioactive nuclei B are formed in the foil.



What should be done to ensure that the foil functions as a radioactive preparation of a given strength?

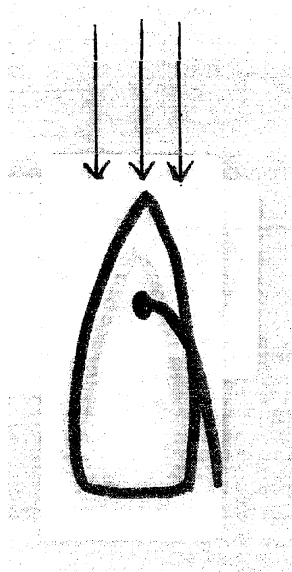
Justify your answer.

4. A building is heated by an oil-fired boiler that keeps an indoor temperature of 22°C while the temperature outside is -3°C . What is the efficiency when 40% of the produced heat is lost through the chimneys?

State other relevant efficiency measures and discuss the significance of a thermodynamic efficiency measure, which focuses on the quality of energy (from the second law).

5. Interstellar neutral hydrogen atoms can be detected because they emit radio radiation of $\lambda=21\text{ cm}$. Give an explanation based on the hyperfine splitting of the ground state. Is there a corresponding line for helium atoms?
Justify your answer.

6. How is it possible for a sail boat to sail up against the wind as sketched? Why is it an advantage to have a small sail (a foresail) in front of the storm sail? Justify your answers



7. A hollow cylindrical conductor is made of a known material. A potential difference between the inner and outer surface is applied to the conductor so that a stationary current is flowing from the inside to the outside. How large is the electrical resistance?

Justify your answer

8. A space lab is shaped as a cylinder of radius $R=100$ m. To create a natural gravitational field along the “floor” the space lab is put in rotation around its axis with constant angular velocity.

A balloon containing a gas of density about $1/3$ of the density of the atmosphere of the lab is released from the floor. How will the balloon move?

Justify your answer.

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First written test in the breadth module of physics

To be held Monday, January 10, 1983, 09:00-13:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. The cosmic background radiation has a distribution corresponding to a Planck distribution of maximum intensity at a frequency of about $2.80 \cdot 10^{11}$ Hz. It turns out that this maximum depends on the direction of measurement. It assumes a 0.13% larger value in direction of the constellation Leo, while it assumes a 0.13% smaller value in the diametrically opposite direction. (Between these two values, the variation is uniform.)

What do these measurements tell us about the motion of the Earth in cosmos?

2. According to a television program, a supertanker of 285,000 tons sails at a speed of about 20 km/h. A braking to a complete halt would last about 20 min. and occur over about 10 km.

Assess the correctness of these statements.

3. You are preparing for your teaching and want to perform the following experiment to demonstrate conservation of angular momentum. A student is placed on a chair that rotates easily. She gets weights in each hand, stretches her arms and is put in rotation. Then she pulls the weights toward her body and should, as you know, rotate faster. You don't know whether this increase of angular velocity is clearly observable, but you don't want to go to the school to check whether it is the case.

Assess the increase in angular velocity and describe your assumptions etc.

4. A water dam of low water level has a constant temperature at the bottom of 4°C , while the temperature above the water surface is constantly -5°C . After some time, ice will have formed on the water. How will the thickness of the ice depend on the coefficients of heat conductivities of the water and the ice?

5. To obtain better reception of English radio broadcasts during the war, in my home we used a coil as depicted in figure 1.

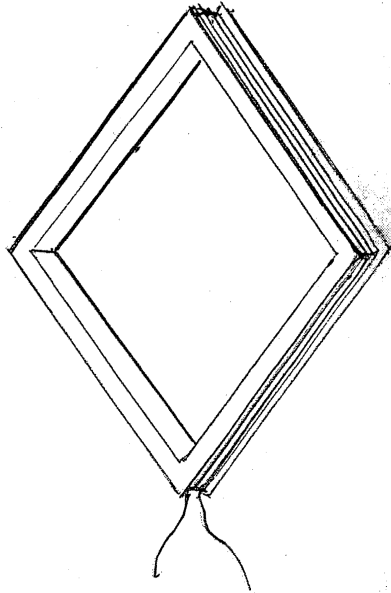


Fig.1

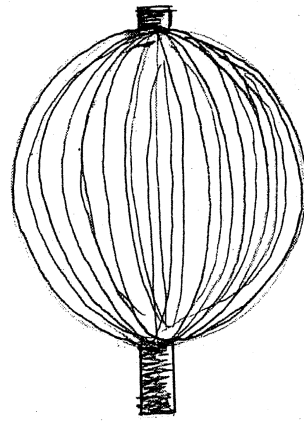


Fig.2

Explain what should be done to get the best possible radio reception with the coil and why?

Is the wavelength of any significance for the shaping of the coil?

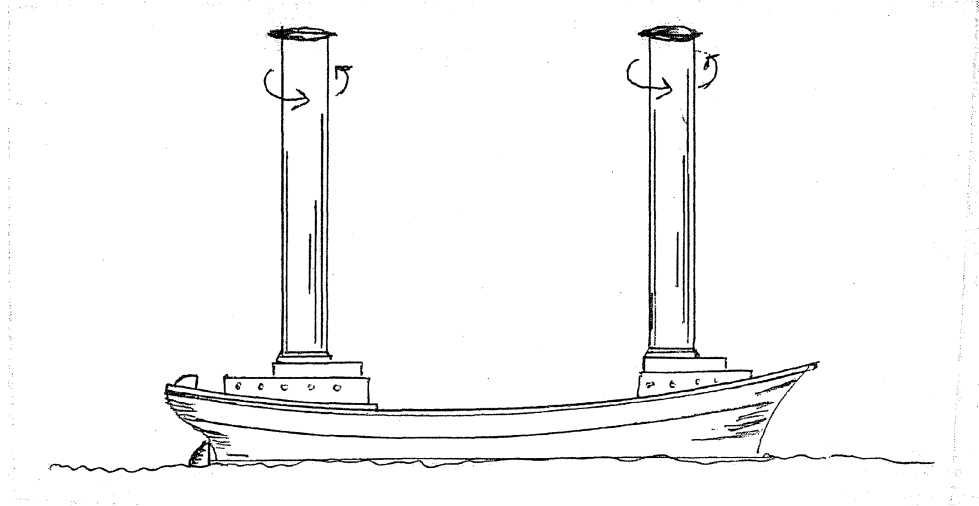
Are there other of the coil's physical parameters that you think are significant?

My father also made an antenna out of a piece of multi-threaded cable. The cable threads were joined at the two ends while they were bended away from each other in the middle of the piece, so that the whole looked like a ball (see figure 2). Explain why some thought this was a good idea. Do you think it was a good idea?

6. In 1925, the Flettner ship crossed the Atlantic. It was propelled by two large vertically rotating motor driven cylinders.

Explain how this was possible.

Do the course and speed depend on the wind direction?



7. If a large current is sent through a solenoid the windings may burst.

Explain why this can happen.

8. A pi-meson of charge $q=+e(=1.6 \cdot 10^{-19} \text{C})$ makes a track in a bubble chamber. The spatial determination can be done with an uncertainty corresponding to the radius of the bubbles $r \sim 5 \cdot 10^{-4} \text{m}$. The pi-mesons move perpendicular in a homogenous magnetic field, the magnitude of which can be determined to be $1.70 \pm 0.07 \text{T}$. The radius of the pi-mesons' trajectory can be measured to be 0.325m . What is the implication of the uncertainty relation for this experiment?

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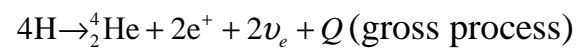
Second written test in the breadth module of physics

To be held Wednesday, January 12, 1983, 09:00-13:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. Nuclear processes such as

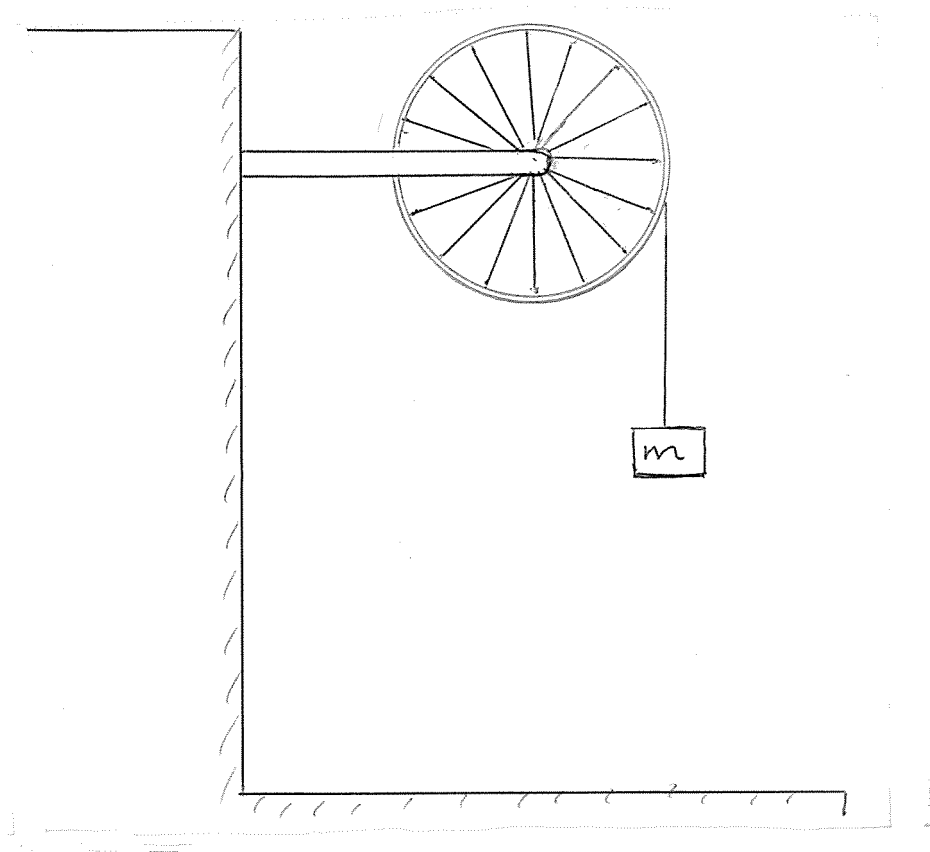


only happens in the central parts of the Sun.

Why?

Discuss which factors can promote or delay such a process.

2. A physics collection contains a wheel used for the demonstration of conservation of angular momentum and the like. For an experiment it is necessary to know the moment of inertia of the wheel. It is decided to determine this experimentally. The wheel, which looks like a bicycle wheel with a heavy rim, is suspended so that its axis is vertical. A string is wound up around the wheel rim and has a weight of mass m suspended at its end.



It is now assumed that the weight will get a constant acceleration. Set up an equation from which it is possible to calculate the moment of inertia as a function of an observable experimentally measurable parameter, such as the time of fall.

3. Figure 1 is from Leybold's "Handblätter", i.e. instructions for how to perform experiments in physics education. An aluminium disk on a shaft is suspended from an arm and placed between the pole shoes of an electromagnet. If the disk is put in rotation, it is quickly stopped.

Explain why.

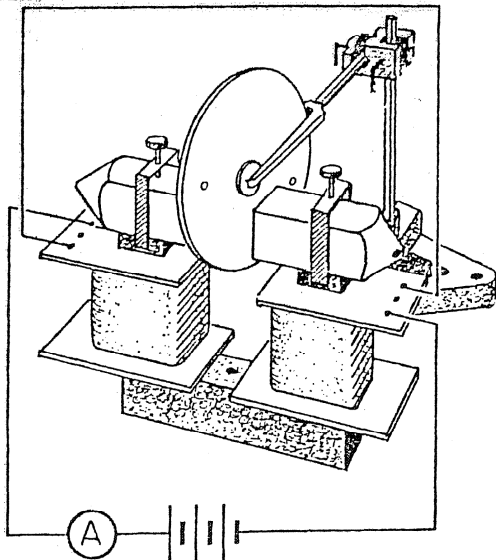


Fig.1

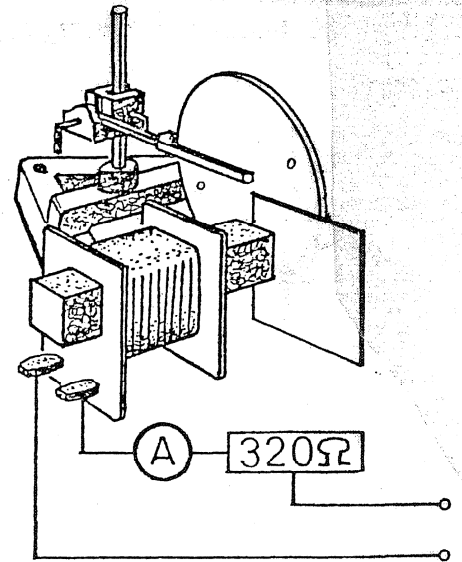


Fig.2

Figure 2 shows another arrangement. First the coil is connected to an alternating voltage. Then the disk is placed about 5 mm from the iron core of the coil. Nothing happens. However, if an aluminium plate is placed between the iron core and the disk in such a way that the iron core is about half covered, then the disk rotates.

Explain why.

4. A long thin copper strip is placed between two 1 mm thick plates of asbestos, so a “sandwich” is formed.

The sandwich is now placed in a room kept at a constant temperature of 0°C . A current is sent through the copper strip.

The resistance per unit length of such a copper strip is given by $R_l = a(1 + b \cdot t)$, where t is the temperature of the copper strip.

How does the temperature depend on the current?

What other quantities will in practice limit the temperature?

5. Two very small slits at a distance of 0.5 mm from each other emit a coherent visible light that forms an interference pattern on a screen. One slit emits 4 times as much energy as the other.

If we look at the middle part of the spectrum, what is the ratio of the intensity of a maximum to the intensity of minimum right next to it?

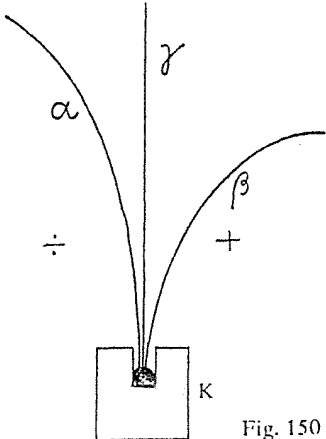
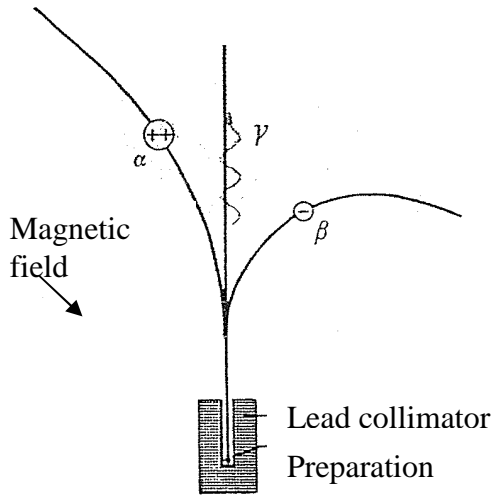
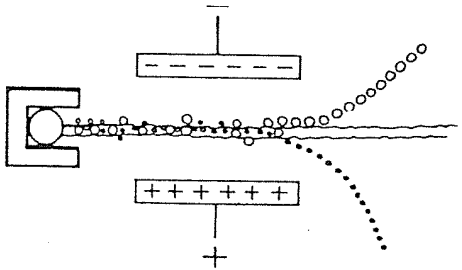
Is this ratio valid for the entire spectrum?

6. γ radiation can spontaneously be transformed into a positron-electron pair (e^+, e^-). Why does this not happen in complete vacuum?

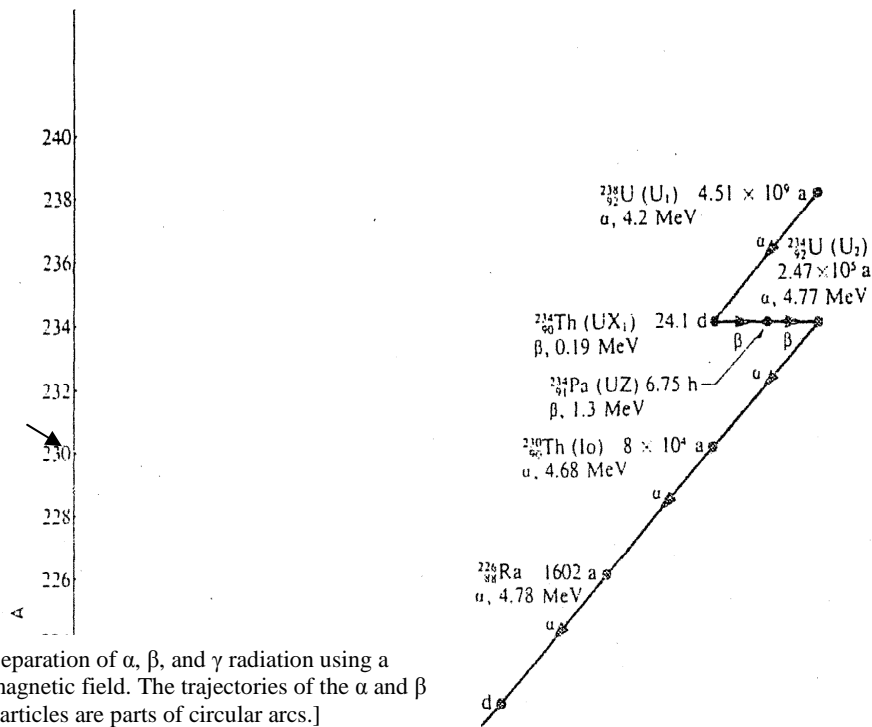
7. A cyclotron accelerates deuterons to energy of 16 MeV. If deuterium is replaced by helium nuclei then what are their energy?

8. For a long time the coverage of “radioactive radiation” has been followed by the illustrations below. The first drawing (with a suitable text excerpt) is from 1961. The two others are from books used today. What comments, identification of errors and inaccuracies, maybe amendments, can you suggest?

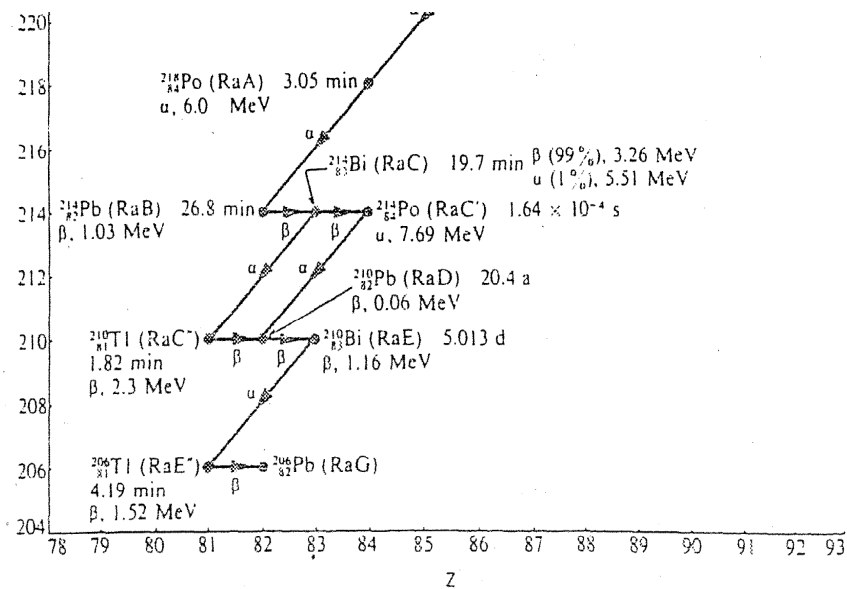
Appendix to the problem: The uranium family (1 sheet)

 <p>Fig. 150</p>	<p>For the demonstration of the influence of radiation on a photographic plate a small block of lead with a small depression containing radium is used. If the photographic plate is held above K, a spot appears on the plate. If a positive electrical body is placed on the right of the rays, a negative one on the left, three spots appear on the plate; hence it is concluded that radium emits three types of radiation.</p> <p><u>A.</u> Th.Sundorph: Fysik, 1961</p>
<p><u>B.</u> Fysik i grundtræk, 1974</p>  <p>Separation of α, β, and γ radiation using a magnetic field. The trajectories of the α and β particles are parts of circular arcs.</p>	 <p><u>C.</u>Højgaard: Tidens Fysik, 1980 .</p>

Uran-familien $A = 4 \cdot N + 2$
(i parentes gamle symboler)



Separation of α , β , and γ radiation using a magnetic field. The trajectories of the α and β particles are parts of circular arcs.]



Roskilde University

First written test in the breadth module of physics

To be held Monday, June 13, 1983, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. An air balloon can assume a certain maximum extent. The balloon usually first assumes its full extent well into the atmosphere. Using the balloon valve it is possible to let some of the gas in or out of the balloon. But what determines how high a balloon filled with a given gas can rise?

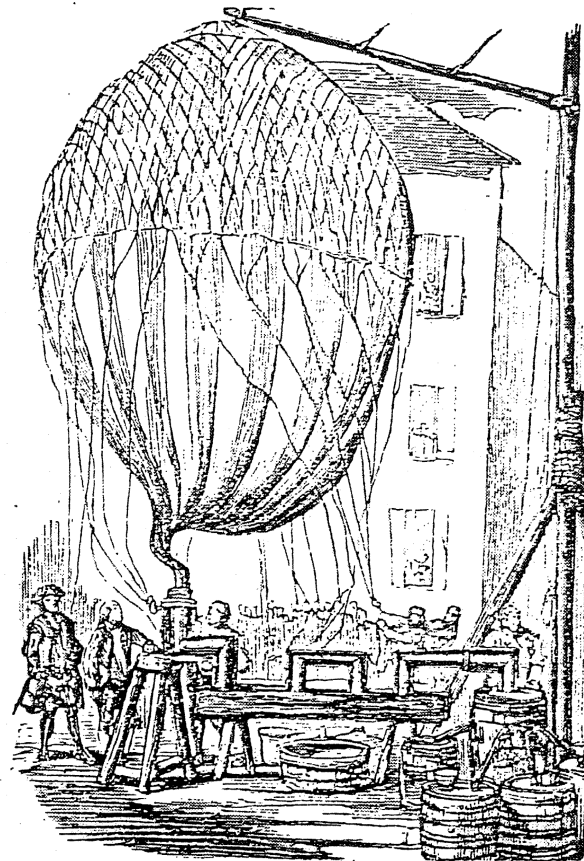


Fig. 98. Fyldning af en af de første Charlierer.

[The figure is only for decoration and inspiration]

2. There are two types of supernova explosions: Type I and Type II. Type I is observed in all types of galaxies, Type II only in spiral galaxies and irregular galaxies. Where in the Milky Way can we expect to find respectively Type I and Type II supernova explosions?

3. In calm weather, a bike rider can ride at a constant speed of 7 m/s . He wishes to know his speed in headwind, where the wind velocity is known. He reckons that a perfect gearing will enable him to yield the same steady effort irrespective of his own speed and that the resistance essentially comes from the air (the wind). How does his own speed depend on the wind velocity and will he get to his destination if the headwind is 7 m/s ?

4. Barlow's Wheel is a demonstration equipment that can be bought at Leybold. It consists of a massive revolving copper disk and a block with a trench containing mercury. (fig. 1)

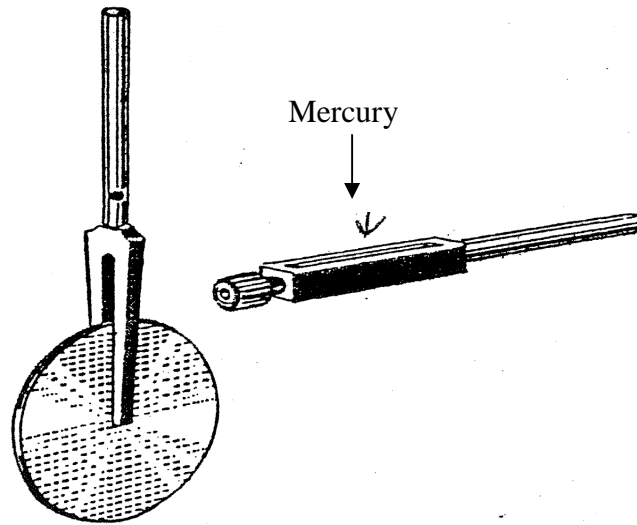
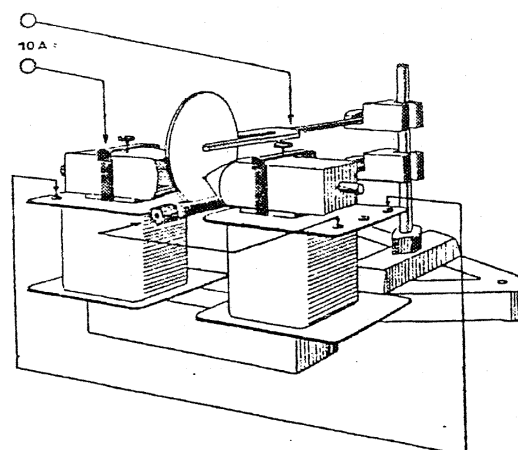


Fig. 1

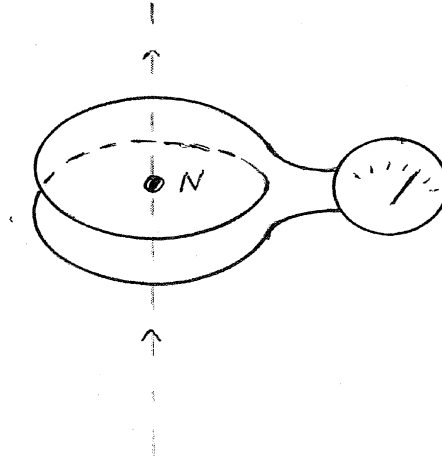
Wheel and trench is now arranged so that the wheel rim is running in the trench with mercury. A current is sent through the wheel. One pole of the voltage source is connected to the wheel axle and the other pole to the mercury in the trench.

An electromagnet is placed so that a large magnetic field passes through a small part of the wheel, more precisely between the wheel axle and the trench (figure 2).

The wheel is claimed to be able to rotate. Explain why and estimate the torque on the wheel.



5. According to Maxwell's theory, magnetic monopoles should not exist. Nevertheless, it is at present intensively examined whether they do in fact exist. A point-like magnetic monopole (north pole) is thought to be moved through a coil. Discuss qualitatively the current through the coil as it is measured on the galvanometer.



6. An excited atom usually decays very fast to its ground state with the emittance of an energy quantum – a photon. A typical decay time is 10^{-8} s. Some substances, however, have excited states in which the atom stays longer (up to several hours). These are the so-called metastable states. In a spectral analysis, the spectral lines from the decay of metastable states will show a weak but sharp (narrow) line, while decay from normal states will show as light intensive and broader lines. Explain why.

7. The half-life of a neutron is about 12 minutes. What energy is required of a neutron for it to have 50% chance of surviving a trip to the Earth from a star 10 light years away?

8. A nucleus of nucleon number 20 moves at a speed of $3 \cdot 10^5 \text{ m s}^{-1}$. It spontaneously divides into two particles, each of nucleon number 10 that moves away from each other, so that their trajectories form a right angle.

How large is the increase in kinetic energy?

What is the source of this energy?

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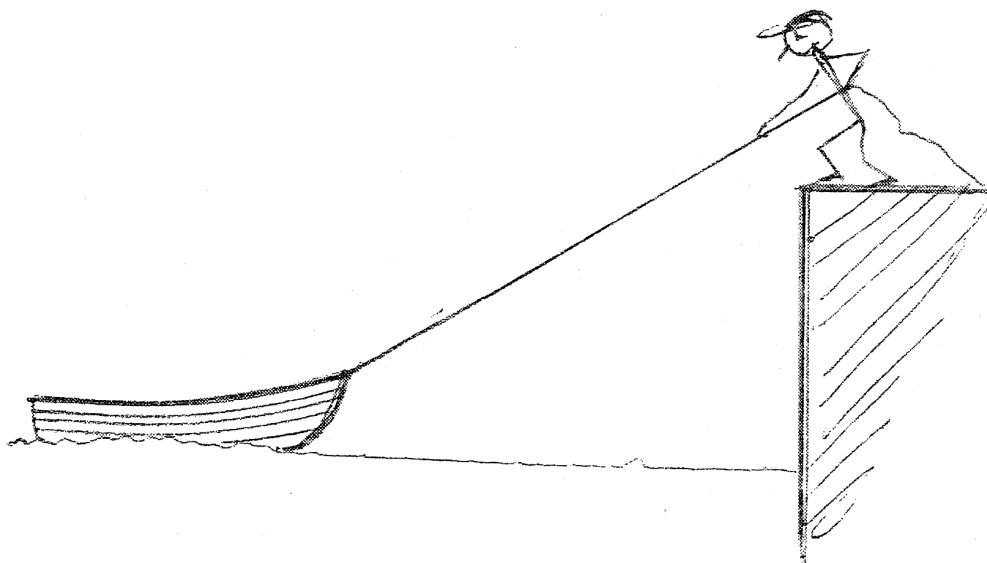
Second written test in the breadth module of physics

To be held Tuesday, June 14, 1983, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

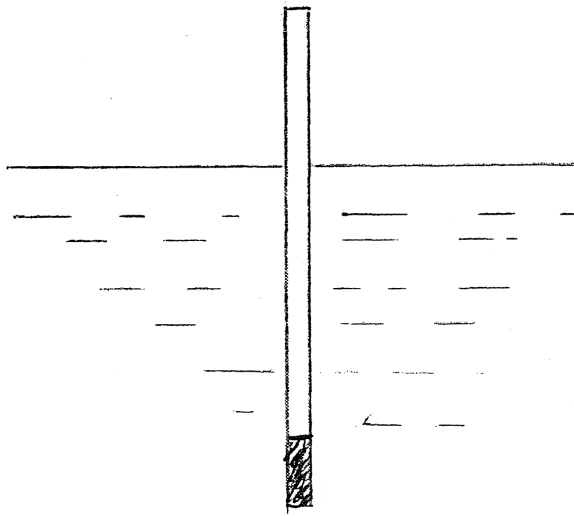
1. A man is standing on a tall quay wall and pulls a boat toward the quay. He pulls the rope at an even pace. Describe how the boat will move towards the quay.



2. A thin stick, which can float on water, is placed so that it floats in a horizontal position. Then an appropriate piece of metal with the same cross section is placed at one end of the stick.

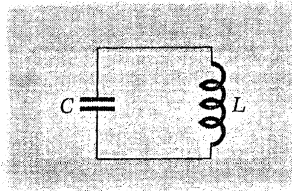
How large a portion of the stick will be above the water?

What is the condition for the stick to float in a horizontal position in a stable manner?

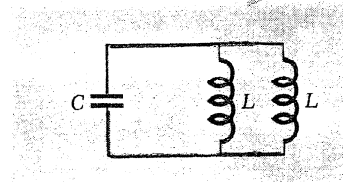


3. The power of the radiation emitted by the Crab nebula is of the order of 10^{31} J/s. The energy source of this has been suggested to be the rotational energy of the Crab pulsar. Its rotation period P is 0.0331 s, and the temporal change of the period $\frac{dP}{dt}$ has been measured to be $\sim 420 \cdot 10^{-15}$ s/s. Assess (order-of-magnitude-wise) whether it is reasonable to see $E_{\text{rot, pulsar}}$ as the source of energy of the nebula. Assume that the neutron star, which makes up the Crab pulsar, is a homogeneous ball of mass = 1 solar mass $\approx 2 \cdot 10^{30}$ kg and radius 10 km.

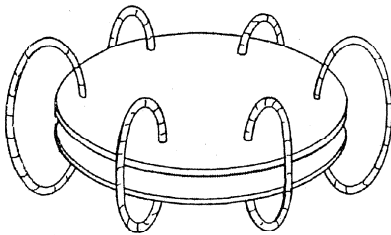
4.



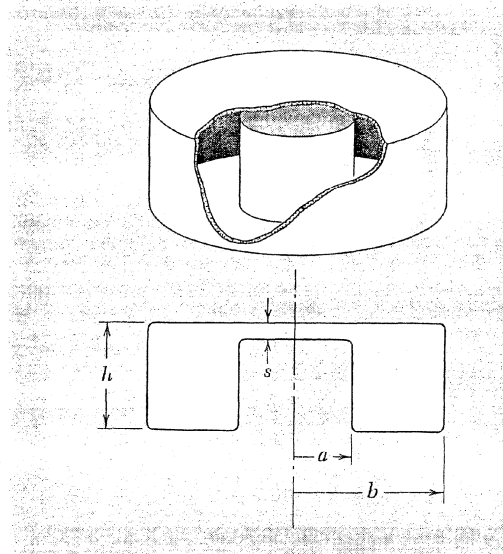
(a)



(b)



(c)

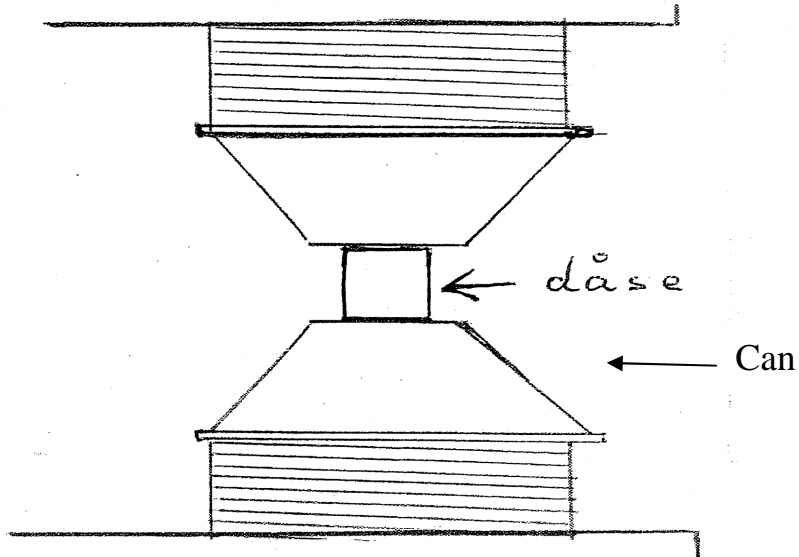


(d)

All of the figures above show resonant circuits.

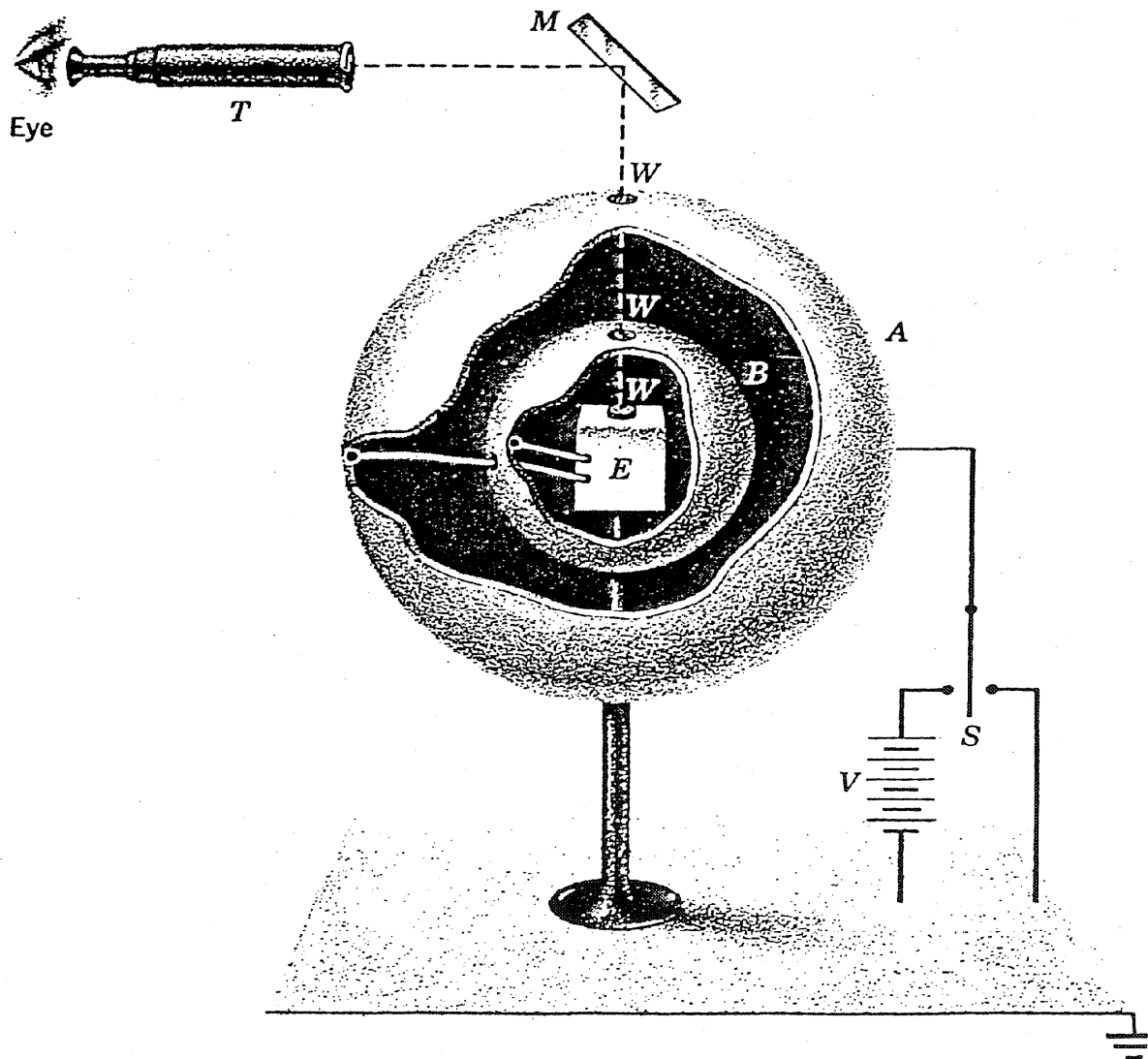
Figure (a) and (b) show usual circuits with capacitor and inductor separated. In figure (c) the capacitor plates are connected by six separate windings that form the inductor and in figure (d) the capacitor plates are connected by “a single winding”, which forms a sort of “can,” a cavity resonator. Explain how the resonance frequencies changes from (a) to (b) to (c) to (d) and why? How will the resonance frequency of the cavity resonator change if the height h is made smaller? And what happens with the frequency if the distance s is made larger so we get a beer can?

5. To demonstrate the field strength of a large electromagnet, an empty can was placed between the poles of the magnet.



When the current to the magnet was turned on, the can crumpled with a bang. Explain why this happened.

6.



A and B are two (completely insulated) metal balls. Through a sensitive electrometer E (which can be read using a mirror) they are connected to each other. All the charge going from A to be B can hence be measured at E. Using the switch S, ball A can be charged and discharged again to ground.

The device is a principle sketch of the device Plimton and Laurton used in 1936 to prove experimentally Gauss' and Coulomb's laws.

Explain how.

At this occasion, the power in Coulomb's law was measured to be between 1.999999998 and 2.000000002.

7. Poisson's spot. The shadow of a very small ball (fig. 1) looks like concentric shadow rings with a bright spot in the middle (fig. 2) – Poisson's spot. Explain the phenomenon.

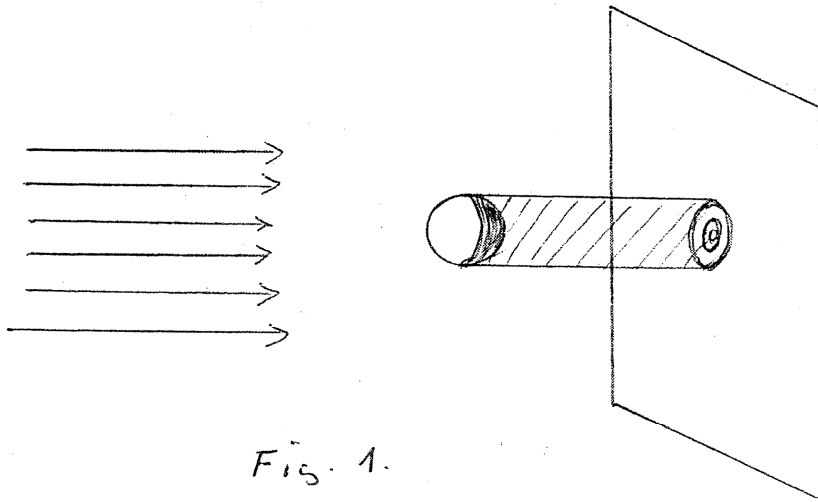


Fig. 2.

8. [Not translated]

Roskilde University

First written test in the breadth module of physics

To be held Thursday, August 25, 1983, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.


1. At what speed does a car loose its grip of the road when passing a hill top? Justify your answer.


2. In the athletics discipline shot put (where the athlete throws a metal ball), the length of the put depends on the speed of the ball when it leaves the hand. How?

3. Metal alloys consisting of two components can either be ordered (fig. A) or disordered (fig. B).

Fig. A. 

Fig. B. 

 :komponent 1

 :komponent 2

How is it possible to distinguish the two states using x-ray spectra?

4. When performing hard physical labor one eats and sweats more than otherwise. Are additional eating and sweating both necessary from a physics point of view?

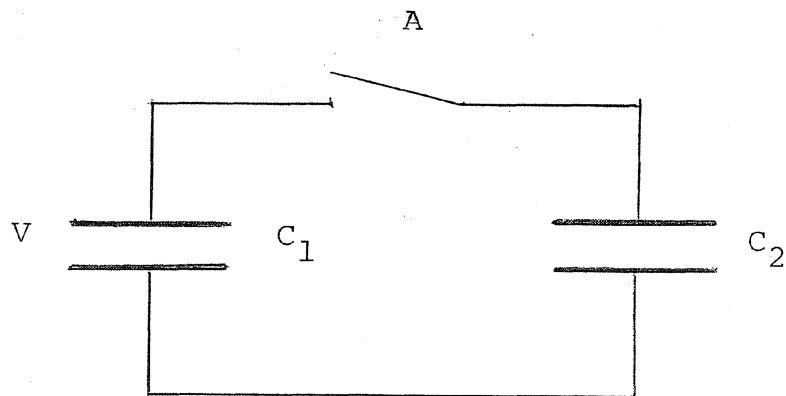
Justify your answer.

5. Why do stars show a tendency in their development towards consisting of iron?

6. After Rutherford's discovery that atoms are not compact, but consists of empty space with a positive charged nucleus of small extent and electrons, which revolve around the nucleus, of even smaller extent (one most imagine), it is a puzzle that matter does not collapse by a pull of the electrons towards their nuclei, so that the atoms shrinks. Why does this not happen?

Justify your answer.

7.



Over a capacitor of capacitance C_1 the voltage of V is applied, while the voltage 0 is applied over C_2 . What is the energy loss when the switch A is turned on and what happens to the energy?

Justify your answer.

8. How small amounts of charge can possibly be used for information storage in microelectronic equipment when the presence of cosmic radiation and radioactive alien atoms are taken into account?
Justify your answer.

Roskilde University

Second written test in the breadth module of physics

To be held Friday, August 26, 1983, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. A 50 GeV electron accelerator is used to perform experiments where electrons are scattered on atom nuclei. How can we calculate whether electrons of this energy can “see” nucleons?

2. How large is the pressure in the center of the Earth?

3. In 1981 the minister of energy inaugurated the world’s largest heat pump, which shall deliver heat to 2200 houses in Frederikshavn. It is constructed so that heat is tapped from the wastewater of the municipality. Why not from the Kattegat?

4. Normally, children and adults do not come down a hill equally fast on bicycles. Who is fastest down?

5. Pentagon's plans for satellite carried laser weapons include an arrangement of lenses of diameter of 10 m to obtain sufficient focusing of the laser energy on targets 1000 km away. On how small an area is the energy focused?

6. Why is it possible to assume that the law of inertia holds in a coordinate system with the Sun as the center and axis fixed relative to the stars in our galaxy, when we know that the Sun participates in the rotation of the galaxy?

7. A rubbed glass beam is capable of attracting small pieces of paper. Explain this phenomenon.

8. Entire crystals of insulators are usually transparent. Metals are always opaque.
Explain this fact.
What is the case for semiconductor materials?

Roskilde University

First written test in the breadth module of physics

To be held Friday, June 7, 1985, 10:00-14:00

NO AIDS ALLOWED

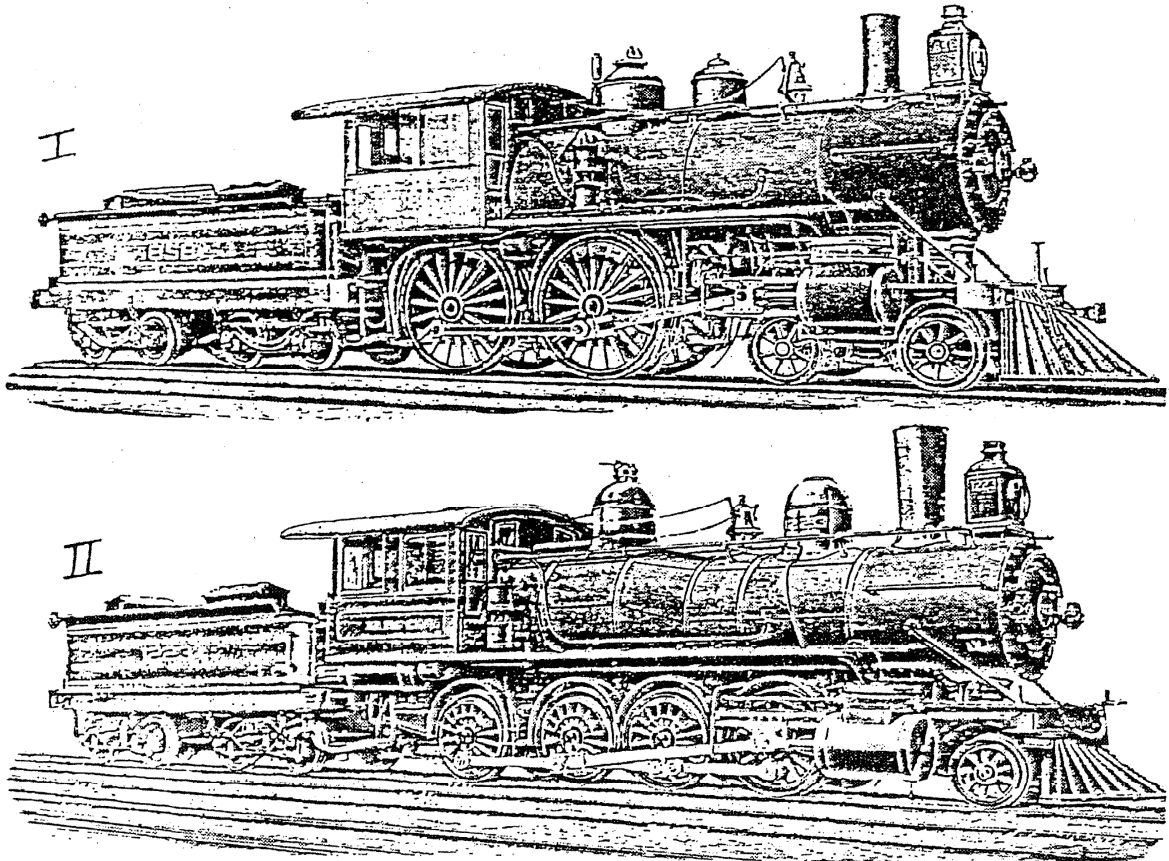
Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. For black-and-white exposures, photographers often use either a yellow filter or a Polaroid filter to make the clouds in the sky appear more distinct. Explain the physical background of the functioning of the two filters.

2. When liquid is poured into a large bottle, a glugging sound is often heard. Similarly, sounds appear when a bottled is emptied of liquid. Do the sounds change during filling or emptying of the bottle? Is there a difference between the sounds for the two cases? Explain your answers.

3. Locomotives meant for transportation of people differ from locomotives meant for goods transportation. The passenger locomotive is designed to drive fast, whereas the goods locomotive is designed to pull heavy, loaded carts. Two types of steam locomotives, I and II, are shown below. For each type, state whether it is a passenger or goods locomotive.

Justify your answers.



4. These years it is discussed whether the masses of galaxies are somewhat larger than assumed until now. The extra mass is assumed to be placed as very weak stars in the outer parts of the galaxies. Discuss how such “massive haloes” might possibly be observed.

5. Friday afternoon, a careless scientist leaves a helium container (20° and 200 atm.) with the tap barely closed so that the gas slowly escaped during the weekend. What is the change of entropy per kilo gas?

Justify your answer.

6. The functioning of cyclotrons is based on having the frequency of revolution of the charged particle independent of their velocities. Do special constructional problems arise when the velocities become relativistic?

Justify your answer.

7. The moon of Mars, Phobos, moves in such a low orbit that the tidal forces remove energy from its trajectory. The period of revolution is 7.7 hours. Its angular velocity is measured to increase by about $1.75 \cdot 10^{-5}$ rad/year per year. Estimate the relative change in the moon's distance to Mars during one year.

8. Our Milky Way is thought to collide with a spiral galaxy of a mass of 10^{12} solar masses, i.e., they pass through each other. Estimate the chance of collision between the Earth and an "alien" Sun.

Roskilde University

Second written test in the breadth module of physics

To be held Monday, June 10, 1985, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

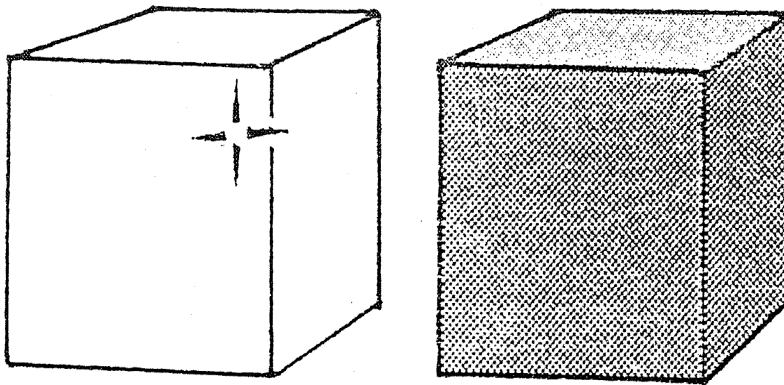
1. If a container filled with compressed air is punctured the container will move in the opposite direction of the emitted air like a sort of rocket. How does the container move if it instead is evacuated of air to almost vacuum and then punctured?

Justify your answer

2. A metal block with white surface and a metal block of the same size with black surface are both heated to 500° .

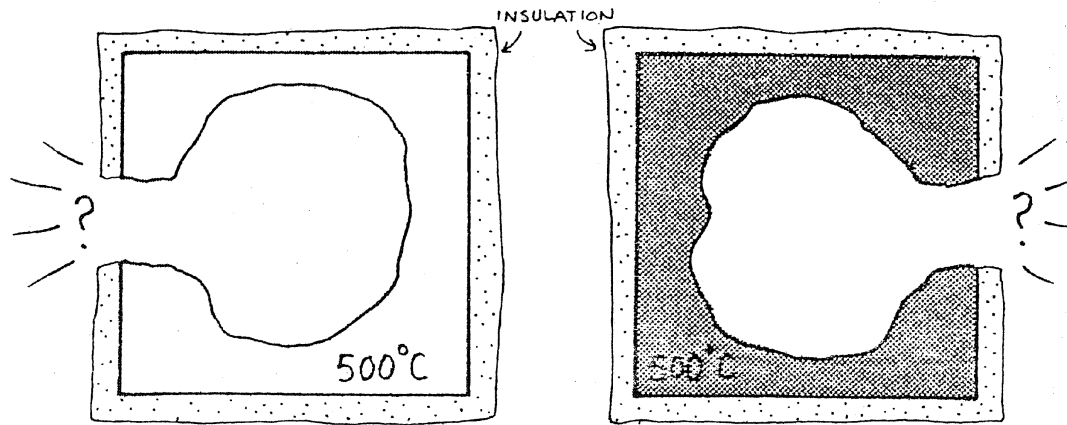
a) Which block emits most energy?

fig. a



If we instead cut out a hole in each block and insulate the surface around this hole (see fig. b.), what is then the ratio between the radiations for the two holes?

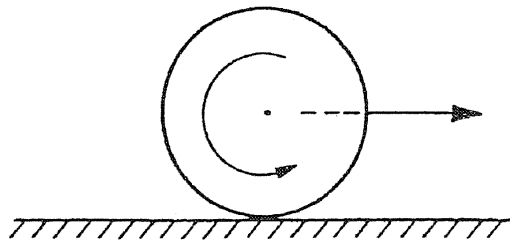
fig. b



Justify your answer.

3. One can enjoy oneself by sending a marble ball along a horizontal table so that it starts with a certain translation velocity and a certain “backwards” rotation (see fig. c.)

fig. c.



What should the initial situation be in order that the ball after some time turns around and runs back with a velocity larger than at the start?

Justify your answer.

4. A π mesonic atom is an atom where a π meson (rest mass 140 MeV) with the same charge as an electron revolves around the nucleus instead of one of the electrons.

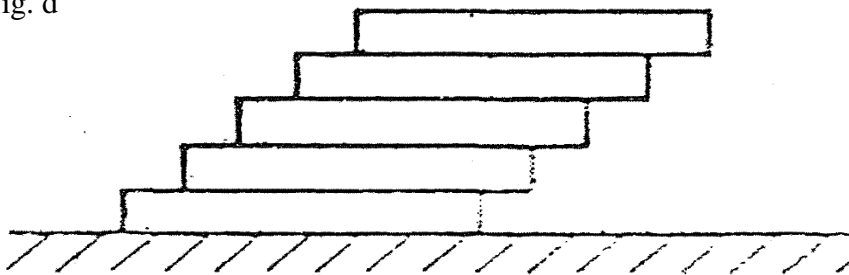
For what values of the atomic number z can a π mesonic atom possibly exist? Justify your answer.

5. A potential difference $V = V_0 \cdot \cos \omega t$ is applied to a capacitor. What is the force between the plates? Show that time independent information about the force can be used to measure alternating voltages.

Justify your answer.

6. Similar boards of length L are stacked as suggested in the figure so

fig. d



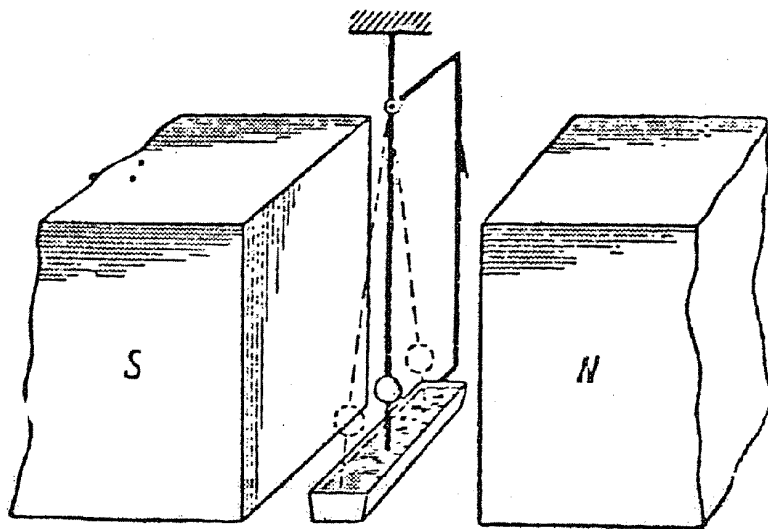
that for each board a piece of length L/n protrudes (n is an integer). How many boards can be stacked before the stack topples?

Justify your answer.

7. The famous German physicist Sommerfeld has claimed that the energy of indoor air in a house (at a pressure of 1 atm.) does not increase when the temperature increases. How come?

8. A small pendulum consists of a metal cord and a ball with a metal tip, which touches a trench with mercury. The mounting cord is connected to the mercury container so that a closed electric circuit is formed.

(see fig. e.)



The pendulum is placed between the poles of an electromagnet. The pendulum is made to oscillate so that the tip is in contact with the mercury all the time.

What happens?

Justify your answer.

Roskilde University

First written test in the breadth module of physics

To be held Thursday, January 9, 1986, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. How fast does a tumble dryer rotate?

Justify your answer.

2. The history of experimental elementary particle physics is the story of how smaller and smaller study objects require larger and larger energies of the particles that are used as probes, and thus larger and larger accelerators.

What is the relation between object size and the required minimum energy?

Justify your answer.

3. What is the effect of capacitors connected in series and in parallel, respectively, in a circuit?

Justify your answers.

4. Explain why galaxies are often formed as flattened rotating systems. Why are the very old stars and star clusters in such galaxies not assembled in a thin disk, but rather distributed over an almost spherical area?

5. How does the curvature of the trajectory of a ping pong ball depend on its spin and its speed?
Justify your answer.

6. The inspiring Danish physicist Holger Bech Nielsen assumes (as one of the starting points for his deliberations on the status of the natural laws) that the so-called Planck length (about 10^{-35} m) is the minimum length in nature. The Planck length is fixed by being allowed to depend only on the magnitude of the three universal constants: Planck's constant (h), the speed of light (c) and the gravitational constant (G).

Show how it depends on h , c and G .

7. From an earthquake waves propagate through the Earth and along the surface of the Earth. At a suitable distance from the earthquake, the surface waves are the strongest.
Why?

8. How does the heat capacity vary with temperature for a collection of identical particles, each of which can only be in two possible energy states?
Justify your answer.

Roskilde University

Second written test in the breadth module of physics

To be held Friday, January 10, 1986, 10:00-14:00

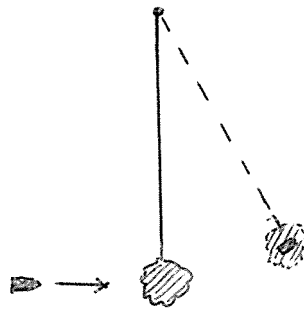
NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. There is no power to start a car, because it was left with its lights on. How should the battery be connected to the battery of the friend's car?

Justify your answer.

2. The figure suggests the principle of a so called ballistic pendulum used to measure projectile velocities. What is the relation between deflection and projectile velocity?



Justify your answer.

3. The temperature of fusion plasmas is such that the atoms are broken down into electrons and ions. In a magnetic field, the electrons and ions move in spiral trajectories. What is the relation between the radii of trajectory for the two kinds of particles?

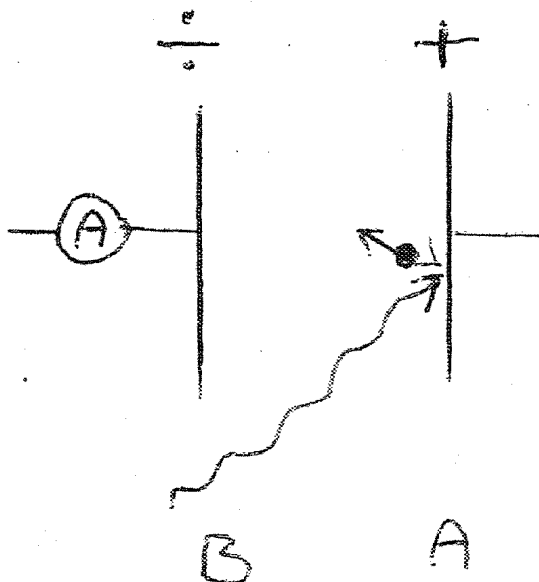
Justify your answer.

4. In heat treatment of cancer tumors, a system of several microwave emitters can be used. Explain why a system of several weak emitters rather than a single strong emitter is used.

5. Superluminal particles – so-called tachyons – are purely mathematical constructions within the framework of the special theory of relativity. Outside the physicists' circles, however, some credit them with a more real existence. What is the mathematical consequence of assuming superluminality for the rest masses of the tachyons?

6. With what frequency does water slop in a large bath tub compared to the slop frequency in a small bath tub of similar shape? What is the ratio if the small bath tub belongs to a bath room and the large one is Lake Geneva?

7.



The figure is a principle sketch of a measurement set-up for the demonstration of the photoelectric effect: Electrons are supplied to metal plate B from metal

plate A, where they are knocked out due to light exposure. Whether a current of electrons flowing away from B is registered, turns out to depend on the wavelength of the light and not its intensity. At long wavelengths no current flows even at very large light intensities. At shorter wavelengths, a limiting

voltage between the two plates exists for each wavelength, so that a current flows when the voltage difference is smaller than the limiting voltage, while no current flows when the voltage difference is larger than the limiting voltage. What is the relation between wavelengths and limiting voltage?

8. Explain why bottle openers are so excellent to remove metal caps from bottles.

Roskilde University

First written test in the breadth module of physics

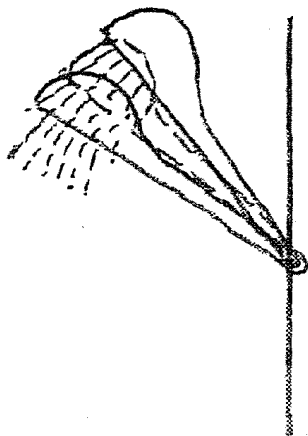
To be held Tuesday, June 3, 1986, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. Voltmeters often consist of an amperemeter with a series resistor. What is the purpose of the resistor?

2.



A hand shower in its holder can sway between the two extreme positions shown. Is there a water pressure that can make it stand in the middle position?

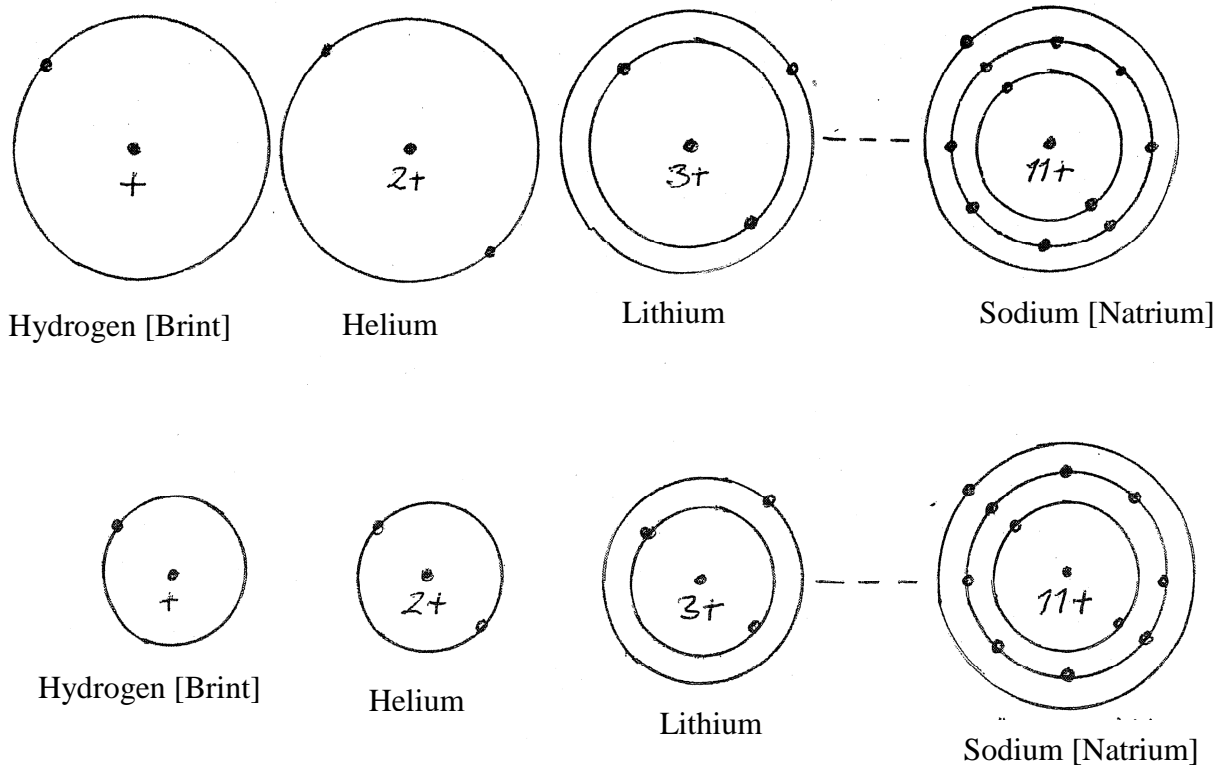
Justify your answer.

3. How do the surface temperatures of the planets depend on their distance from the Sun?

Justify your answer.

4. What determines the temperature in an unheated room in an otherwise heated house?

5.



Which of the two shown illustrations of the explanation by quantum mechanics of the structure of atoms seem most reasonable?

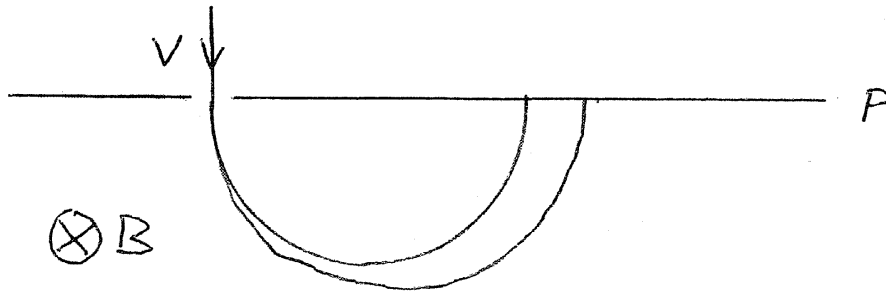
(Both kinds appear in the literature)

Justify your answer.

6. In relation to the so-called quantum Hall effect (Nobel Prize 1985), a fundamental resistance appears, which depend only on the two universal constants Planck's constant (h) and the charge of the electron (e). There are plans to use this as a resistance standard in the future.

How does the resistance depend on h and e ?

7.



In an ordinary mass spectrograph, the various kinds of ions in an ion beam are separated using a magnetic field as suggested in the figure.

In addition to the masses and charges of the ions, the deflection depends on the speed, which thus needs to be fixed at a particular value.

However, this requirement does not need to be fulfilled if an electric field in the same direction as the magnetic field is added to the spectrograph. Then the deflection out of or into the plane of the paper, that is caused by the electric field, can be used for mass separation of the ions, even if v varies since this deflection does not depend on v .

Where in the plane p can ions of a certain mass be accumulated?

Justify your answer.

8. How high does a child sitting at one end of a seesaw fly if she does not hold on to the seesaw, when an adult sits down at the other end?
Justify your answer.

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, June 4, 1986, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

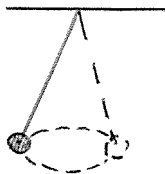
1. In 1808, Gay-Lussac advanced the fundamental law of chemistry about simple volume ratios: Gaseous substances react with each other in simple volume ratios.

Gay-Lussac gave as an example:

2 vol. carbon monoxide + 1 vol. oxygen gives 2 vol. carbon dioxide

Explain the law.

2.



The figure is a sketch of a so-called conic pendulum. What is the period of revolution?

Justify your answer.

3. Mass spectroscopic C^{14} registrations (for instance for geological age determinations) are disrupted by N^{14} occurrences. At a very high resolution C^{14} and N^{14} can be distinguished.

How come?

4. The point of departure of the so-called quantum Hall effect (Nobel Prize 1985) is the two-dimensional motion of electrons in thin semi-conductor layers, where motion across the layers is quantum-mechanically impossible.

How thin do the layers have to be?

Justify your answer.

5. What is the trick of letting the plates on the juggler's cane rotate?

6. Among the planets and moons, some can sustain an atmosphere, while others cannot.

What is required and why?

7. How much energy has to be delivered from an electric generator to increase the current through a coil from zero to a certain value?

Justify your answer.

8. Explain the ability of glass prisms to separate light into its color constituents.

Roskilde University

First written test in the breadth module of physics

To be held Wednesday, June 10, 1987, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

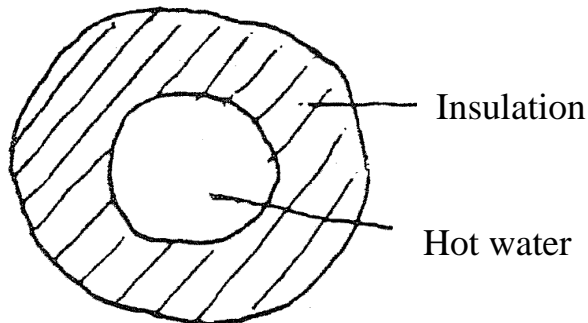
1. In what position does the rope of a swing break if it breaks?

What happens?

Justify your answers

2. How does the heat loss in district heating pipelines depend upon the insulation?

Justify your answer



Cross section

3. In the chain of radioactive decays from ${}^{238}_{92}\text{U}$ to ${}^{206}_{82}\text{Pb}$, α and β radiation is emitted. Does the β radiation consist of electrons or positrons?

Justify your answer

4. The spectral lines emitted by luminous hydrogen can be described by the equation

$$\nu_{n,m} = R \left(\frac{1}{m^2} - \frac{1}{n^2} \right)$$

Which fundamental quantities does the constant R depend on and how does it depend on them? Justify your answers

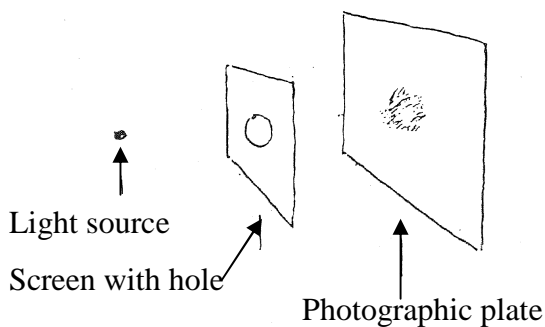
5. If an electric device is turned off by pulling the plug out of the socket, a spark may occur. This does not happen when the device is turned on by putting the plug into the socket.

Explain why.

6. So called gravimeters, used for measuring gravitational fields, measure so accurately that they register the difference between being placed on a table and on the floor next to it.

How accurate is that?

7.



In the sketched arrangement, at what size of the hole is the smearing spot become smallest?

Justify your answer.

8. In windy weather paper and leaves in the street are typically stirred up rather than pressed down to the Earth.

Explain why.

Roskilde University

First written test in the breadth module of physics

To be held Friday, June 12, 1987, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. Who slips easiest on a slope, a child or an adult?

Justify your answer.

2. Experience indicates that the viscosity of liquids typically varies as $\exp\left(+\frac{T_0}{T}\right)$

with temperature T (T_0 is a constant). Does this seem reasonable from a microscopic perspective?

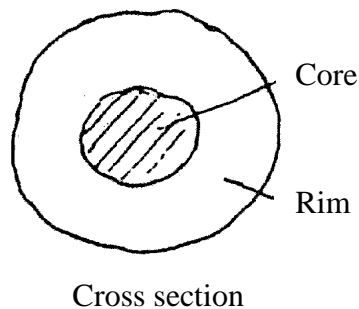
Justify your answer.

3. In connection with the latest observed supernova explosion, a strong neutrino flux was recorded here on Earth. The event in the course of the explosion that caused the neutrino emission was also optically observed. According to the observational material, the arrival of the neutrinos at the Earth took place at most 1 hour after the arrival of the light. The distance to the supernova is 170,000 light years.

What upper limit on the order of magnitude of the rest mass of the neutrinos can be derived from this?

4. A beer can is 16 cm tall. It can contain 320 g beer and weighs itself 40 g. What is the lowest position of the center of gravity for can and beer combined for varying beer content?

5. Optical glass fibers for signal transmission consists of a core and a rim, both of which are of glass, but with different refractive indices:



The light signals are transmitted through the core. Is the refractive index of the core larger or smaller than the index of the rim?
Justify your answer

6. To protect the door hinges, carpenters typically place the door stop at a distance of two thirds of the door width from the support of the door.
Why at precisely this distance?

7. Stefan-Boltzmann's law, that the energy density of black body radiation is equal to a universal constant times the absolute temperature to the fourth power, can be derived from electrodynamics and thermodynamics. The magnitude of the universal constant, however, is explainable only from more fundamental constants of nature within the framework of quantum mechanics, which suggests a relation between quantum mechanics and thermodynamics.

What is the relation between the constant in Stefan-Boltzmann's law and more fundamental constants of nature?
Justify your answer.

8. In a house heated by electricity, the risk of breaking the fuse is largest in the case when all the electricity radiators are cold and turned on simultaneously. Why?

Roskilde University

First written test in the breadth module of physics

To be held Wednesday, September 9, 1987, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. Does spring tide occur at full moon, new moon or half moon?

Justify your answer.

2. At the bottom of a swimming pool, light can be seen from a circular area of the water surface vertically above the bottom, whereas the surface further away is dark.

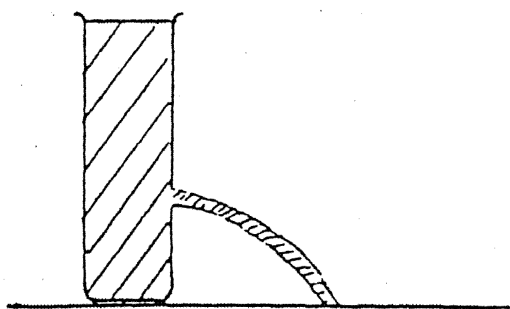
What is the radius of the area?

Justify your answer.

3. To produce integrated microelectronic circuits, electron beams are often used because a lower limit for component size has been reached when light is used for the projection of the circuit patterns. What is the least kinetic energy of the electrons?

Justify your answer.

4.



At what height of the hole in the container with liquid does the stream get farthest away? Justify your answer.

5. The recoil effect on the excited atoms in a luminous gas during light emission leads to a small deviation of the frequency of the emitted light relative to the frequency that corresponds to the difference between the rest energy of the atoms before and after light emission.

How large is the deviation?

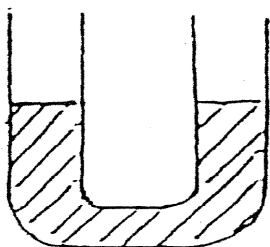
Justify your answer.

6. In a junction box, three metal clamps connect two cords from a light bulb, two cords from a power switch and two cords from the alternating current network of which one is earth. Of course, the two metal clamps connected to the two network cords have network voltage and voltage zero, respectively. This can be registered with, for instance, an electrician's screwdriver. What is the voltage in the third clamp?

7. The temperature variations on the surface of the Earth during 24 hours, during the year and from ice age to ice age are each reflected in damped temperature waves through the underground. How do the wavelengths depend on the period and the properties of the underground?

Justify your answer.

8.



What is the oscillation period for the liquid in the shown U-tube? Justify your answer.

Roskilde University

Second written test in the breadth module of physics

To be held Friday, September 11, 1987, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. Does the gravitational field strength increase or decrease down through a drilling hole?

Justify your answer

2. How do the sounds of a by-passing car change?

Justify your answer

3. In a solar cell, a fraction of the light irradiation on a semiconductor material is transformed into electrical energy via the generation of electron-hole pair.

What is the relation between the composition of the light and the efficiency of the solar cell?

4. A board is leaning against a relatively smooth wall. At what inclination does it slip?

Justify your answer

5. In a so-called “time-of-flight” mass spectrometer, (at Odense University such a device is used in the study of protein substances) molecules of different masses are separated from each other by pulsing ionization in an electric field; subsequently, they spent different times reaching a detector. How does this time of flight of a molecule depend on its mass?

Justify your answer

6. In hydrology, the flow of water in the underground is described by what is called Darcy’s law. The law says that the flow rate at a certain place is proportional to the pressure drop per unit length at the place in question. The constant of proportionality depends on whether it is, say, clay, sand, or gravel that is permeated and is called the permeability through water of the medium in question. The permeability must be assumed to depend on size and shape of the grains composing the medium as well as how they are packed. How does the permeability depend on the grain sizes in media whose grain shapes and packing patterns are assumed to be similar?

Justify your answer.

7. What is the order of magnitude of the strain that the electricity network has to be able to stand from the electric motor of an escalator compared to the strain from a typical electric radiator?

Justify your answer

8. Does a cup of coffee that is to be served with milk and not drunken right away, stay warmer if the milk is poured in the coffee initially rather than later?

Justify your answer.

Roskilde University

First written test in the breadth module of physics

To be held Friday, January 8, 1988, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. Superconductivity and especially the new superconductors make possible the establishment of very large magnetic fields. Explain what happens if, for some reason, the superconductivity suddenly fails.

2. James Clark Maxwell realized that the ring of Saturn has to be composed of single particles. For if the ring was a solid ring (like carved out of a huge metal plate), it would crack.

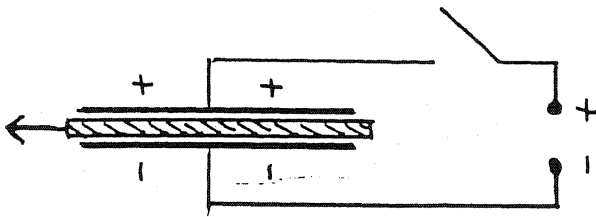
Explain what deliberations can lead to this realization.

3. Robert Hooke advanced before Newton a theory concerning the interaction of masses. He proposed that the interaction increases directly proportional with the distance between the masses. Assess this theory and Newton's law of distance squared in relation to the observable planetary motions.

4. The filament of light bulbs is mainly made of wolfram that have a resistivity of $54 \cdot 10^{-9} \Omega \cdot \text{m}$.

Estimate the length and thickness of the filament in a 40 W bulb.

5.



Two capacitor plates, with a dielectric material, e. g. a glass plate, placed between them, are charged. The connection to the voltage is cut and then the glass plate is removed.

By doing so, what happens to the capacitance, with the voltage difference and with the energy of the capacitor?

Explain how energy is conserved.

6. Recently, it was experimentally shown that a “double β -decay” is possible. With a half-life of $1.1 \cdot 10^{20}$ years, $^{82}_{34}\text{Se}$ decays to $^{82}_{36}\text{Kr}$ with the emission of two β particles.

The double decay can be explained by a short-lived formation of $^{82}_{36}\text{Br}$.

Explain how this is possible, considering conservation of energy. Is it possible to say something about the decay times of the subprocesses?

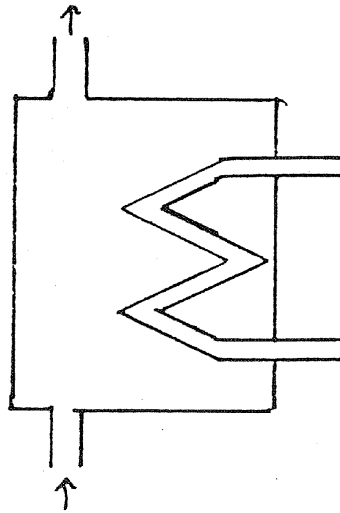
The respective atomic masses are

Se - 82: 81.916708

Br - 82: 81.916798

Kr - 82: 81.913482

7.



If one opens for the hot utility water from a hot water tank, cold water is flowing into the container instead. How does the temperature of the utility water vary if the container is open for a long time?

8. Both for the Sun and for a neutron star, the emitted power is of the order of magnitude of 10^{30} W. The surface temperature of the Sun is about 6000 K, while it for a neutron star is about 1 000 000 K.

Find the radius of a neutron star.

Roskilde University

Second written test in the breadth module of physics

To be held Monday, January 11, 1988, 10:00-14:00

NO AIDS ALLOWED

Please solve 6 out of the below 8 problems. It should be clear which 2 problems that are deselected.

1. Electrons can lose energy by elastic collisions with atomic nuclei. They are slowed down in the field of the nucleus. Radiation in the x-ray area is thereby emitted, the so-called “bremsstrahlung”. The intensity of the radiation depends on the square of the acceleration of the electrons in field.

For which substances is the intensity the largest, and why don't we get “bremsstrahlung” when the electrons collide with each other?

2. How does the conductivity depend on temperature in substances for which the conductivity is due to ions?

Justify your answer.

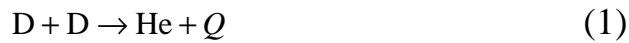
3. A compass needle floating in water in the magnetic field of the Earth turns until it is aligned with the direction of the field. A compass needle in the field of a bar magnet moves towards the bar magnet as well as align with the field. Why doesn't a compass needle moved towards one of the poles of the Earth when it is placed in e.g. water or on another frictionless foundation?
4. Explain why one shouldn't steer and brake at the same time in a car.
5. A train wagon has swing doors between the sections. The doors are controlled by springs and when the train accelerates the doors open. How large is the angle for a given acceleration?
6. Due to its fusion processes, the Sun will loose about 0.4 % of its mass during the main sequence phase. What does this imply for the length of the year at the Earth during the main sequence phase?

7. Newton calculated the gravitational acceleration by means of

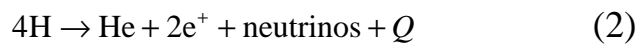
- the period of revolution of the moon
- the radius of the orbit of the moon
- the radius of the Earth

What equation did he obtain and did he use the moon's sidereal period of revolution or the period in the Earth-Sun system, i.e. the time between two full moons?

8. In present fusion research on Earth, scientists are attempting to realize the process



In the center of the Sun, however, it is the gross process



that delivers the energy.

Discuss why we prefer (1) on the Earth, while (2) is the only process happening in the Sun today.

Roskilde University

First written test in the breadth module of physics

To be held Monday, June 12, 1989, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A heating element ensures that the water temperature in an aquarium is higher than the temperature of the surroundings. By an accident, the current to the heating element is cut. How does the cooling time depend on the size of the aquarium?

Justify your answer.

2. A standard method for the determination of the refractive index of water uses a small glass container (with a rectangular cross section) formed by glass plates that are plane parallel. The glass container is filled with air and is immersed in water. One of the sides of the container is lit with a horizontal light beam directed perpendicularly to the side. Then the container is rotated around a vertical axis until the passing-through light beam vanishes.

How can the refractive index subsequently be determined?

What is the effect of the refractive index of the glass?

Justify your answers

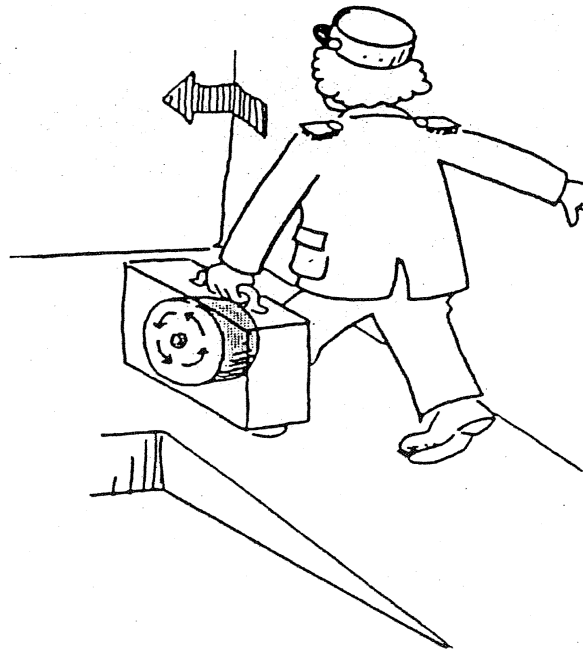
3. Diatomic molecules can both rotate and vibrate. In a semi classical description, one can assume that the oxygen molecule has a moment of inertia of $2 \cdot 10^{-46} \text{ kg} \cdot \text{m}^2$ and a spring constant for the molecular potential of $1.3 \cdot 10^3 \text{ N/m}$. Estimate which rotational and vibrational states are found to be excited when oxygen molecules collide at room temperature. ($1 \text{ J} = 0.62 \cdot 10^{19} \text{ eV}$)

Justify your answer

4. During the main part of the life of a star, a gravitational collapse is prevented by the energy production in the center parts of the star. Assume that the energy production suddenly ceases. Give an estimate (e.g. using a dimensional analysis) of the time a collapse typically takes.

Justify your answer.

5. According to an anecdote, a physicist once placed a large rotating flywheel in his suitcase. The hotel bell boy took the suit case and walked with it. What happened when he turned around the corner as shown in the figure?



Justify your answer.

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Second written test in the breadth module of physics

To be held Wednesday, June 14, 1989, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A certain amount of a radioactive isotope is delivered to a hospital the same time every week.

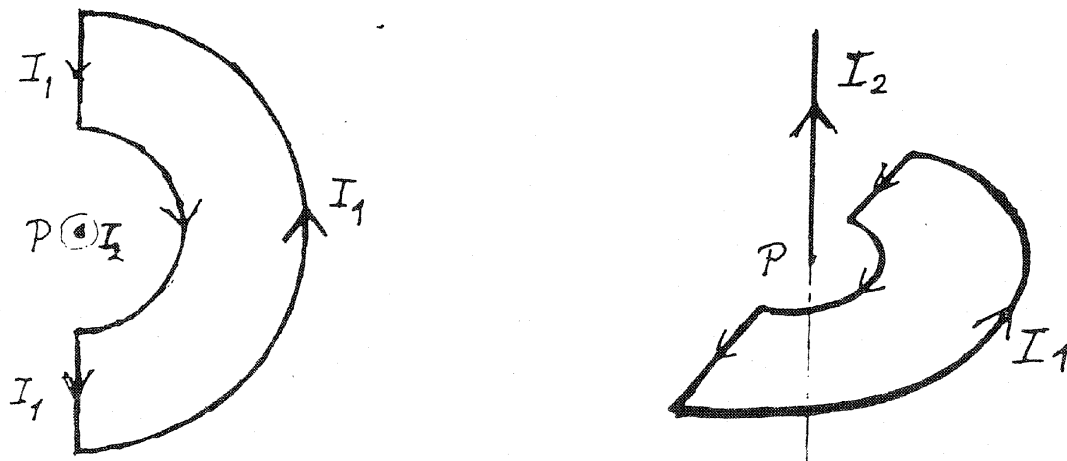
One day the doctor discovers an unopened container with the isotope, where the label is missing. With a Geiger counter she measures the activity of the container and compares it with the activity of the new portion of isotopes that was delivered the same day.

How can she then calculate the delivery date of the unlabelled container?

Justify your answer.

2. A closed circuit formed by two semicircles and two line segments (see the drawing) carries a constant current I_1 .

A straight conductor through the center P of the two semicircles and perpendicular to the plane of the circuit carries the constant current I_2 .



What torque acts on the circuit due to the current I_2 ?

Justify your answer.

3. Neutrinos from the Supernova SN 1987A were detected on the Earth. How are they formed according to scientists?

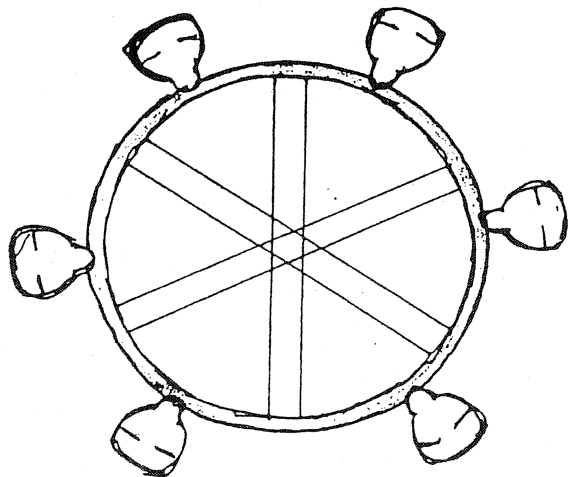
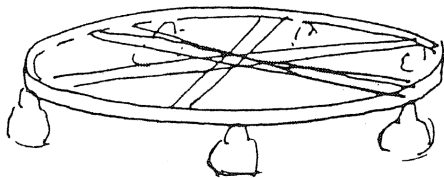
How can one in principle use the detection of neutrinos with different energies to estimate their rest mass?

Justify your answer.

4. In neutron diffraction, neutrons are sent into a crystal lattice. Is it possible to observe Bragg reflection when thermal neutrons (i.e. neutrons in thermal equilibrium with the surroundings at room temperature) are used?

Justify your answer

5. One of the so-called amusements of the amusement park Bakken is a very large wheel on which small cabins with seats are hanging. The wheel starts rotating in an almost horizontal position, but is gradually lifted to a position where it rotates in a vertical plane with the cabins bristling, so that bold people can hang with their heads down in the upper part of the motion.



How fast is the wheel rotating?

How do the passengers experience “the gravitational field” during the rotational motion when the wheel is vertical?

Justify your answers.

Roskilde University

First written test in the breadth module of physics

To be held Monday, June 11, 1990, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A can with a small hole in the bottom is initially filled with water. How long time does it take before all the water has ran out?

Justify your answer.

2. Why are high temperatures necessary to start fusion, but not fission?

Justify your answer.

3. In the classical (demonstration) experiment, e/m_e is determined by first letting electrons run through an accelerating voltage and then sending them perpendicularly into a homogeneous magnetic field, where their tracks are measured.

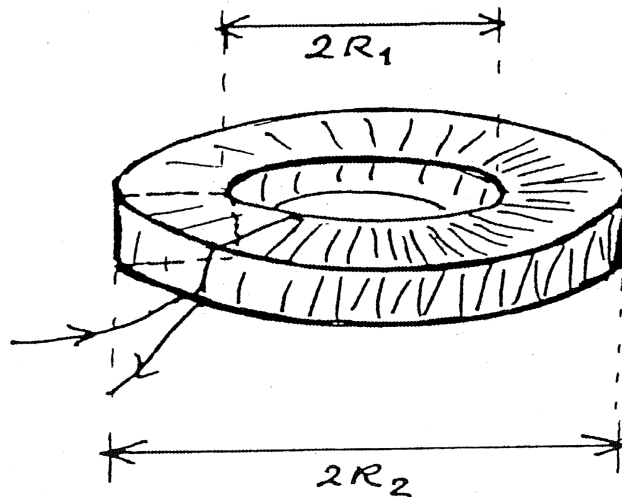
Can a corresponding experimental determination of e/m_e happen for the relativistic case?

Justify your answer.

4. About a year after the supernova explosion SN 1987A, American astronomers claimed that they had discovered a pulsar with a period of 0.5 millisecond. Why is it hard to believe them?

(Since then they have withdrawn the “discovery”. It was due to interference from a TV camera used to control the telescope!)

5. A “quadratic toroid” (see the figure) has an inner radius R_1 and outer radius R_2 . The cross sectional area is quadratic. A direct current flows in the windings of the coil, which are quite closely spaced.



How does the B-field depend on the distance from the axis of symmetry?

What is the magnetic energy stored in the coil and what is the self-inductance coefficient of the coil?

Justify your answers.

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, June 13, 1990, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

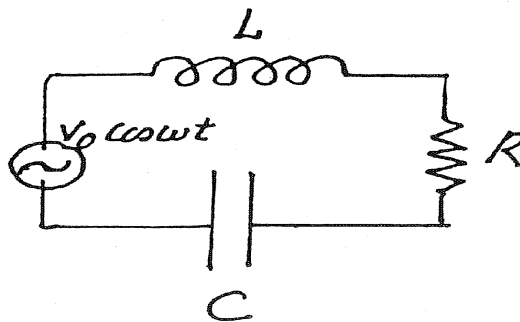
1. Galileo formulated the law of fall for free falls as follows: The length of fall is proportional to the square of the fall time. He experimentally demonstrated the law by, inter alia, measuring the motion of a ball rolling (without slipping) down an almost horizontal inclined plane – thus a motion that is far from being a free fall!

Explain why the “law of fall” is satisfied in this case.

What is the constant of proportionality between the covered distance and the square of the time interval?

Justify your answers.

2. Determine the electric power that the LRC circuit (see the figure) on average draws from the external alternating voltage source.



At what frequency is the largest power drawn?

Justify your answer.

3. On a hot summer day a crowd of tired city dwellers arrive at a borrowed holiday home. They fill immediately the fridge with lukewarm beers and soft drinks and turn it on.

How much electricity is consumed for the cooling?

Justify your answer

4. Around the turn of the nineteenth century, J. J. Thomson imagined an atom as a cloud of positive charges in which electrons are sitting like “raisins in a cake”. Let us take point of departure in such a model for the hydrogen atom – without, however, copying Thomson’s calculations.

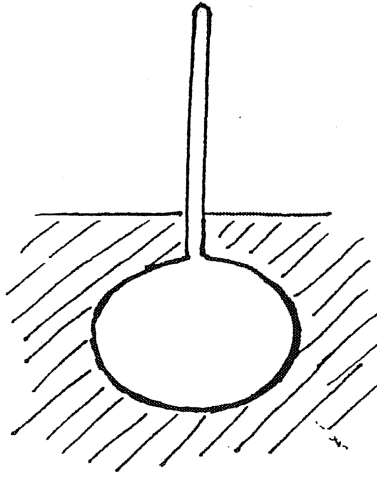
Show that the electron can oscillate along a diameter in the cloud.

Find an expression for the energy when the electron just stick to the inside of the positive cloud and compare with the energy of a quantum mechanical oscillator of the same frequency.

Estimate the size of the hydrogen atom based on this.

Justify your answer.

5.



A hydrometer is a gismo shaped like a ball with a vertical thin rod attached (see the figure). It is used among other things for the determination of the alcohol percentage of wine. One place the hydrometer so that it floats in the wine and reads off the alcohol percentage on the scale of the rod.

Explain how this works.

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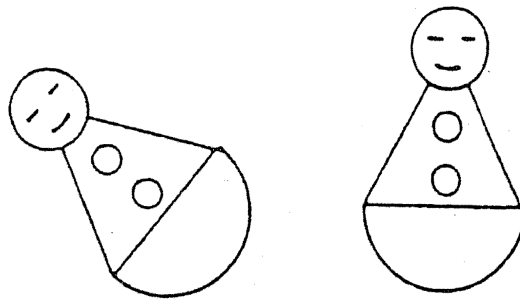
First written test in the breadth module of physics

To be held Tuesday, June 4, 1991, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

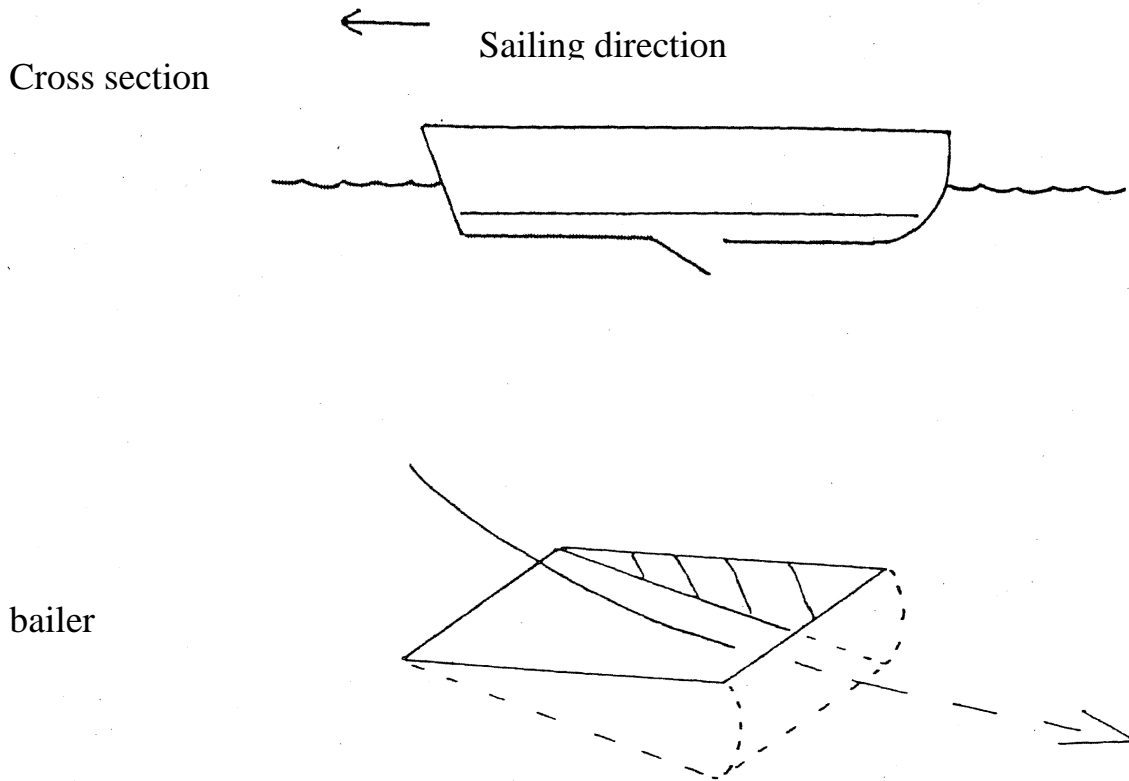
1. A tumbler is a piece of toy. The bottom is hemispherical, while the top can depict a clown. When the figure is put down, it rises by itself. It contains no movable parts. How is it designed?



2. Which is hardest: to compress an ideal gas when then temperature is kept constant or when the gas is thermally insulated? Justification

3. In 1971, the theory of relativity was tested in an experiment where a watch placed on the Earth was compared to two other watches that where flown in opposite directions around the Earth in commercial jets. The watch that flew east lost a little compared to the watch on the Earth; while the watch that flew west gain relative to the watch on the Earth. What precision of the watches was required to make the effect trustworthy and why was this east-west asymmetry observed?

4. The yachtsman Paul Elvstrøm has ingeniously solved the problem of automatically draining a boat of the water which inevitably splash into it. In the bottom of the boat a small leaf, called a bailer, is placed, which can be opened. When the boat sails sufficiently fast, the bailer is opened and water is sucked out. Why does this happen and how fast must the boat sail before it works?



5. Why is a light beam refracted when it passes through the interface of two media? A physical explanation (derivation) of the law of refraction should be given; it is not enough simply to state it.

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Second written test in the breadth module of physics

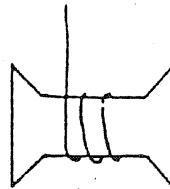
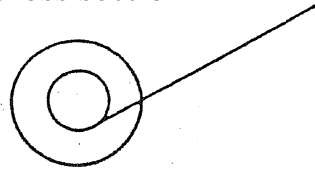
To be held Thursday, June 6, 1991, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

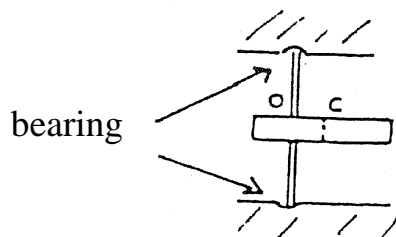
1. If you pull in the yarn of a reel (an object around which the yarn are wound for storage), it rolls towards or away from you depending on the angle between the foundation and the yarn. Explain the phenomenon. How large is the angle where the direction of motion changes?

Cross section



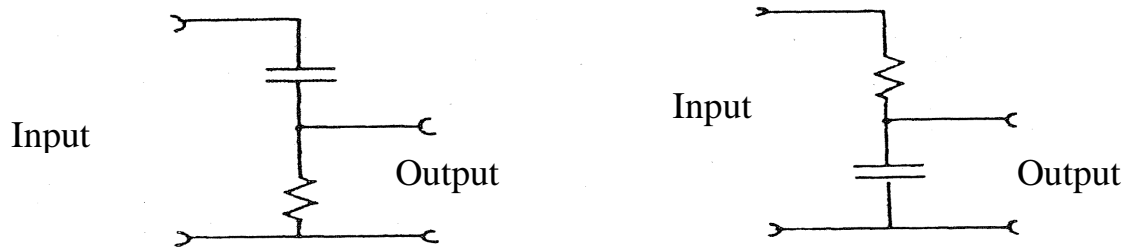
2. Two parallel electrical wires are placed so that the distance between them is much smaller than their length. With what force per length and in what direction does one wire influence the other when electrical currents of same direction are flowing in the wires? The equation should be justified.

3. A massive disk is fixed on a shaft perpendicular to the disk; but the disk is centered askew so that the center of the shaft does not coincide with the center of the disk. What forces arise in the bearings of the shaft due to askew centering when the disk rotates?



4. A star goes through a rapid change, whereby its surface temperature doubles and its average density of mass simultaneously falls by a factor of eight. What is the new radius and luminosity of the star?

5. The diagram shows two circuits (quadrupole), each of which has an input and an output. One is called a low-pass filter and allows mainly low frequency voltage signals to pass, while the other is called a high-pass filter and allows mainly high frequency signals to pass. The filters are assumed to be unloaded, i.e. only a vanishing current is flowing out of the output. Which one is the low pass filter and which one is the high pass filter?



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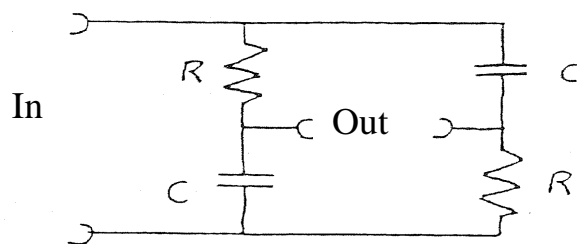
First written test in the breadth module of physics

To be held Wednesday, June 3, 1992, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. Why is the lamp in the darkroom of a photographer red?
2. If one accelerates strongly on a motor bike, one can make the bike lift the front wheel. How large an acceleration is required?
3. How large temperature fluctuations does a sound wave in air of moderate intensity, 10^{-6} W m^{-2} (60 dB), give rise to?
4. The pressure of saturated vapors above a liquid typically increases with temperature proportionally to $\exp\left(+\frac{T_0}{T}\right)$. Explain this and state what T_0 depends upon.
5. The figure below shows an electric circuit with two similar resistances and two similar capacitors. It is used to change the phase of a harmonically oscillating signal. What is the ratio of the amplitudes of the output voltage to the input voltage, when the circuit is unloaded (i.e. the output current is practically speaking zero)?



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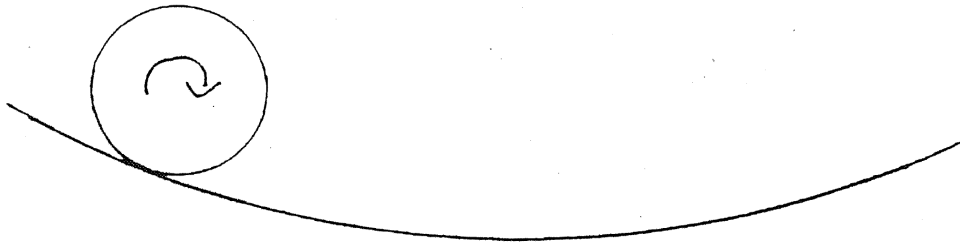
Second written test in the breadth module of physics

To be held Tuesday, June 9, 1992, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. If you press your index and middle fingers together and look at the light through the formed slit, you see a row of dark lines. Explain the phenomenon.
2. A ball rolls back and forth in a bowl. The motion stays in the horizontal plane. What is the period?



3. A so-called linear star model assumes (somewhat unrealistically, but qualitatively correct – and instructively) that the density of mass $\rho(r)$ varies linearly throughout the star following the equation

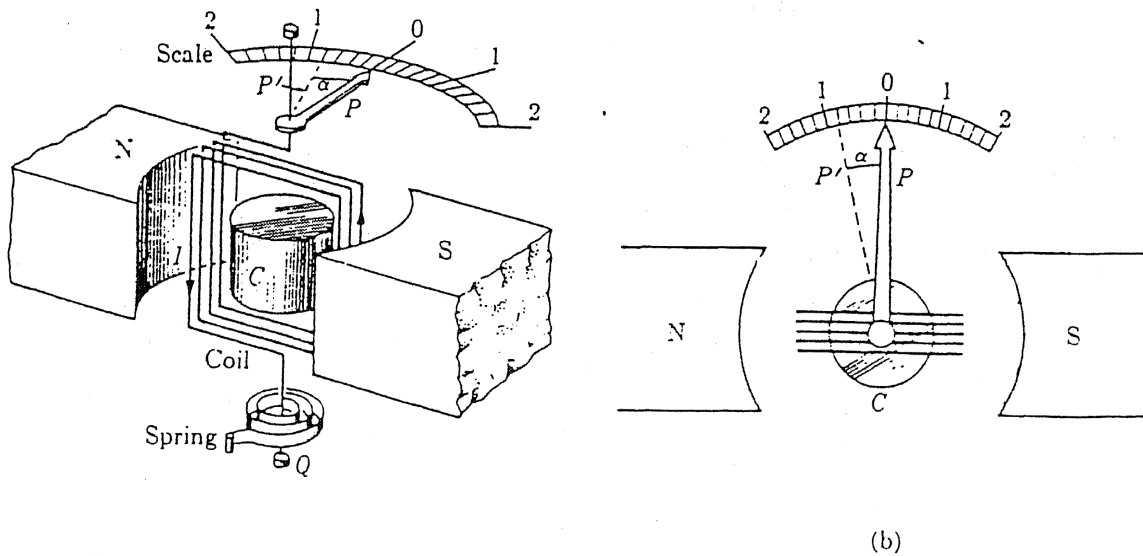
$$\rho(r) = \rho_0(1 - r/R)$$

where R is the radius of the star, and r is the distance from the center of the star where the density of mass has the value ρ_0 .

Estimate the mass density of mass in the center of such a star – compared to the average density of mass of the star and explain how, in principle, it is possible to determine the pressure and temperature in the center of such a star.

4. The two figures below illustrate the principles of a galvanometer. Between two permanent magnets, a small coil is placed that can rotate about an axis (perpendicular to the plane of the paper in figure b). A coil spring keeps the moving coil in an equilibrium position, when there is no external torque. The permanent magnets can be imagined to be replaced by two serially connected coils of many windings. Through these a current can be sent independently of the current through the moving coil. The apparatus can now be used as a direct current Wattmeter (power gauge).

Explain how.



(a) Basic components of a moving coil galvanometer. (b) Top view of galvanometer shown in (a).

5. A science fiction novel imagines a rocket driven by a light beam emitted from the rocket. With what power should the “engine” shine to give the rocket an acceleration equal to the gravitational acceleration and will this be an effective way to drive a rocket compared to conventional emission of fuel?

Roskilde University

First written test in the breadth module of physics

To be held Tuesday, June 8, 1993, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. By how much is a rod stretched under its own weight when it hangs vertically from one end?
2. In an electrical network one can replace three resistances in a triangle (figure 1) with three others in a star (figure 2) without changing the external conditions. How?

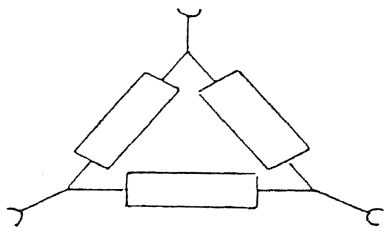


fig. 1

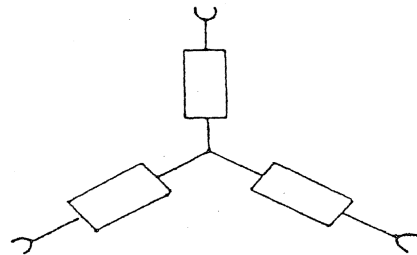


fig. 2

3. Small bubbles of air floats with a liquid through a tube of varying cross section. Will the diameter of the bubbles decrease, increase or remain the same when they pass a narrow place in the tube?
4. Even if two events are not simultaneous in one inertial frame of reference, they can be so in another. What is the condition for this?
5. What would the ratio of the electron's spin to its electrical moment be, if the electron could be perceived classically as a massive ball with all the charge placed on the surface?

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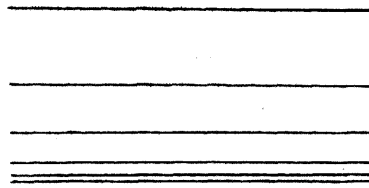
Second written test in the breadth module of physics

To be held Thursday, June 10, 1993, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. The electrical field strength is often illustrated by drawing field lines. Can a static field in a part of space look as in the figure?

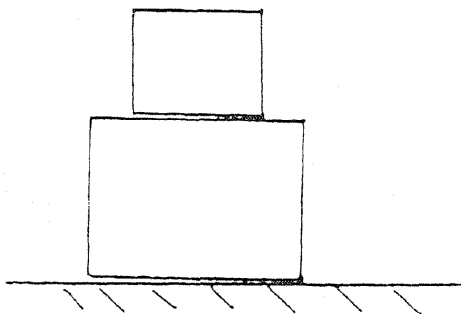


2. Account for the equivalence of the following two formulations of the second law of thermodynamics:

- a) (Kelvin, Planck) No process, whose only result is the uptake of heat from a heat reservoir and transformation of this heat to work, is possible.
- b) (Clausius) No process, whose only result is the transfer of heat from a colder to hotter body, is possible.

3. How do we know that stars with radii much smaller than the radius of the Sun exist?

4.



Two boxes are placed on top of each other. With how large a force can one pull horizontally in the lower box before the upper box starts to slide?

5. Estimate the average velocity of the electrons in a metal at room temperature.

Roskilde University

First written test in the breadth module of physics

To be held Monday, June 6, 1994, 10:00-14:00

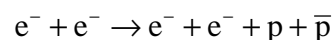
NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A bag filled with sand falls from a scaffold and hits the ground. The bag doesn't crack but changes shape. How large is the change of entropy?
2. A constant voltage difference V is applied to an air-filled plate capacitor with plate distance d . The space between the plates is then half-filled with a dielectric (dielectric constant ϵ) in two different ways:
 - a) A plate of the material of thickness $\frac{d}{2}$ and the same area as the capacitor plates is placed between the plates.
 - b) A plate of the material of thickness d , but of area equal to half that of the capacitor plates is placed between the plates.

State the magnitude of the electrical field strength within and outside the dielectric for the two cases, and sketch the course of the field lines.

3. A satellite circles at a low height around a moon. The moon has a density of 5000 kilogram per cubic meter. Determine the period of revolution.
4. Using an electron-accelerator it is possible to produce a proton-anti proton pair in the following process



Determine the smallest energy of the accelerated electrons required in the following two experimental situations:

- a) An accelerating electron collides with an electron at rest.
 - b) Both electrons are accelerated (to the same energy) but move in opposite directions and are then brought to collide.
5. For one star in a binary star pair, a hydrogen line of wavelength 656.20 nanometers is measured. A few days later the wavelength of the same line is measured to be 656.37 nanometers.
Explain the result and calculate the minimum velocity.

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, June 8, 1994, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. There is some worry of possible damaging effects on humans arising from long-term stays in the magnetic fields surrounding the high voltage wires used for electricity distribution.

Estimate the magnitudes of such magnetic fields at the surface of the Earth under the wires of a transmission system of 50 Hz AC. Often voltages of the order of 100 kV and powers of 25-100 MW are used. Assume for simplicity that the three phase wires hang vertically above each other at, say, 15, 20 and 25m, respectively, above the ground.

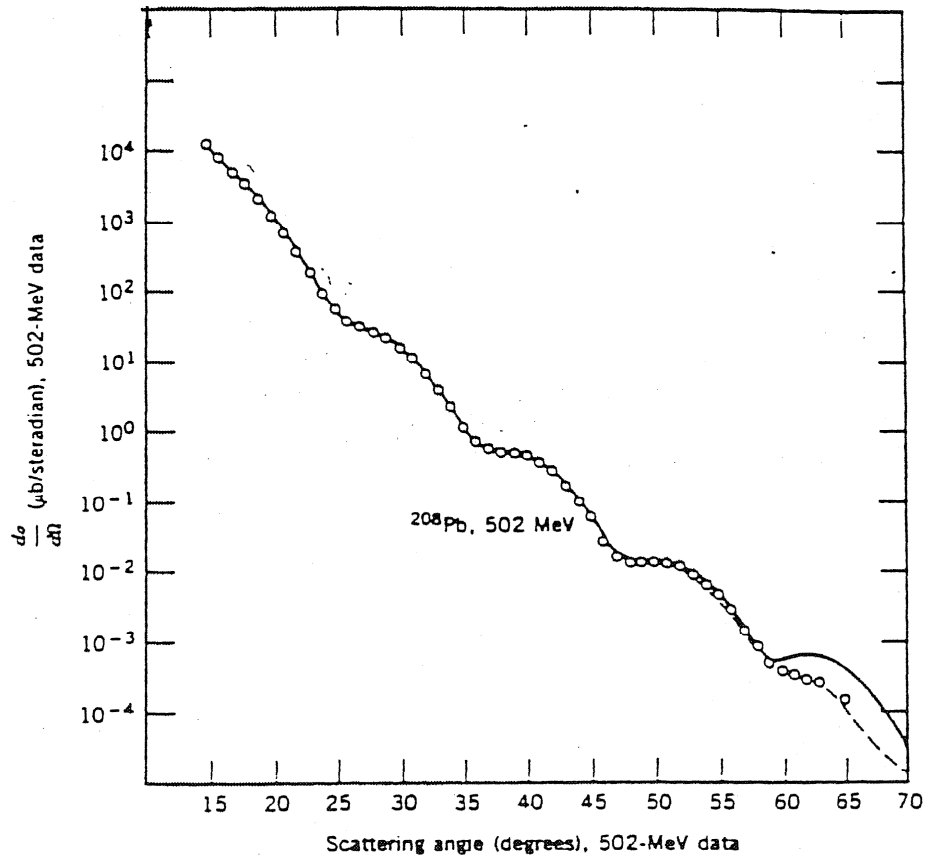
2. During an intergalactic travel we look back at the Milky Way. The longest side of our galaxy fills 7 degrees of the sky. We look at a star of absolute magnitude 0.

What apparent magnitude do we measure?

3. How much mechanical work can at maximum be gained when a body of heat capacity C_p and temperature T (K) as well as a heat reservoir of constant temperature $T_0 < T$ are available?

4. So far, two- or three-stage rockets have been used to place satellites in stable orbits around the Earth or to send a space ship away from the Earth. Describe why one stage is not sufficient.

5. A beam of electrons of sufficiently high energy is sent through a sample of an isotope. The angular distribution of the electrons that are scattered elastically on the nuclei is measured, see the figure.



The figure shows how the cross section of elastic scattering of electrons varies as a function of the scattering angle when electrons of 502 MeV are shot at the isotope ^{208}Pb .

Obviously, the dependence of the cross section on the scattering angle does not follow a uniformly decreasing curve, but exhibits certain minima and maxima relative to such a curve.

Show how we from the positions of these relative minima can determine the radii of the atom nuclei.

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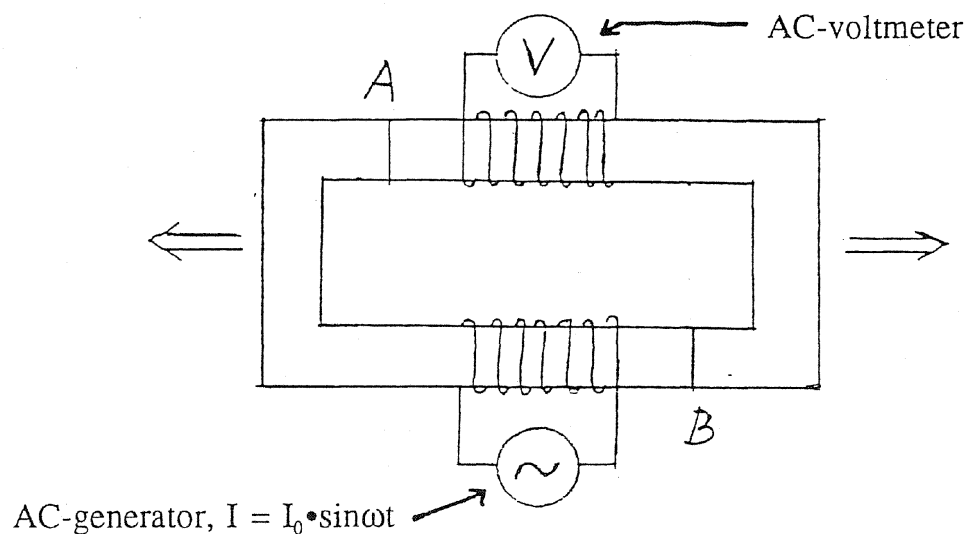
First written test in the breadth module of physics

To be held Monday, June 12, 1995, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. The drawing shows a magnetic circuit consisting of a rectangular ring of soft iron on which two coils are wound. A sinusoidal alternating current is sent through one of the coils using a generator. A voltmeter is inserted between the ends of the other coil.



The iron ring is cut through at A and B. We now pull gradually the two parts of the iron ring a little apart, as indicated by the arrows, so that (equally sized) air gaps appear at A and B. How will the voltage shown in the voltmeter (the effective value) change?

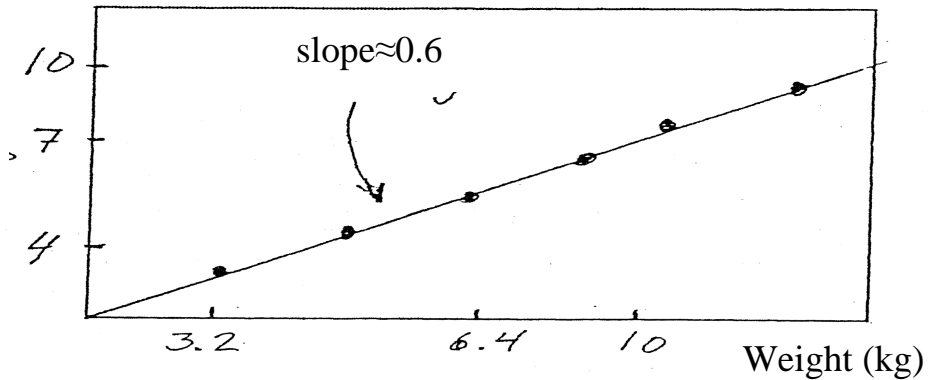
2. Explain what happens when a violin string is tuned.

3. Often, the cooking time of, say, turkeys are given as a certain number of minutes per kilo at a stated oven temperature. This means that there should be proportionality between the weight of the turkey and the cooking time used at the particular oven temperature.

Tests shows, however, the relation between weight and cooking time sketched in the figure. Note that a double logarithmic representation is used.

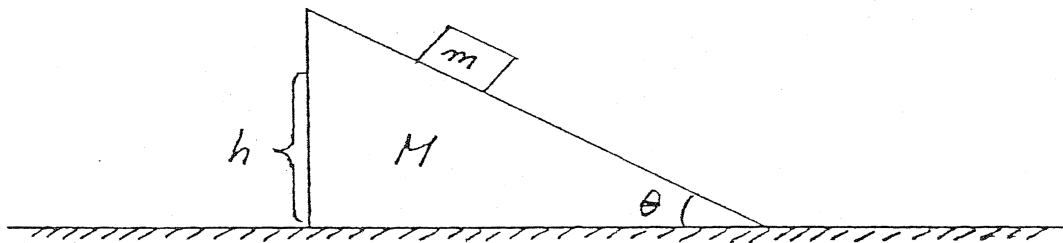
Give an explanation of this empirical relation.

Cooking time (hours)



4. A quasar has the same apparent luminosity as the Sun would have if the Sun were placed in a distance of 3000 parsec. However, the quasar is one million times farther away. Express the luminosity of the quasar in solar luminosities. If we assume that all quasars have the same absolute magnitude and that they are homogeneously distributed in the universe, then we can determine a relation between the apparent magnitude and the number of quasars that can be observed with this or larger apparent luminosity. Estimate this relation except for a factor of proportionality.

5.



A block of mass m slides frictionless down an inclined plane that forms the angle θ with the horizontal foundation. The inclined plane, which has mass M , can slide frictionless on the foundation.

The block starts on the inclined plane with velocity 0 at the height h over the horizontal foundation and slides down the inclined plane.

What is the velocity of the block when it reaches the base of the inclined plane?

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Second written test in the breadth module of physics

To be held Wednesday, June 14, 1995, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. Recently – March 1995 – “Science” published a study on the possible influence of the moon phase on the Earth’s daily average temperature, measured by satellites.

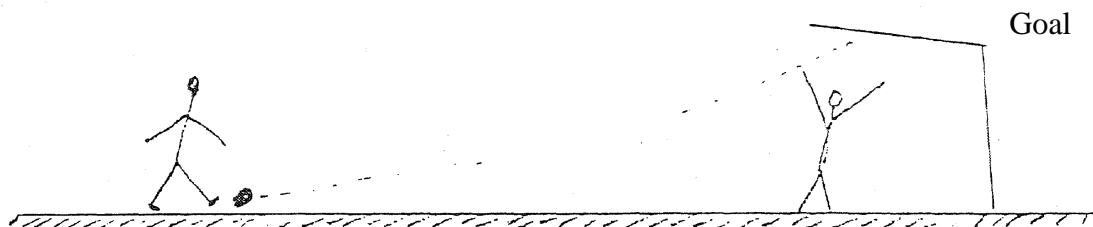
The results show a significant correlation between variations in the global average temperature and the moon phases. The mean temperature is about 269 K and exhibits a variation of 0.02 K between new moon and full moon so that the temperature is the highest at full moon.

Discuss whether the variation in the Earth’s distance from the Sun caused by the Earth’s and the Moon’s motion of their common center-of-mass can account for a temperature variation of the found order of magnitude if we as a first, rough assumption see the Earth as a black body.

Mass of the Earth = $5.98 \cdot 10^{24}$ kg, mass of the Moon = $7.34 \cdot 10^{22}$ kg,

Distance Moon – the Earth = $3.84 \cdot 10^8$ m, distance the Sun – the Earth = $1.5 \cdot 10^{11}$ m.

2. Skilled soccer players can make the ball “bend” or “curve”. This means that the ball due to a rotational motion about the center of gravity follows a trajectory with an extra, special curvature relative to the usual parabola of projectile motion. For instance, the ball can be made to move as shown in the sketch, where the ball bends upwards.



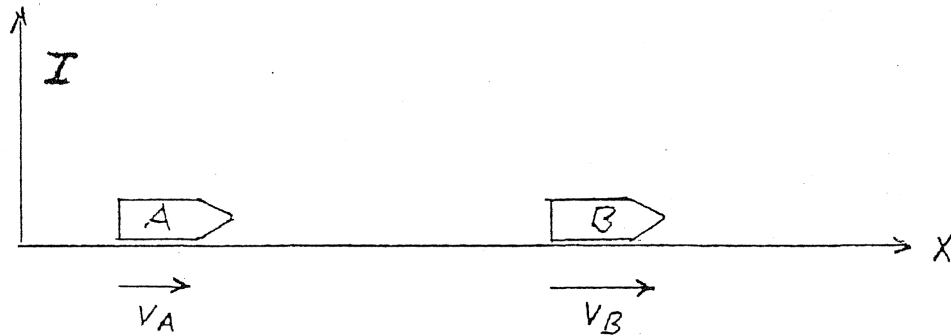
How should the kicker put the ball in motion in order to make it follow such a trajectory? Do the wind conditions play any role?

3. Consider an ideal gas characterized by the following macroscopic equations:

- 1) $pV = nRT$ (the general equation of state)
- 2) $pV^{5/3} = \text{constant}$ (the adiabatic equation of state)

Based on 1) and 2), express the internal energy of the ideal gas in question and discuss the results on the basis of a microscopic description.

4. Two spaceships, A and B, move at constant velocity along the x-axis in inertial system I (see drawing)



The velocities of the two spaceships are $v_A = 0.4 \cdot c$ and $v_B = 0.6 \cdot c$, respectively (c is the speed of light and both velocities are measured relative to I). From spaceship A, a monochromatic light beam of wavelength λ_A (measured relative to A) is emitted along the x-axis in direction of B using a laser.

What wavelength λ_B will an observer in spaceship B observe for the light beam?

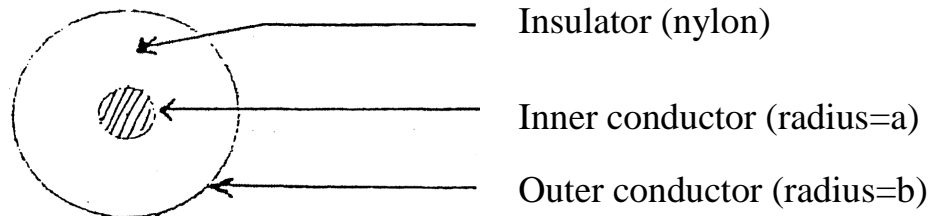
Let us now assume that the spaceship B is equipped with a fixed plate that absorbs all light hitting it. From spaceship A, a quantity of light of total energy E (measured in A) is emitted; subsequently, it hits the plate on B perpendicularly.

Find the energy and the momentum that the plate on B absorbs judged from an observer in B. (We ignore the influence of the radiation on the motions of the space ships relative to the inertial system.)

5. A high voltage cable is designed as a coaxial cable with a massive inner conductor of radius a and a concentric outer conductor of radius b . The gap is filled with an insulating material.

An insulating material can be characterized by its permittivity, ϵ and its breakdown field strength, which is the maximum field strength that the material can be subjected to without breakdown with a spark.

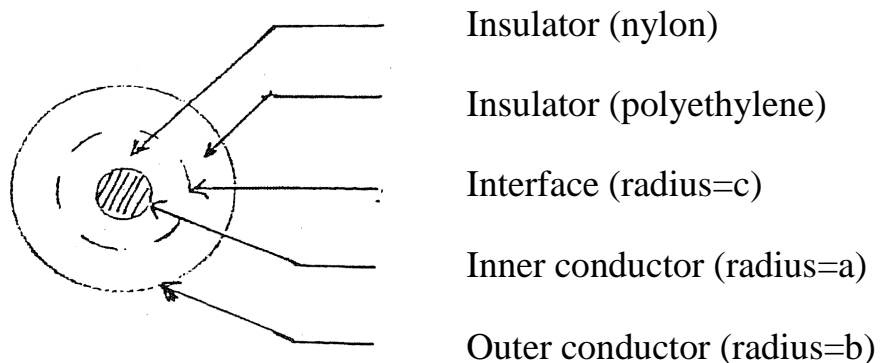
A) We first look at a situation where the gap between the conductors is filled with a single insulating material, nylon (see figure 1)



Find the maximum voltage difference that can be sustained between the inner conductor and the outer conductor if $a=0.5$ cm and $b=3.0$ cm.

For nylon the permittivity is $\epsilon_{\text{nylon}} = 3.5 \cdot \epsilon_0$, and the breakdown field strength is $E_{\text{max, nylon}} = 1.8 \cdot 10^7 \text{ V} \cdot \text{m}^{-1}$,

B) We then look at the situation where the gap is filled with two layers of different insulating materials, nylon (inner) and polyethylene (outer). See figure 2. The radius of the cylindrical interface between the two materials is denoted c .



Polyethylene has by and large the same breakdown field strength as nylon, i.e.

$E_{\text{max, polyethylene}} = 1.8 \cdot 10^7 \text{ V} \cdot \text{m}^{-1}$, but a smaller permittivity $\epsilon_{\text{polyethylene}} = 2.3 \cdot \epsilon_0$

With the same size for the cable's inner and outer conductor as in case A, determine the radius c of the interface that gives the largest possible value for the admissible voltage difference over the cable. Show that the cable can now resist a larger voltage difference than in case A.

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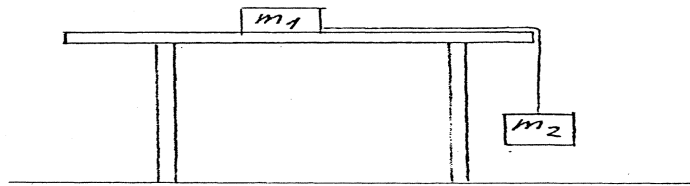
First written test in the breadth module of physics

To be held Wednesday, January 10, 1996, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. Two blocks of masses m_1 and m_2 are connected by a thin, inelastic string. One block is placed on a vertical table top, while the other hangs in the string from the table top, as shown in the figure.

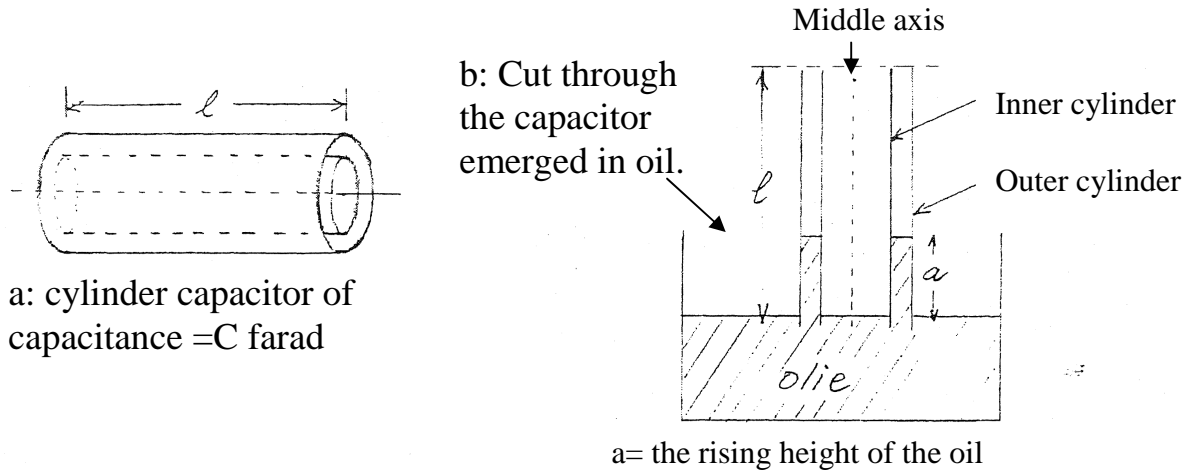


Find an expression for the tension in the string.

2. If you stand at a straight, flat sloping beach and the wind is onshore, then you will see the waves approaching perpendicularly to the beach, i.e. the wave crests are parallel with the beach even if the wind direction is not perpendicular. What is the cause of this?

3. A cylinder capacitor (consists of two concentric metal cylinders, that are electrically insulated from each other) of capacitance C farad is charged with the charge Q coulomb (figure a). One end of the capacitor is tucked just beneath the surface of oil in a container (figure b, which shows a section through the middle axis of the capacitor). The oil is an insulator with electrical susceptibility $\chi > 1$. This means that oil will rise in the gap between the outer and inner cylinder of the capacitor.

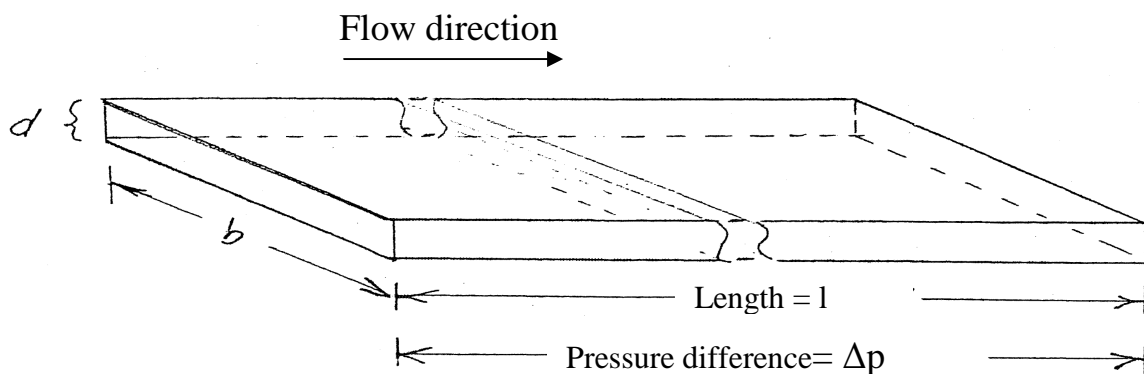
Give an explanation and state what determines how high the oil rises.



4. A neutral pion (π^0) that moves with velocity v m/s decays during the motion into two photons ($\gamma_1 + \gamma_2$) that are emitted in directions forming the angle θ with the pion's direction of motion.

Find the energy of the electrons and give an expression for the determination of the angle θ .

5. Derive the structure of an expression for the amount of liquid that flows per second through a long, narrow, split shaped channel (its geometry appears from the figure) between whose ends there is a pressure difference Δp . Assume that the flow is laminar. The friction coefficient of the liquid is denoted η .



Note: $b \gg d$ and $l \gg b$

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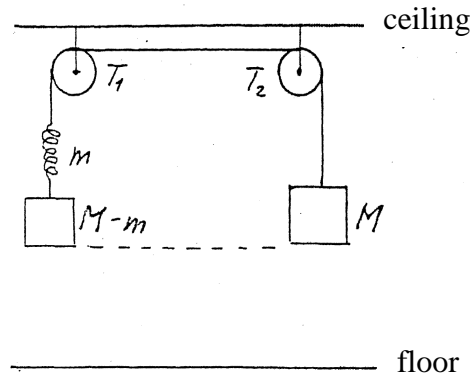
Second written test in the breadth module of physics

To be held Friday, January 12, 1996, 10:00-14:00

NO AIDS ALLOWED

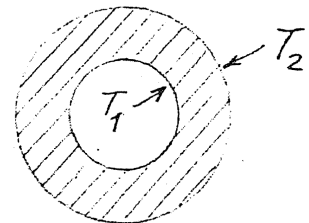
Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A mechanical system consists of two parts (see the figure): a weight of mass M and a weight of mass $M - m$ connected to a spring of mass m . The two parts are fixed to the two ends of a thin ("massless") inelastic string, which is taken above two pulleys T_1 and T_2 . Initially, the system is in static equilibrium and the lower sides of the weights are at the same distance from the floor.

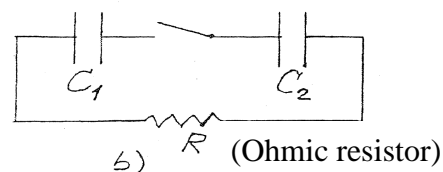
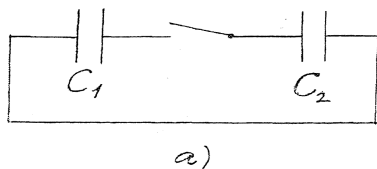


Then the string is cut right in the middle of the pulleys and the weights fall to the floor. Do the weights hit the floor at the same time or does one arrive before the other? Justify your answer.

2. A cylindrical mantle of a heat conducting material has the temperature T_1 on the inside and the temperature T_2 on the outside. It is in a stationary state. How does the temperature vary throughout the mantle?



3. In the two small circuits a) and b) in the figure below, the capacitor C_1 in the initial state (with the switch open) is charged with the charge Q , while C_2 is uncharged. Then the switches are closed and we wait for a sufficiently long time to allow the two circuits to be in a stationary equilibrium (the final state) again.



What are the charges on the capacitor in the final states and what are the total energies of the capacitors in the two circuits in the initial and final states, respectively? If there are changes of energy changes, account for the cause of them.

4. A flute player, who starts to play on a cold flute (perhaps coming in from the winter cold) will experience that the notes played shift towards higher frequencies as the flute is heated during use. What is the cause of this? Estimate the magnitude of the frequency variation.

5. A Danish physicist, Prytz, conceived some simple demonstration experiments for the illustration of an important physical concept. He placed a candle in the body of a lantern, so that the flame is protected from the influence of the wind. If we (a) let the lantern fall freely, the flame becomes weaker and will vanish after a fall of 1-2 m. If we (b) swing the lantern from side to side, then during the horizontal acceleration the flame will lean to the side corresponding to the direction of the acceleration. Thus, the flame e.g. leans to the right if the body is accelerated to the right.

Give a summarizing explanation of the observations.

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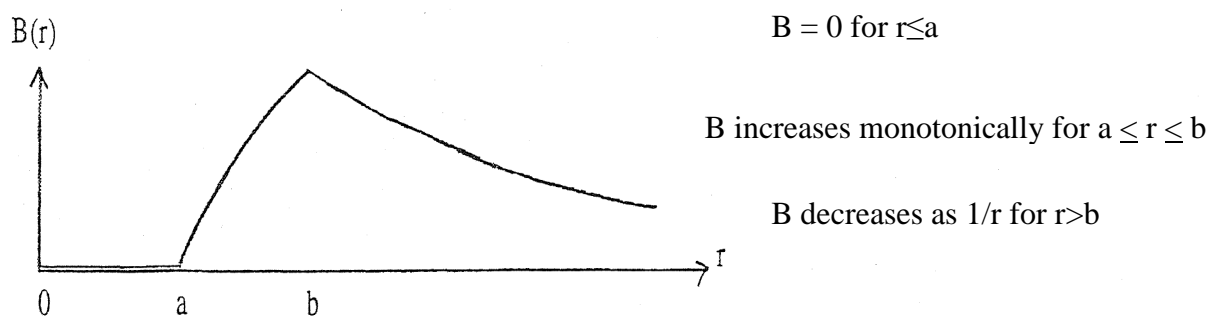
Second written test in the breadth module of physics

To be held Tuesday, June 4, 1996, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. When moving by foot, there's a certain speed interval where walking is the least strenuous. On the one hand, it is strenuous to walk much slower and on the other hand it is more comfortable to start running rather than force the walking pace past a certain limit. For an average adult, the optimal walking pace is 5-7 km/h. Give an explanation.
2. The refractive index of water, measured by various optical methods, is about 1.3. The relative dielectric constant of water, ϵ_r , measured by electrical methods, is about 80. What is the relationship?
3. In the winter, it is possible to save quite some heat by pulling the curtains, venetian blinds or the like during the night. Explain how such relative thin layers of material can influence the heat loss significantly.
4. Is it possible, and if yes how, to produce a magnetic field where the spatial field strength is rotationally symmetric about a symmetry axis and where the field strength at a point placed the distance r away from the axis of symmetry depends on r as shown in the figure?



5. At low velocities (where classical mechanics gives the right description), a collision between two equally heavy particles of which one is at rest *before* the collision and the other moves at a certain velocity, v , will always lead to a situation where the velocities of the two particles will form an angle of 90° with each other. (Except for a central collision, where the two particles exchange velocities in the collision so that the incoming particle is at rest after the collision while the particle initially at rest now moves at velocity v .)

For very large velocities, e.g. when a high energy proton collides with a proton at rest, the velocities of the two particles will form an angle of less than 90° with each other after the collision. The angle is smaller, the larger the energy of one proton.

Show that this is what should be expected from the theory of special relativity.

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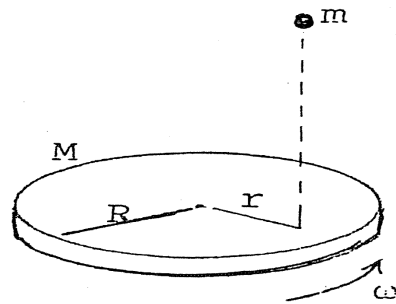
Second written test in the breadth module of physics

To be held Thursday, June 6, 1996, 10:00-14:00

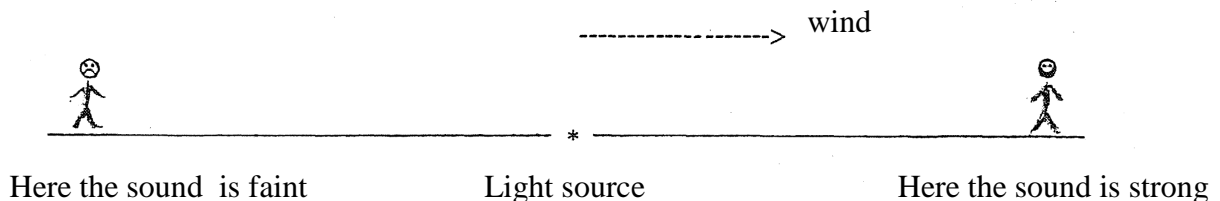
NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

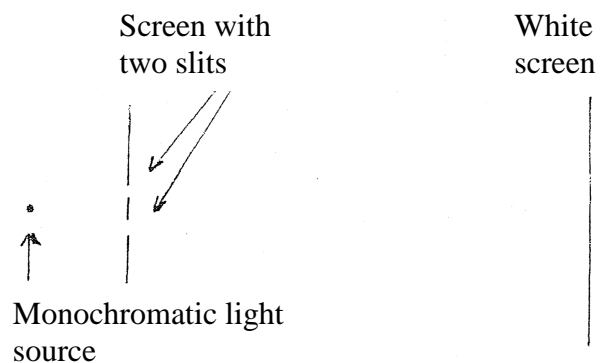
1. A circular disk of radius R and mass M lay on a completely smoothly surface and rotates with angular velocity ω . A lump of clay of mass m falls on the disk at the distance $r < R$ from the center of the disk and sticks to the disk.
Describe the new motional state of the system (the disk and the lump of clay).



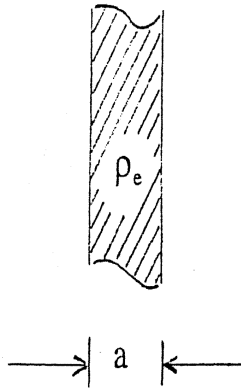
2. Why is it easier to hear the sound from a sound source (placed on the ground) if one is in “the lee direction,” i.e. in the direction from the sound source that corresponds to the direction of the wind? The compared listening positions are at the same distance from the sound source.



3. The figure shows a principle sketch of Young's experiment. What image will be formed on the screen on the right? How does this image change if a thin, transparent glass plate is placed in front of one of the slits?



4.



The figure shows a cross section through a small part of a plate with a (in principle infinite) large area. The plate has thickness a and consists of an insulating material with dielectric constant ϵ . The material has a uniform distribution of charge, $\rho_e \text{ C/m}^3$.

How are the electrical field and the electrical potential distributed inside and outside the plate?

5. A diesel engine is a machine that transforms heat to mechanical work by a cyclic process as shown in the figure. The cyclic process contains the following elements:

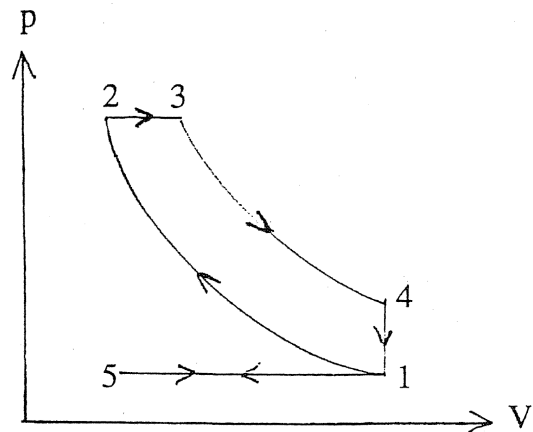
1→2 Adiabatic compression of air in the cylinders of the engine. At 2 fuel is injected (at high pressure). It is ignited and burns during the next part of the cyclic process:

2→3 Heat transfer because of the combustion. The piston moves so that the pressure is constant. At 3 the combustion is over.

3→4 Adiabatic expansion.

4→1 Heat removal at constant volume.

(In 1→5→1 the combustion products are emptied and new air is sucked in so that the cyclic process can be repeated. We neglect this “assisting process” in the following.)



Express the efficiency of the engine in terms of the compression ratio V_1/V_2 , the expansion ratio V_1/V_2 and $\gamma = c_p/c_v$ if we assume that air and air + fuel can be assumed to be an ideal gas.

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First written test in the breadth module of physics

To be held Monday, June 2, 1997, 10:00-14:00

NO AIDS ALLOWED

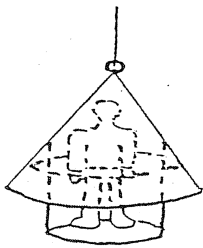
Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1.1. Shall the distance between lens and film in a camera be increased or decreased when going from photographing landscapes to portraits?

1.2. If the average density of mass of the universe is small then the current expansion will continue for ever. If the average density of mass of the universe is large then at some point the universe will start to contract again. The critical density of mass corresponding to the boundary between the two evolutionary paths is given by the gravitational constant and Hubble's constant. How? Justify your answer.

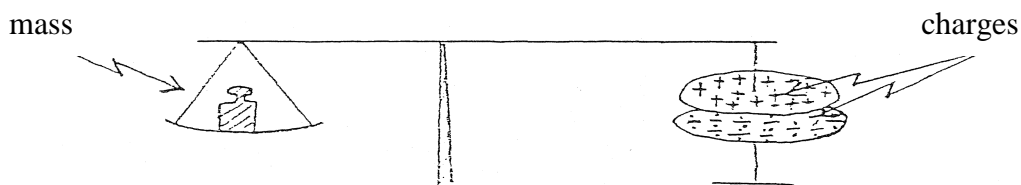
1.3. For a train accelerating from rest to its march velocity, we assume that only a negligible part of the power of the train engine is used to overcome friction. How long a distance does the train need to reach the march velocity at a given, constant power of the train engine? Justify your answer.

1.4. In 1628 the Swedish flagship Wasa capsized and sank at a depth of 30 m. Before its precise position was forgotten for about 300 years, 53 of its valuable bronze canons were rescued.



For the rescue, diving bells were used that in principle looked like the one suggested in the figure, i.e. as a cone in a rope with a board hanging below it. How high was the rise of water within the bell when it was immersed close to the wreck? Justify your answer.

1.5. The figure shows a principle sketch of a so-called electrostatic balance:



What is the relation between the mass on the scale pan and the charges on the capacitor, when it balances?

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, June 4, 1997, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

2.1. Which has the largest resistance: A 60 W or a 40 W light bulb?

Justify your answer.

2.2. In order to clean it, a well is emptied of water. The water inflow to the well is observed to come from sources near the bottom. How does the water level of the well rise after the emptying as time passes?

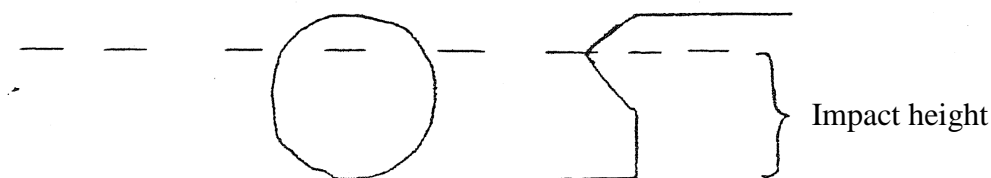
Justify your answer.

2.3. What is the magnetic field between the circular disks of a plate capacitor during charging or discharging?

Justify your answer.

2.4. The cushions of a billiard table are constructed with an impact height (cf. the figure) for impact between balls and cushions, so that a purely rotational motion perpendicular to the cushion is reflected in a likewise purely rotational motion away from the cushion. How large is the impact height?

Justify your answer



2.5. How does the electrical conductivity of a semiconductor depend on the temperature?

Justify your answer.

Roskilde University

First written test in the breadth module of physics

To be held Monday, June 22, 1998, 10:00-14:00

NO AIDS ALLOWED

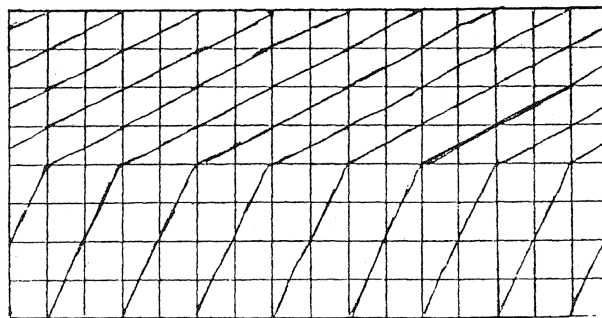
Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1.1. A man and a woman are going to carry heavy ladder, log or the like. The woman grabs one end. The man grabs some distance away from the other end in order to take more than half of the load. How does the ratio of the woman's and the man's loads depend on where he grabs? Justify your answer.

1.2. How does the firepower of a cannon depend on the length of the cannon barrel?

1.3. The energy influx from the Sun at the top of the Earth's atmosphere is 1.4 kW m^{-2} . For what additional physical quantities do we need numerical values in order to use this to calculate how many tons of hydrogen the Sun burns per sec.? Justify your answer

1.4. The figure shows a section of a sea wave phenomenon seen from above through a quadratic lattice. It has to do with the passage of the waves over a place where the sea depth jumps suddenly. What is the ratio between the two sea depths? Justify your answer



1.5. How long time does it take the sand to run through an hour glass on the moon? Justify your answer.

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Second written test in the breadth module of physics

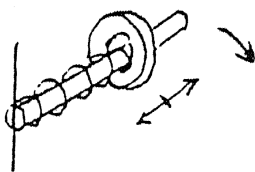
To be held Wednesday, June 24, 1998, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

2.1. Why are the wires that go to and from the battery of a car much thicker than the wires that go to and from the power plugs of a house?

2.2. A ring is fixed to the end of a spring, which slides on a rod that rotates in a horizontal plane. Cf. the figure.



At what frequency does the ring oscillate back and forth on the rod? Justify your answer.

2.3. Viscoelastic materials are materials that react like solid materials when exposed to quickly varying transversal mechanical perturbations, whereas they react like liquids if the perturbations vary slowly. The characteristic time that separates “slowly” from “quickly” for a given viscoelastic material is the so-called Maxwell relaxation time. State and justify an express for this relaxation time.

2.4. How do the electrical potential energies of atom nuclei depend on their mass number and their proton number? Justify your answer.

2.5. A sink is filled with cold water up to the overflow drain; then the hot water tap is turned on. How does the temperature change as time passes? Justify your answer

Roskilde University

First written test in the breadth module of physics

To be held Monday, January 25, 1999, 09:00-13:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1.1. Do tall trees fall slower or faster than small trees when they are cut down? Justify your answer.

1.2. The electrical conductivity of pure silicon and pure germanium are of the order of 10^{-11} and 10^{-7} times the conductivity of typical metals, respectively. What is the ratio of the band gaps of silicon to germanium? Justify your answer.

1.3. The two vocal chords of the throat start to oscillate when air is blown between them. Explain this phenomenon.

1.4. Tycho Brahe had been dead for some years when Galileo as the first started to use the telescope for astronomical observations. Tycho Brahe's measurements were done using a sight instrument as well as the naked eye. His accuracy of measurement was a few arc minutes. Using his method, is it possible to measure more accurately than he did? Justify your answer.

1.5. How does the thickness of the ice on a lake of water of 0°C grow with time if the air is freezing cold? Justify your answer.

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, January 27, 1999, 09:00-13:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

2.1. Are the lenses of the eyes most curved when the eyes focus on far away objects or on nearby objects?

2.2. A harmonic signal in the telephone cord propagates according to the equation

$$I(x,t) = I_0 e^{-\beta x} \cos\left(\omega t - \frac{\omega}{v} x\right)$$

In general, β and v depend on the frequency of the signal ω . However, in telephone cords with vanishing leakage currents to the surroundings and large self-inductance coefficients, β and v depend only on the cord's self-inductance coefficient per unit length, the cord's resistance per unit length and the cord's capacitance per unit length. In this distortion-free limit, how does β and v depend on the said quantities?

Justify your answer.

2.3. Estimate the order of magnitude of the difference of water level between the east side and west side of the Great Belt sound at a flow rate through the sound of about 5 km per hour.

2.4. If we assume that the charges of electrons and protons differ slightly, then at long distances hydrogen atoms will repel each other electrically in addition to their mutual gravitational attraction. The perpetual expansion of the universe has some Steady State theoreticians attempted to explain by such an assumption of charge difference between electrons and protons. How large a relative charge difference is at least required by their theory?

Justify your answer.

2.5. How does the number of remaining, living bacteria in food after food irradiation depend on the radiation dosage?

Justify your answer.

Roskilde University

First written test in the breadth module of physics

To be held Wednesday, June 23, 1999, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

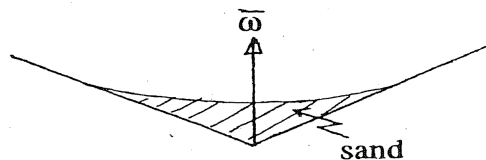
1.1. How big is the force between foot and pedal compared to the friction force between road and tire when bicycling?

Justify your answer.

1.2. In an idealized gas model, where the gas is taken to consist of a large number of similar hard spheres, one can calculate the viscosity of the gas and the thermal conductivity from the mass and radius of the spheres, Boltzmann's constant and the simulated temperature. How do the viscosity and the thermal conductivity depend on the mentioned quantities?

1.3. How much sand can a smooth rotating funnel (cf. the figure) contain without flinging sand out of the funnel?

Justify your answer.



1.4. There are plans to build rocket engines that work in empty space by sending ions rather than uncharged particles rearwards from the rocket. The advantage is that, with the help of a voltage drop in the engine, higher exhaust velocities can be obtained for the ions compared to the uncharged particles.

Are light or heavy ions to be preferred?

Justify your answer

1.5. How shortened do vertical objects look under water?

Roskilde University

Second written test in the breadth module of physics

To be held Friday, June 25, 1999, 10:00-14:00

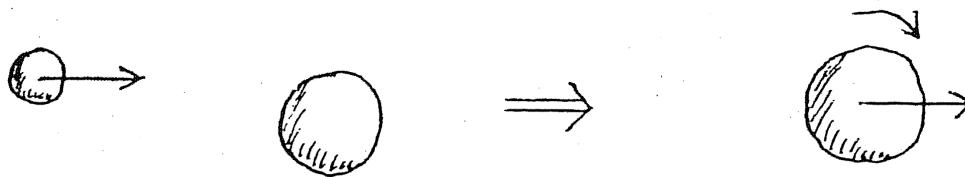
NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

2.1. How does the pressure of the atmosphere decrease with height if the temperature decreases linearly with height?

2.2. What is the temperature of a spark discharge or a lightning bolt? Justify your answer.

2.3. Heavy atom nuclei colliding at relativistic speeds can fuse as sketched in the figure:



How fast does the fused nucleus rotate according to a non-relativistic calculation?

Justify your answer.

2.4. In soil erosion, the fertile material of the farm land is washed or blown away. Why is this problem – all other things being equal – greatest for fine-grained material?

2.5. When a substance containing permanent atomic magnetic dipole moments is placed in the field between the poles of an electromagnet, the alignment of the dipoles enhances the field. What should we expect if the atomic magnetic dipoles arise from pairs of a north pole magnetic monopole and a south pole magnetic monopole rather than revolving charges?

Justify your answer.

Roskilde University

First written test in the breadth module of physics

To be held Monday, January 24, 2000, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1.1. When hot tea is poured into a thermally insulating jug with an incompletely tight plug, the jug with the plug inserted will hiss for a while. Explain the phenomenon. Does air enter or leave the jug? If the system is left for a while, the jug will start to hiss again after a pause. Explain the phenomenon. Does air enter or leave the jug?

1.2. In the novel “From the Earth to the Moon” by Jules Verne, a space cabin is fired from a 300 meter deep shaft in the Earth, which functions as a cannon muzzle. How many times stronger than the gravitational impact is the force impact on the passengers in the space cabin on the way out of the cannon muzzle?

Justify your answer.

1.3. A coil with a given number of windings can be wound tightly or less tightly, so that the coil gets a smaller or longer length. How does the self-inductance coefficient depend on the length?

Justify your answer.

1.4. How does the image that a converging lens (e.g. in a magnifying glass) forms of an object vary with the objects distance from the converging lens?

1.5. For ordinary, horizontal motions of wind driven by horizontal pressure gradients, but with height dependent wind velocities, meteorology uses friction forces that are proportional to velocity, $\vec{F}_{fric} = -\gamma \cdot \vec{v}$ per unit mass of air. What is the angle between the horizontal pressure gradient and the wind direction for steady, non-accelerated wind?

Justify your answer.

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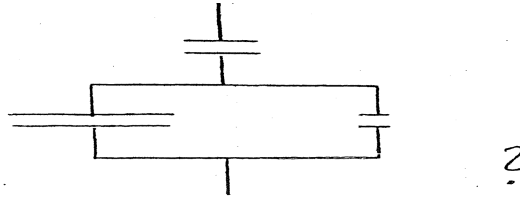
Second written test in the breadth module of physics

To be held Wednesday, January 26, 2000, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

2.1. What is the capacitance of the circuit element:



Justify your answer.

2.2. Prior to Niels Bohr's explanation of the equation

$$\frac{1}{\lambda} = K \left(\frac{1}{n^2} - \frac{1}{m^2} \right) \text{ (n and m are integers)}$$

for the spectral lines of hydrogen in 1913, scientists claimed to have observed spectral lines for hydrogen corresponding to, say, $n=3/2$ and $m=\text{integer}+1/2$. It was one of Niels Bohr's achievements in 1913 that he could explain these extra spectral lines as coming from helium. How could he do that?

2.3. How does the precession frequency (the frequency with which the symmetry axis rotates about the vertical axis) for a spinning top depend on how fast it spins? Justify your answer.

2.4. The utility room of a house borders only the kitchen, not the other rooms of the house. By simultaneously measuring the temperature outside, in the utility room and in the kitchen, the insulation between the outside and the utility room can be estimated relative to insulation between the utility room and the kitchen. How?

2.5. How does the frictional resistance on an object moving through a strongly diluted gas depend on the speed of the object? Justify your answer.

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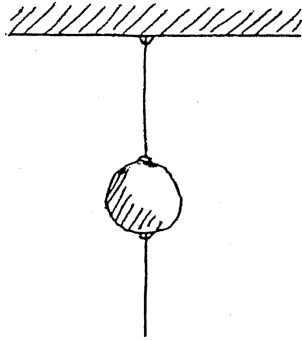
First written test in the breadth module of physics

To be held Monday, June 26, 2000, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1.1.



An iron ball is hung up in a cotton string. A similar cotton string is attached at the bottom of the ball. See the figure.

If we pull gradually and slowly in the lower string, one of the strings will break at some point. Which one?

Which string breaks if we pull strongly and quickly in the lower string? Justify your answers.

1.2. What resistance is met by an electric current flowing from the inside to the outside of a hollow metal ball?

Justify your answer

1.3. When a road is strongly heated, e.g. an asphalt road in sunshine, a layer of heated air can form. This layer functions like a mirror if observed at a very acute angle. Does this phenomenon attest to an increasing or decreasing velocity of light in air of increasing temperatures? Justify your answer

1.4. In the reactor DR3 at RISØ, impurity atoms in pure silicon are formed by nuclear reactions with neutron irradiation. Does this lead to a p-type semiconductor or a n-type semiconductor? Justify your answer.

1.5 In the novel “From the Earth to the Moon” by Jules Verne, the following equation can be found

$$\frac{1}{2}(v^2 - v_0^2) = g \cdot r \cdot \left[\frac{r}{x} - 1 + \frac{m'}{m} \left(\frac{r}{d-x} - \frac{r}{d-r} \right) \right]$$

What are the meanings of the symbols if this equation should be relevant for the travel to the moon? Justify your answer.

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, June 28, 2000, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

2.1. Why does an airplane tilt when changing its course? What is the relationship between the change of course and the tilting? Justify your answers.

2.2. The burning of fossil fuel on the Earth frees energy corresponding to about 0.1 per mille of the energy influx from the Sun. The burning affects the green house effect of the atmosphere due to the increase of the CO_2 content in the atmosphere. How large an increase of temperature on the Earth due to the burning of fossil fuel would result if we could ignore the green house effect and consider the Earth simply to be a black body?

2.3. In the so-called optical trapping technique it is possible to hold and move single polarizable protein molecules with the help of light. The protein molecule is held at the place where the light intensity has a maximum. Explain why.

2.4 The horizontal pressure on the tracks exerted by a fast-moving train depends weakly on whether the train moves east, west, north or south. In what direction of travel is the pressure largest and in what direction is it smallest? Justify your answer.

2.5. A hole is accidentally knocked in the bottom of truck carrying liquid chlorine under pressure. At what pace does the truck leak chlorine?

Roskilde University

First written test in the breadth module of physics

To be held Monday, June 25, 2001, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1.1. How does the thickness of the curtain of a water fall depend on the distance the water has fallen? Justify your answer.

1.2. When a deep freezer has been open for a while, it may take some strength to open it a short while after it was closed. How much strength is required? Justify your answer.

1.3. If a proton of large kinetic energy is made to collide with a proton at rest, a proton-antiproton pair can be formed in the process

$$p + p \rightarrow p + p + (p + \bar{p})$$

What is the smallest kinetic energy required to allow the process? Justify your answer.

1.4. How large a magnetic field is needed to approximately align the magnetic dipoles of a paramagnetic substance? Justify your answer.

1.5. According to Kepler's second law, a line joining a planet and the Sun sweeps out equal areas during equal intervals of time. Explain the law.

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, June 27, 2001, 10:00-14:00

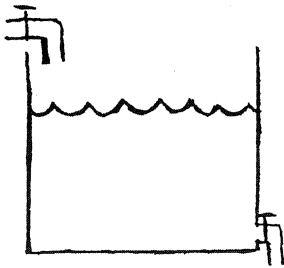
NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

2.1. What is the capacitance of capacitor consisting of two hollow metal spheres with a common center?

Justify your answer.

2.2.



With both taps open, a constant water level will appear after a while. Why? What is the height of the water level?

Justify your answer

2.3. When the reception conditions are bad, an FM receiver will often be sensitive to whether somebody in its vicinity goes, say, one step to either side. Why is the similar phenomenon not observed for medium wave radios?

Justify your answer.

2.4. What is the relation between wind velocity and the plane in which a high voltage cord or a washing line is hanging?

Justify your answer.

2.5. How does the specific heat of a cavity depend on the temperature?

Justify your answer.

Roskilde University

First written test in the breadth module of physics

To be held Monday, January 21, 2002, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1.2 If you are dragging a heavy box up an inclined ramp it may be convenient that the frictional resistance of the ramp can prevent the box from sliding backwards if you wish to rest at some point.

What extra work will this at least cost you?

1.2 Back in the old days, households often used a so-called haybox, i.e. a thermally insulated box. Here, a pot could be put so that it could finish boiling and keep hot.

Describe how the cooling of the food progresses and compare the effectiveness of large and small hayboxes with respect to how they keep the food hot.

1.3 What makes so-called energy saving light bulbs more energy economic than ordinary light bulbs?

1.4 An atom nucleus emits a gamma quantum and thus changes its rest mass from M to $M - \Delta M$. What is the energy of the gamma quantum?

1.5 Describe the electric field in the space near a metal ball on which an electric charge is placed. Describe how the electric field changes if the charged metal ball is contained in a spherical, dielectric mantle and calculate the capacitances for the two cases.

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Second written test in the breadth module of physics

To be held Wednesday, January 23, 2002, 10:00-14:00

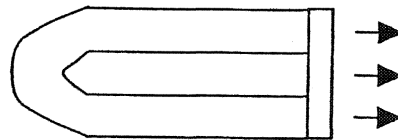
NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A school of neoimpressionist artists used a special painting technique where the image is composed of a very large number of round dots each painted with a pure color pigment. The dots have diameters of 2-3 mm and are placed close together. The illusion of a merging of the pure colors arises in the eye of the beholder.

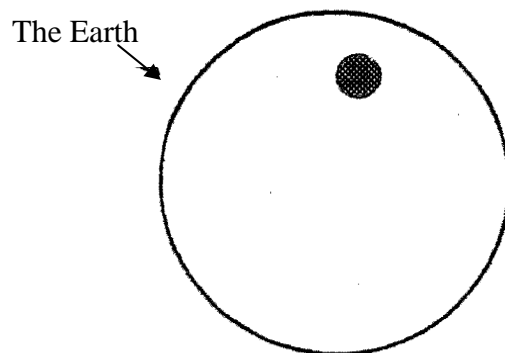
How far away do you have to be from such a painting to achieve this effect?

2. If you remove the rod at the bottom of a horseshoe magnet from the horseshoe magnet by pulling it as suggested by the arrows in the figure, you have to apply a large force at first. But when the horseshoe magnet has “let go” of the rod, the force necessary to move the rod further away becomes much smaller. Moreover, it is easier to remove the rod by pushing it sideways.



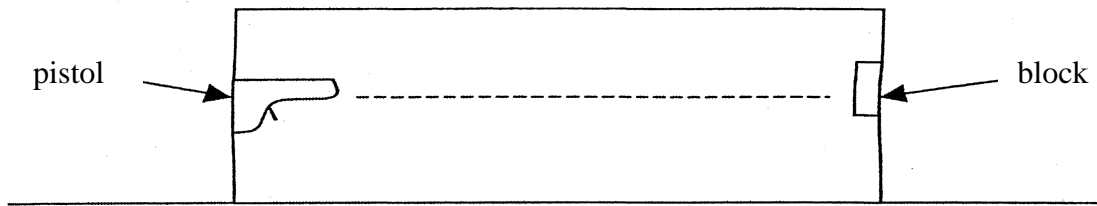
Explain these facts.

3. By moving along the Earth's surface with a sensitive gravitometer it is possible to reveal irregularities in the composition of the Earth's crust.



By how much is the gravitational acceleration at the Earth's surface changed by the existence of a (spherical) region with a deviating mass density relative to the surroundings and located somewhat below the surface?

4. A bullet is fired from a pistol fixed to one end wall of a box and is stopped by a block at the other end wall. The box is placed on a horizontal, smooth surface. Does the box move? Justify your answer



Max Born set up a “Gedankenexperiment”, where the pistol is replaced by a light source and the block by a light absorber. Using the relation between energy and momentum for electromagnetic radiation (which is given by electromagnetic field theory) and the rule of conservation of momentum of center-of-gravity for an insulated system, it is easy to obtain Einstein's energy-mass-equivalence ($E=mc^2$). Demonstrate this.

5. Two identical containers, both with taps at the bottom, are filled to the same height with two different liquids: They have the same viscosity, but different mass densities.

Which container is emptied fastest when the tap is opened?

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First written test in the breadth module of physics

To be held Monday, June 17, 2002, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

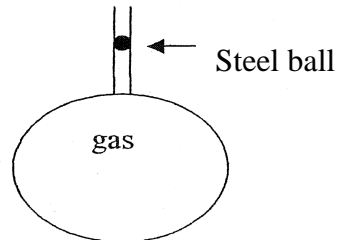
1.1 A space ship whose rest length is l_0 , moves past the Earth in a rectilinear path with uniform velocity. Seen from an observation post at the Earth, the passage of the space ship takes the time τ . How fast does the space ship move relative to the Earth?

1.2 In 1929 R  chhardt published an experimental method for the determination of Poisson's ratio $\gamma = c_p / c_v$ for an ideal gas.

Gas is filled into a large container with a tube (see the figure), which is closed by a small, tightly sealing steel ball that can move up and down.

The ball is made to oscillate.

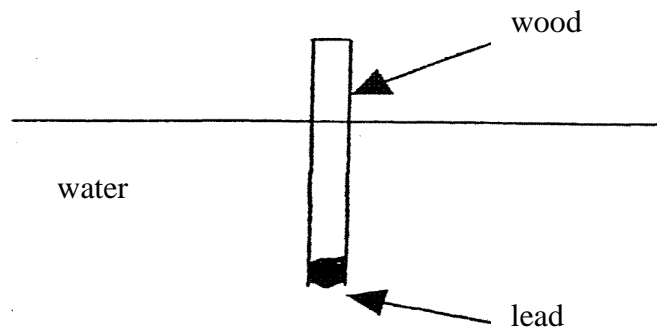
Show that one can determine γ by measuring the oscillation time of the ball if the system is thermally insulated.



1.3 Two persons carry a log of wood, one at each end of the log. The log width varies from one end to the other. How does the ratio of the loads of the two persons depend on this variation?

1.4 How much lead is needed at the end of a wooden stick to make it float in an upright position in water?

Justify your answer



1.5 In the traffic, you can sometimes see cars whose windows (except the front window) look like mirrors so that (in daylight) you can't see what is happening inside the car. The passengers, however, can see the surroundings of the car. Explain which factors, such as the optical properties of the glasses, the functioning of the eye etc, that can contribute to this slightly paradoxical phenomenon.

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, June 19, 2002, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

2.1 In “Bungee Jump” you jump from, say, a high bridge above a gorge, with a very elastic rope fixed at the bridge and tied around your feet.

The rope stopping the fall is very elastic and is prolonged by 50% when the jumper is at rest. The rope is adjusted to the weight of the individual jumper. How long is the fall, and where during the fall are the acceleration and the velocity, respectively, largest?

2.2 Hot coffee at 100°C is poured into a Thermos bottle, which is then closed with a tightly sealing plug. How large a pressure can at most built up in the bottle?

2.3 It is well known that the moon produces a so-called tidal water field at the Earth’s surface that it is strongest in the directions towards and away from the moon.

Show that the Earth likewise must produce a tidal force field at the surface of the Moon. What is the ratio of the strengths of these two tidal force fields?

2.4 For a number of galaxy clusters, the distance and velocity of a galaxy in the cluster has been measured. The results of these measurements are shown in the table

Cluster	Distance (in Mly)	Velocity (in 10^3 km/s)
Formax	78.2	1.38
Pegasus	215	3.88
Pisces	283	5.11
Perseus	323	5.47
Coma	411	7.41
Hercules	648	11.2

Explain how these results can be used to estimate the age of the Universe and give an estimate of this age.

2.5 One of the many methods for the determination of radii of atomic nuclei is based on measuring the mass difference between two atomic nuclei that form a so-called pair of mirror nuclei.

A pair of mirror nuclei consists of two nuclei with the same mass number (A), where one nucleus has one more proton than the other, but one less neutron.

Examples of pairs of mirror nuclei are ${}^{13}_7\text{N}_6$ and ${}^{13}_6\text{C}_7$ or ${}^{39}_{20}\text{Ca}_{19}$ and ${}^{39}_{19}\text{K}_{20}$.

Show how a measurement of the difference in mass and thus the binding energy between the two nuclei of a pair of mirror nuclei can be used for the determination of their radii.

Roskilde University

First written test in the breadth module of physics

To be held Wednesday, January 29, 2003, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

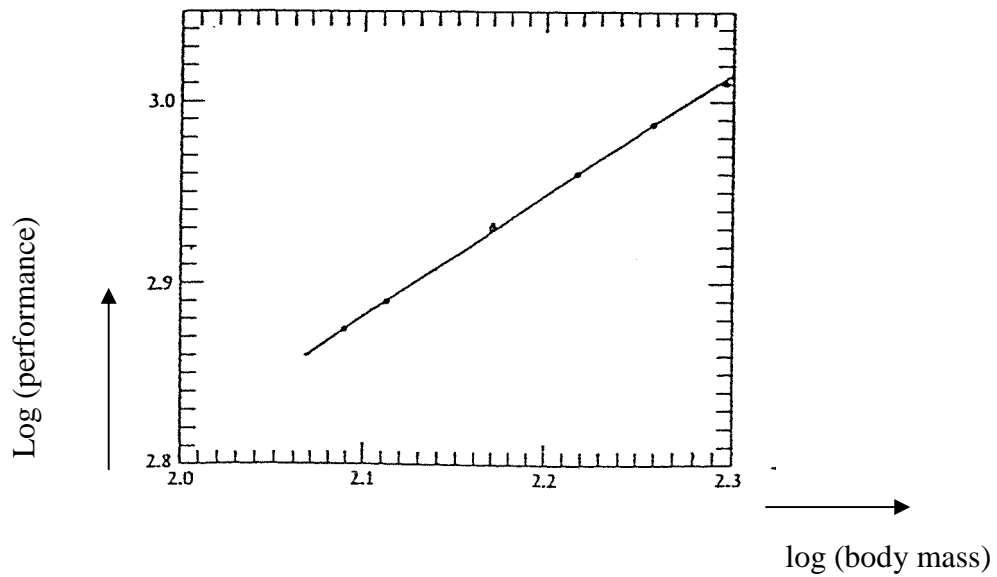
1. For the hammering down of large poles, e.g., for the piling of buildings, a so-called pile driver or block hammer is used: A heavy block is lifted and then made to fall on the end of the pole that is to be hammered down.

How does the achieved hammering down depth depend on the number of strokes?

2. The so-called greenhouse effect produced by the Earth's atmosphere influence greatly the temperature conditions at the Earth's surface and thus the conditions for life at the Earth.

Calculate the relative increase in temperature at Earth's surface caused by the presence of the atmosphere under the following assumptions: The Earth's surface is a black body and the atmosphere can be seen as material layer that allows sunlight to pass without absorption, but is a black body when it comes to the heat radiation from the Earth, so that this radiation is absorbed completely and heats the atmosphere.

3. Large Olympic weightlifters can lift (pull, jerk and press) larger weights than small weightlifters. The figure shows in a double logarithmic plot the relation between world-record performances (the ordinate axis) and the mass of weightlifters (the abscissa axis)



According to these results, how does the muscle strength scale with the linear dimension of the organism? Does the result seem plausible?

4. A metal ball of radius \mathbf{a} carries an electric charge $\mathbf{q_a}$. It is surrounded by a concentric, hollow, thin metal sphere of radius \mathbf{b} ($\mathbf{b > a}$) that carries the electrical charge $\mathbf{q_b}$. The two bodies are insulated and placed in vacuum far away from other influences.

Find the electric field strength in the space between the ball and the sphere as well as the field strength outside the sphere. Moreover, calculate the electrostatic energy of the total system.

5. What is the oscillation time for a pendulum hung up in a lift if the lift accelerates in its up- or downward motion?

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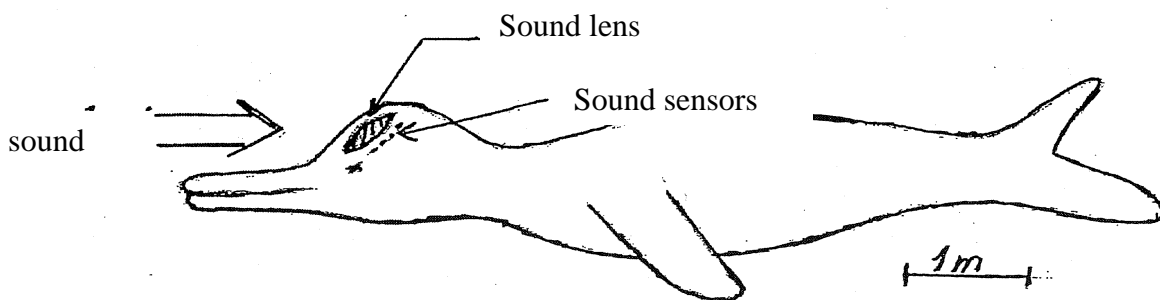
Second written test in the breadth module of physics

To be held Friday, January 31, 2003, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. The dolphin has (see the figure) a sound lens in the upper part of the head that can focus the incident sound waves at a focus plane behind the lens, where some sound sensors are placed.



The sound received is typically sound waves emitted by other dolphins or by the dolphin itself and reflected (by objects).

Dolphins can determine the direction of the sound source/reflector with an angular resolution of $1\text{-}2^\circ$.

How large frequencies do the dolphin typically have to utilize? Justify your answer.

2. A space ship (A) flies past another space ship (B). Their paths are rectilinear and parallel and the space ships fly at a constant speed.

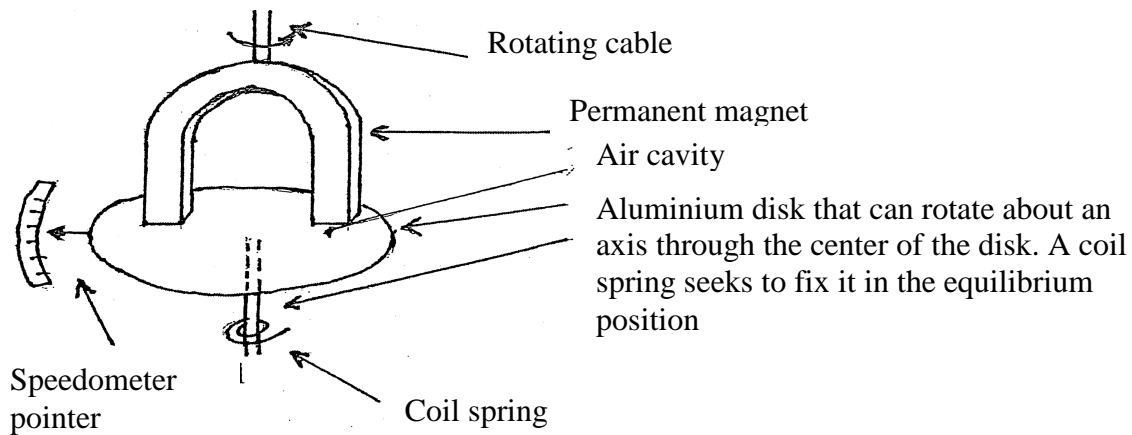
Clocks, C_1 and C_2 , are placed at each end of B; these are synchronized by the crew of B.

An observer at space ship A observes, however, that C_1 is delayed by Δt relative to C_2 , and measures, moreover, the length of B to be 1.

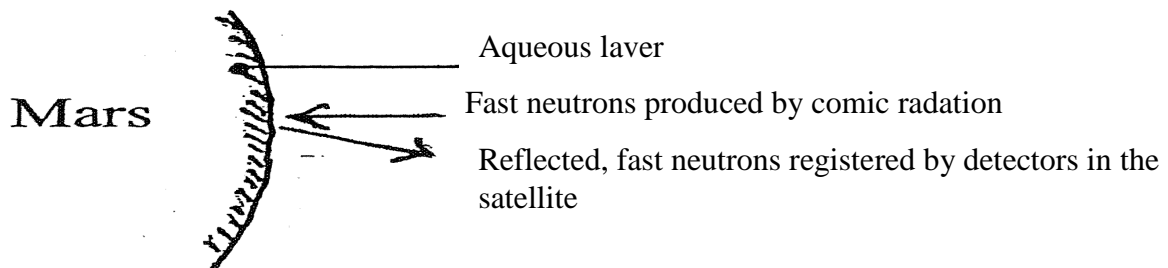
What is the rest length of space ships B?

3. The figure below shows the principle of an electromechanical speedometer. Show that the speedometer pointer, which is fixed to the dial, is deflected as a measure of the rotational speed of the speedometer cable.

To what side is the speedometer pointer deflected relative to the direction of rotation of the speedometer cable?



4. Recent intensity measurements of reflected, fast neutrons from Mars's surface done by a satellite near Mars have rendered it probable that large parts of Mars contain significant amounts of water, corresponding to a layer with a depth of at least 1m.



The measurements can only show that there seems to be water at the surface corresponding to a depth of at least 1 m, but they cannot measure the depth which may be significantly larger. Explain this fact.

5. The standard of mass continues to be a cylinder shaped object of a platinum-iridium alloy that can be said to have a mass of 1 kg. It is kept in Paris. The determination of the masses of other objects (secondary standards) takes place by comparing with the standard kilo using a scale. The relative accuracy of this comparison is $2\text{--}3 \cdot 10^{-9}$. Obviously, this requires excellent control of several influencing factors, e.g. the variation of the buoyancy on the weights.

What temperature stability is required, solely for this reason, to obtain the mentioned accuracy of mass determination?

Roskilde University

First written test in the breadth module of physics

To be held Wednesday, June 18, 2003, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A power plug is connected to a water heater. Heat is generated in the power plug due to a loose connection. How much heat can possibly be generated in the power plug?

Justify your answer.

2. Sports journalists have recently advanced the hypothesis that the cause of the frequent gold medals of African runners at the world championships, particular for short distances, should be sought in their very slender lower legs. Is the hypothesis plausible?

Justify your answer

3. Today, a comet is 2 light years away from the Earth and it is moving directly away from the Earth with $12/13$ of the speed of light. What would comet dwellers (if they existed) have measured the distance to be half a year ago (measured in Earth time)?

4. Show that the relations between angles of entrance and exit for reflection and refraction of light at the interface between two media, respectively, can be derived from Fermat's principle. This says that light follows a path consisting of straight line segments in such a way that the time it takes the light to reach from the entrance point in one medium to the observation point in the other medium has a local minimum.

5. As you know it is possible to produce a strong sound by making a slash with a lash – a so-called whiplash. What kind of sound waves is involved and how are they formed?

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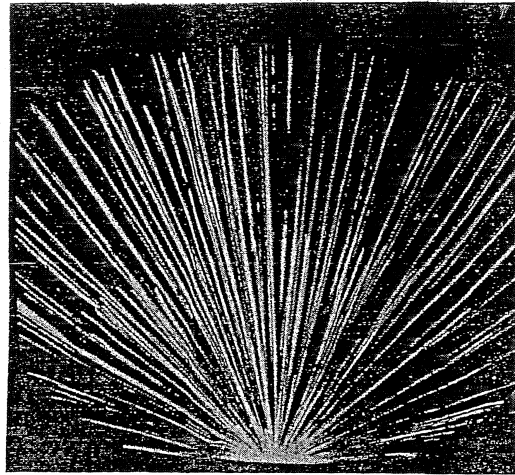
Second written test in the breadth module of physics

To be held Friday, June 20, 2003, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. When tall brick chimneys topple over, they often break into two (or more) pieces. Does the upper part fall forward or backward relative to the lower part? Justify your answer.
2. It has been possible to establish experimentally that the nucleons of atomic nuclei have an inner structure (they are built from so-called quarks) by bombarding the atoms with fast electrons. What energy is (at least) required for the electrons?
3. A diesel engine does not use sparking plugs for ignition. The air in the cylinders of the engine is compressed so much that the fuel is ignited spontaneously when injected into the cylinders. What temperature and pressure are obtained in the cylinders if the volume is decreased to $1/15$ of the precompression volume?
4. When a heavy, charged particle, e.g. a proton or an alpha-particle, moves through a material it is slowed down by collision with the electrons and atomic nuclei of the material. The first and largest part of the particle's path is straight, but it often has a "kink" in the latter part. This can be observed directly on a cloud chamber image (see the figure). Is it collisions with electrons or with atomic nuclei that dominate in the first part of the slowing down? Justify your answer.



α particles from thorium (C+C'). (Rutherford, Chadwick and Ellis)

5. Weak electrical interactions play a great role for the processes in living organisms at the cellular level. Describe qualitatively the electrical interaction in a model system consisting of a charged ball and a conducting ball that is either uncharged or has a net charge different from zero.

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First written test in the breadth module of physics

To be held Wednesday, June 16, 2004, 10:00-14:00

NO AIDS ALLOWED

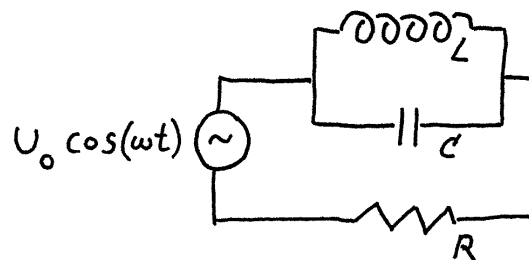
Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. In a problem page in a popular science magazine a reader asks the question: "How heavy is the Earth?"

The following answer was given: "The Earth weighs about $6 \cdot 10^{21}$ ton. This has been calculated by looking at the path of the Earth around the Sun and using a formula for the bodies' attraction on each other that the British physicist and mathematician Isaac Newton wrote down." Can the stated method be used?

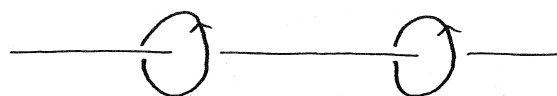
What is needed in order to determine the mass of Earth?

2. An alternating current is delivered to the shown electrical circuit. How large is the current at resonance? How large is it at frequencies much lower and much higher, respectively, than the frequency of resonance?

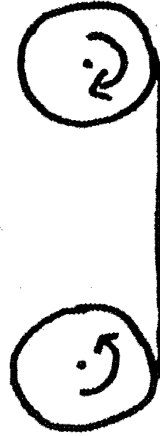


3. A freezer is placed in the boiler room of a basement. Here the temperature is 25°C . You contemplate to move the freezer to the adjacent room where the temperature is only 12°C . With what percentage should we expect that this would reduce the contribution of the freezer to the electricity bill?

4. Helmholtz coils are used for creating fairly homogeneous magnetic field in a region of space. Each coil can be represented by two circular circuits perpendicular to a common axis. What distance between the two coils gives the most homogeneous field possible along the axis between them?



5. Two identical pulleys are connected by a string wound up about both pulleys. One rotates about a fixed horizontal axis, while the other is released and falling down. What is the acceleration of the latter?



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Second written test in the breadth module of physics

To be held Friday, June 18, 2004, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. One of the differences between relativistic mechanics and Newtonian mechanics is that force and acceleration do not necessarily have the same direction in relativistic mechanics. For two interesting cases, however, they do: When the force is parallel with the velocity and when the force is perpendicular to the velocity. What is the constant of proportionality for the two cases?
2. A small electrically charged ball moved towards a neutral metal plate will be attracted by the metal plate. Why does this happen and how large is the force?
3. In a roller coaster the cart is pulled to the highest point of the track and is then running through the track by itself. There is no engine in the cart. Loops have become popular in such tracks in recent years. The first loops were purely circular; they injured the neck or back of some passengers. Calculate the normal and tangential acceleration everywhere in such a circular loop when the initial starting point is high enough that the passengers are weightless at the upper part of the loop. Where is the problem greatest?
4. A kitchen roll stand in its holder, which consists simply of a horizontal stick through the hole of the roll. If you grab the paper with a single hand with a quick stroke then the paper is torn at the perforation, even if you don't hold the paper with the other hand. If you pull it more slowly then you simply unwind the roll. Explain this.
5. Explain how you based on observations of a star with the naked eye can comment on its age. State also your assumptions and possible reservations about the method.

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First written test in the breadth module of physics

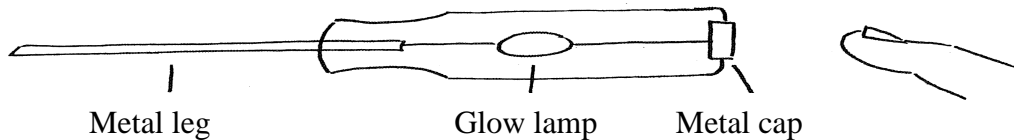
To be held Wednesday, January 19, 2005, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. How does a voltage tester electroprobe work? It is constructed like a screwdriver. A glow lamp is placed in a transparent plastic handle; the lamp has one end connected electrically to the leg of the screwdriver and the other end to a metal cap.

Electroprobe



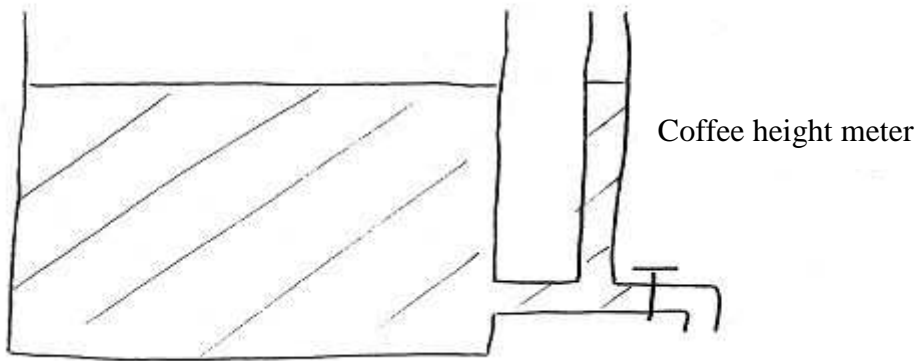
If you touch the metal cap while the screwdriver leg is plugged into the hole of a phase conductor of a socket, the glow lamp beams. The lamp does not beam when plugged into the hole of the neutral conductor. Explain why it works even if you are standing on an insulating surface.

2. A photon hits an electron at rest. After the collision, the photon goes back in the same direction as it came from. By how much has the wavelength of the photon changed?

3. If you inhale helium, you will speak like Mickey Mouse for a while, i.e. with a higher tone of voice. Why?

4. The coffee maker in IMFUFA's kitchen has a coffee height meter as sketched

Coffee maker



When the tap is open, the height meter shows a lower value than when the tap is closed. Why?

5. By measuring the periods of revolution for the innermost stars in the Milky Way as a function of the distance to the center of the Milky Way, scientists have established the existence of an approximately point-like mass in the center (a black hole). How do the periods of revolution vary with the distance? What would the relation have been if the mass distribution was spread out in the central parts of the Milky Way?

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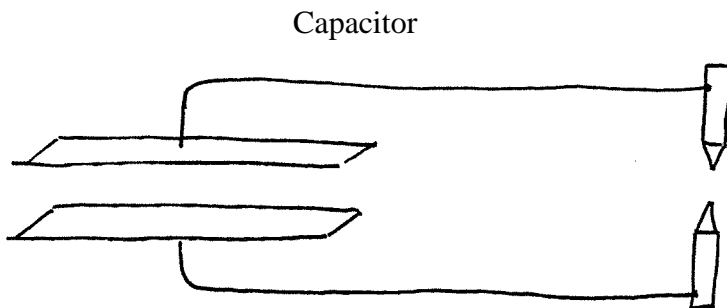
Second written test in the breadth module of physics

To be held Friday, January 21, 2005, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. When you place your hand on a piece of cold metal, a strong heat flow away from the hand into the metal can be felt. How does the heat flow density change with time (for short periods)? Justify your answer using dimensional analysis.
2. A resistance of $300\ \Omega$ in series with a self inductance of $200\ \mu\text{H}$ is connected to an alternating voltage generator. The voltage amplitude over the resistance is $3\ \text{V}$, while it is $4\ \text{V}$ over the self inductance. What are the voltage amplitude and the frequency of the generator?
3. A massive cylinder rolls down an inclined plane. How steep can the inclined plane at most be if the cylinder must not slip?
4. Each of two large capacitor plates is connected to one of two pointed electrodes, which together form a spark gap. If we charge the capacitor plates and then increase the distance between the two plates, one can make a spark pass the gap. Explain this phenomenon.



5. How much energy is released when some dispersed material contracts gravitationally to a spherical star or planet?

Roskilde University

First written test in the breadth module of physics

To be held Wednesday, June 15, 2005, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A space rocket is on its way to the Earth at a speed of 60% the speed of light. The rocket is equipped with a projector that according to the astronauts emits a light cone with an opening angle of 4° . What is the opening angle according to Earthlings?

2. A large metal ball and a small metal ball are charged and electrically connected to each other with a wire.
What is the ratio of the electrical field strengths outside one ball to the electrical field strengths outside the other?

3. If you could stop the Earth in its revolution around the Sun, how long would it take for the Earth to fall into the Sun?

4. Determine – e.g. by considering the dimensions – how the resistance to flow of a fluid through a pipe depends on the diameter of the pipe.

5. Many playgrounds have a one-man roundabout, where you stand on a disk and hold on to a vertical stick in the center. You can speed up if you, when your body is far from the axis of rotation, try to pull yourself towards the center by the arms. It is quite tough. How does the force increase concurrently with your motion towards the center?

Roskilde University

Second written test in the breadth module of physics

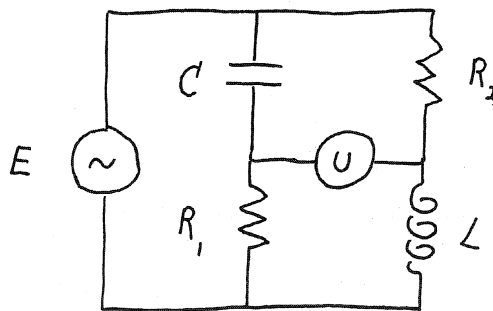
To be held Friday, June 17, 2005, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. The distance between the two stars of a binary star system is equal to the Earth's distance to the Sun. The mass of one star is equal to the mass of the Sun while the other star is three times as heavy. Find the period of revolution of the binary star system.

2. The diagram shows a so-called Wheatstone bridge connected to an alternating voltage source, E and a voltmeter U . R_1 and C are fixed components, whereas R_2 is a variable resistance. Account for how we can measure the magnitude of the self inductance L with this set-up.



3. After elastic, one-dimensional collisions between two different particles with classical velocities, the relative velocity changes sign. Why?

4. Temperature can be defined in many ways. One definition uses the equation of state for an ideal gas. How can we argue that this temperature must be proportional to the mean kinetic of the molecules?

5. Estimate the magnitude of the magnetic forces between the airborne wires of high voltage masts.

Roskilde University

First written test in the breadth module of physics

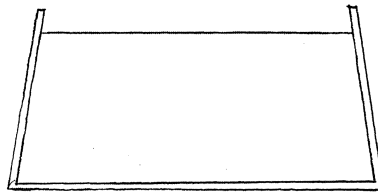
To be held Wednesday, January 18, 2006, 10:00-14:00

NO AIDS ALLOWED

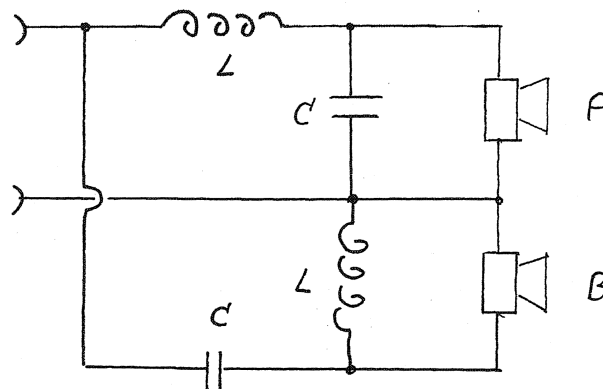
Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. Two playing cards standing on a table lean symmetrically against each other, so that they form an inverted "V". How slanted can they at most be and still stand?

2. A circular swimming pool with an upper diameter of 2.60 m, a lower diameter of 3.00 m and height 1.00 m is filled with water. What is the total force on the side? What is the total force on the bottom?



3. A cross-over network, consisting of two similar coils and two similar capacitors, as shown in the diagram, is to be placed between an amplifier and a loudspeaker consisting of a bass unit and a treble unit. Which of A and B is the bass loudspeaker and which is the treble speaker? Justify your answer



4. N. Bohr assumed in his model of the hydrogen atom that its angular momentum was quantized in multiples of \hbar (Planck's constant divided by 2π), but that the hydrogen atom otherwise obeyed the classical laws. Based on this, determine the energy levels of the electron in a circular motion around the proton.

5. According to an article titled “Judgment day” in Weekendavisen of 11 November 2005, a supernova explosion of the star Betelgeuse should be imminent, i.e. within the next 100,000 years. It is mentioned in the article that the energy production during the explosion is like that of several billion suns and that Betelgeuse is about 400 light-years away from the Sun. According to the article, this should mean the extinction of life on Earth. Assess this conclusion.

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Second written test in the breadth module of physics

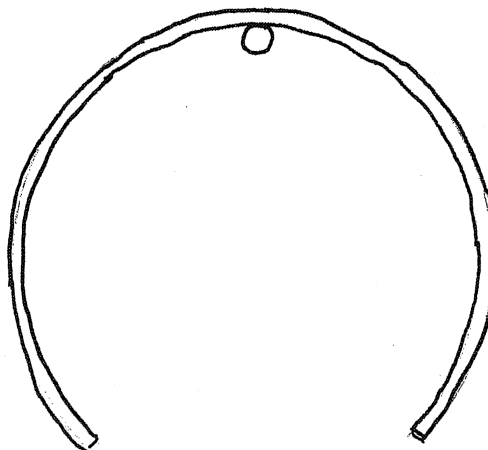
To be held Friday, January 20, 2006, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. Two electric dipoles point in the same direction and this direction coincides with the direction of the line connecting them. What energy is required to turn one of the dipoles?

2. A “hula hoop” ring is lacking one piece. It is hung on a nail at its center point. Find the oscillation time for small oscillations around this position.



3. How can we explain that the transformation ratio for the voltages between the secondary and the primary sides of an electric transformer is simply the ratio between the numbers of windings on the secondary and the primary coils?

4. Some people speculate that in the future freight can be delivered using a space elevator rather than the rockets that are used today. The space elevator should consist simply of a very strong rope that is anchored to a body far away, so that the rope and the body follow the Earth in its rotation. Freight can be relatively cheaply transported up and down an elevator driving on the rope. Steel has a maximum tensile strength of $0.5 \cdot 10^9 \text{ N/m}^2$. Stronger materials are needed. What pull per square meters should the rope at least have to be able to stand?

5. Air is let out through the valve of a car tire. What is the temperature of the air leaving the tire?

Roskilde University

First written test in the breadth module of physics

To be held Monday, June 19, 2006, 11:00-15:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. How does the resistance of each of bulbs connected in series in a chain of Christmas lights depend on the number of bulbs in the chain? Justify your answer.

2. How much work can at most be extracted from two bodies with different initial temperatures? Justify your answer.

3. A person is placed at one end of a room. When a sound source is moved away from the person towards the wall at the other end of the room, the person can sometimes hear beats. What is the frequency of the beats? Justify your answer.

4. In the 14. century, scholars at Merton College, Oxford, succeeded in showing that if the velocity of an object increases steadily from the value v_1 to the value v_2 during the time from t_1 to t_2 , the covered path will be determined by the “Merton relation”:

$$S = \frac{1}{2}(v_1 + v_2)(t_2 - t_1)$$

Is the Merton relation still valid today? Justify your answer.

5. Why do a tsunami and a wave build up when they run towards, respectively, land and a sandbank?

Roskilde University

Second written test in the breadth module of physics

To be held Wednesday, June 21, 2006, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A hollow cylinder and a massive cylinder with similar masses and similar radii roll with the same speed towards an inclined plane. What is the ratio of how far up the plane one cylinder gets to how far the other one gets? Justify your answer.
2. A sugar solution with varying sugar concentration bends light beams passing through the solution. Why?
3. In an electric network, it is possible to replace 3 capacitors in a triangle (fig. 1) with 3 others in a star (fig. 2) without changing the external conditions. What magnitude of the capacitances is required of three capacitors in fig. 2, given the capacitances of the three capacitors in fig. 1?

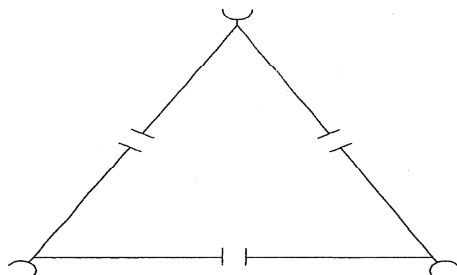


Fig. 1.

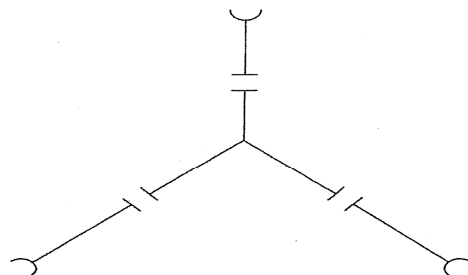


Fig. 2.

4. Light nuclei are more suited for the slowing down of neutrons in reactors than heavy nuclei. How does the maximum relative energy loss of a neutron in an elastic collision with a nucleus depend on the mass of the latter? Justify your answer.
5. A massive metal object packaged in polystyrene is placed in a freezer. How does the temperature of the metal object decrease with time? Justify your answer.

Roskilde University

First written test in the breadth module of physics

To be held Tuesday, January 23, 2007, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. Due to an error, a copper wire gets a radius that is uniformly increasing along its longitudinal direction rather than constant. How does the resistance depend on the length of the thread?

2. For some atomic gasses, the so-called “Bose-condensate” appears when it, for quantum mechanical reasons, no longer makes sense to distinguish one atom from another at sufficiently low temperatures. All the atoms of the condensate act as a whole. How does the temperature where the Bose condensation takes place depend on the densities of the gas?

Justify your answer.

3. A string is hanging vertically. A pulse is sent from the top of the string. How long does it take before the pulse is back?

Justify your answer

4. For the radiation from a black body as well as the radiation from a cavity, Wien’s displacement law applies, i.e. that the wavelength of maximum radiation times the absolute temperature is a universal constant. How does this universal constant depend on more fundamental universal constants?

Justify your answer.

5. A comet coming from the outer parts of the solar system always has a higher speed than the approximately circularly orbiting objects that it encounters in the inner parts of the solar system. How many times larger?

Justify your answer.

Roskilde University

Second written test in the breadth module of physics

To be held Thursday, January 25, 2007, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. For solid materials, what is the relation between the coefficients of length-wise expansion and volume-wise expansion?

2. What is the speed of a wind circulating a high pressure area?
Justify your answer

3. A blackened metal plate is placed in the Sun. How does the temperature of the plate change with time?
Justify your answer.

4. The new, flashing induction bike lights function by induction from magnets fasten at the bike wheels. Estimate the maximum power of the bike lights if their presence should be unnoticeable to bike rider during the ride.

5. How does the magnetic field vary from the center and outwards in a hollow metal tube, when a constant electric current is flowing in the metal?
Justify your answer.

Roskilde University

First written test in the breadth module of physics

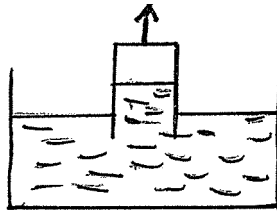
To be held Wednesday, June 20, 2007, 11:00-15:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

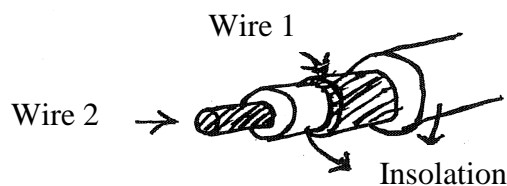
1. Quantum mechanically speaking, an object on a table can not be absolutely at rest on the table even in vacuum and at zero absolute temperature. What is the average height above the table of the object when its average energy is minimal?

2. A glass cylinder is placed upside down in a bowl of water. The water height is as indicated in the figure.



What force is required to maintain the cylinder in the shown position?

3. An electric circuit includes a piece of coaxial cable (cf. the figure) in which the currents of the two wires of the cable are of equal magnitude and oppositely directed.



By how much does the cable contribute to the self induction coefficient of the circuit (the inductance)?

4. The so-called Schwartzchild radius for a black hole around a central mass is calculated using Einstein's general theory of relativity. The same equation also results from a classical mechanical calculation of Schwartzchild's radius as the distance at which speeds larger than the speed of light is required to escape the gravitational field of the central mass. Is it surprising that the two calculations give the same result?
5. How does the speed of a starting car increase with time if the engine delivers a constant power?

Roskilde University

Second written test in the breadth module of physics

To be held Friday, June 22, 2007, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. How large an asteroid is it possible to escape by jumping under one's own effort without using a rocket or the like?

Justify your answer

2. An air condition system keeps a reasonable indoor temperature in a building. The outside temperature oscillates between a maximum value during the day and a minimal value at night; the latter is equal to the indoor temperature. How large is the electricity bill for this case compared to the bill if the outside temperature was the maximum temperature day and night?

3. The first evidence for the existence of planets belonging to stars other than the Sun was that these stars rocked. This could be established by a periodic variation of the frequencies of the stars' light. How is the relative change of frequency related to the distance between planet and star as well as their masses?

4. The physicist Jens Martin Knudsen once let cress grow on a large rotating disk in order to demonstrate to some physics students that the so-called fictive forces are not so fictitious after all. How did the cress grow during the 14 days that the disk rotated?

Justify your answer.

5. Muons are unstable particles that, at rest in the laboratory, decay after only $2 \cdot 10^{-6}$ s. They are formed, among other places, 20 km above the Earth at the top of the Earth's atmosphere by collisions between cosmic radiation and oxygen nuclei. What energy is required for muons moving to the Earth if half of them are to reach the Earth's surface?

Roskilde University

Written test, module 1, Problem Solving in Physics I and Breadth Course

The first test of two in the Breadth Course

To be held Wednesday, January 23, 2008, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. According to Galileo, Aristotle thought that a stone lost from the top of the mast of a moving ship will land some distance away from the mast, while Galileo himself was certain that the stone would land at the base of the mast. Is it possible to detect the distance between the two landing positions? Justify your answer
2. The wind speed required to stir up dust into the air depends on the grain size. What is the relation?
3. A pneumatic tinderbox consists of a cylinder and a tight-fitting piston. An inflammable material is placed at the bottom of the cylinder. A quick pressing of the piston almost to the bottom ignites the inflammable material. What is the relation between ignition temperature of the material and how much the piston needs to be pressed to the bottom?
4. A pedestrian stands on the sidewalk and notes that, nonrelativistically speaking, the velocity difference between the upper and the lower points on a bike wheel on a by-passing bike is twice the velocity of the bike. Does the same apply relativistically? Justify your answer.
5. How does the speed of a starting car increase with time if the engine delivers a constant power?

Roskilde University

Written test, module 1, Breadth Course

The second test of two in the Breadth Course

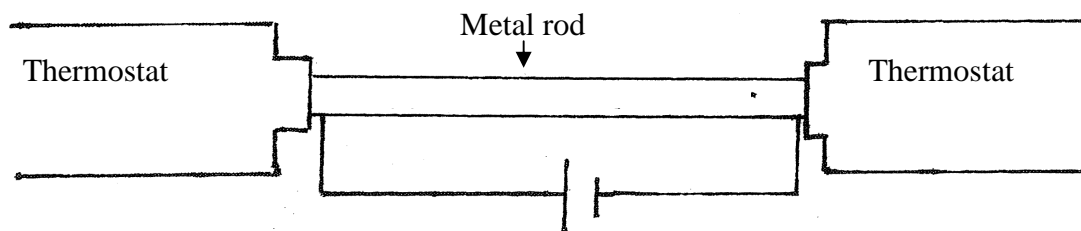
To be held Friday, January 25, 2008, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

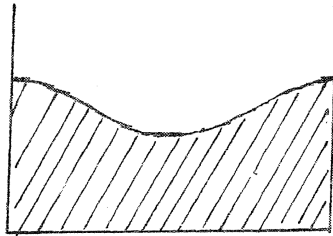
1. The increment of cancer cells per time of a cancer tumor is proportional to the surface of the cancer tumor. How does the cancer tumor grow with time? Justify your answer

2. In the so-called Kohlrausch method, the ratio between the thermal conductivity and the electrical conductivity for metals is measured using the set-up sketched in the figure:



A heat insulated metal rod is placed between two thermostats, which keeps the two ends of the rod at the same fixed temperature. The rod is heated by letting an electric current flow through it. The ratio between the thermal conductivity and the electrical conductivity is then given by the voltage over the metal rod and the temperature difference between the middle of the rod and its ends. How? Justify your answer

3. When a cup of tea or a glass of water is stirred, the surface typically looks like in the figure:



What does this tell us about the motions of the liquid? Justify your answer

4. How many photons are there in this room? Justify your answer

($k_b = 1.38 \cdot 10^{-23} \text{ J/K}$; $e = 1.60 \cdot 10^{-19} \text{ C}$; $G = 6.67 \cdot 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$; $h = 6.63 \cdot 10^{-34} \text{ J} \cdot \text{s}$;
 $c = 3.00 \cdot 10^8 \text{ m/s}$)

5. What is the combined effect of two different coils connected in series and in parallel, respectively, in an alternating current circuit? Justify your answer

Roskilde University

Written test, module 1, Problem Solving in Physics I and Breadth Course

The first test of two in the Breadth Course

To be held Monday, June 16, 2008, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. Lumps of ice slide down a cylinder shaped porch roof. How far down the roof do lumps starting at the top loose contact with the roof? Justify your answer.
2. According to a popular formulation of the second law of thermodynamics, disorder increases. How does this agree with the fact that it is possible to vacuum clean and tidy up? Justify your answer.
3. A box is placed on the truck bed of a truck. The truck makes an abrupt braking. What is the least possible value of the coefficient of friction between box and truck bed that ensures that the box does not hit the cabin of the truck? Justify your answer
4. An atom at rest absorbs a photon. By how much does the rest mass of the atom increase? Justify your answer
5. How does the tone produced by a string on a string instrument depend on the tautness and the properties of the string?

Roskilde University

Written test, module 1, Breadth Course

The second test of two in the Breadth Course

To be held Wednesday, June 18, 2008, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. What is the average force between two parallel wires with the same alternating current in phase? Justify your answer

2. A piece of rock contains a radioactive isotope that decays to a stable isotope; the stable isotope stays in the rock. Determine the age of the piece of rock based on the ratio of the numbers of the two isotopes at the time of formation and the ratio of the numbers of the two isotopes now. Justify your answer.

3. What is the slop frequency in a coffee cup? Justify your answer

4. What is the resistance met by a heat flow from the inner side to the outer side of hollow sphere? Justify your answer.

5. How many photons from a street lamp are seen per millisecond by a person flying in an airplane 10 km above the lamp? Justify your answer.

Roskilde University

Written test, module 1, Problem Solving in Physics I and Breadth Course

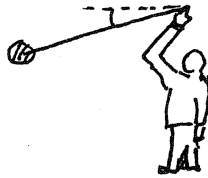
The first test of two in the Breadth Course

To be held Wednesday, January 28, 2009, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. If you swing an object above your head, the angle that the string forms with the horizontal depends on how fast you swing the object. What is the relation? Justify your answer.



2. It is found empirically that the transition from uniform flow to swirling flow when a fluid flows through a tube happens when the dimensionless so-called Reynolds number passes a value of about 2000. What physical quantities enter into the Reynolds number? How do they enter relative to each other? Justify your answer.

3. You sit in a train with closed eyes. Can you feel the difference between when the train is moving forward or backward? Justify your answer.

4. A neutron of large speed is absorbed by an atom nucleus at rest. With what speed does the atom nucleus move afterwards? Justify your answer.

5. In many buildings, the people living there save money by reducing the temperature of the radiator water or by completely shutting off the heating during the night. What is the relative cost reduction of doing so for 24 hours at winter if it means that the indoor temperature falls by about one degree during the night before the heat is turned on again in the morning?

Roskilde University

Written test, module 1, Breadth Course

The second test of two in the Breadth Course

To be held Friday, January 30, 2009, 10:00-14:00

NO AIDS ALLOWED

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A bat is moved towards a table tennis ball thrown for a serve. What is the speed of the table tennis ball immediately after being hit by the bat?

Justify your answer

2. The Danish physicist Bodil Holst has developed a microscope that creates images using a beam of helium atoms. The advantage of the microscope compared to an electron microscope is that the beam is gentler to the object because, among other things, the energy of the beam particles for this microscope is much smaller than for the electron microscope for the same resolution. How much smaller is that?

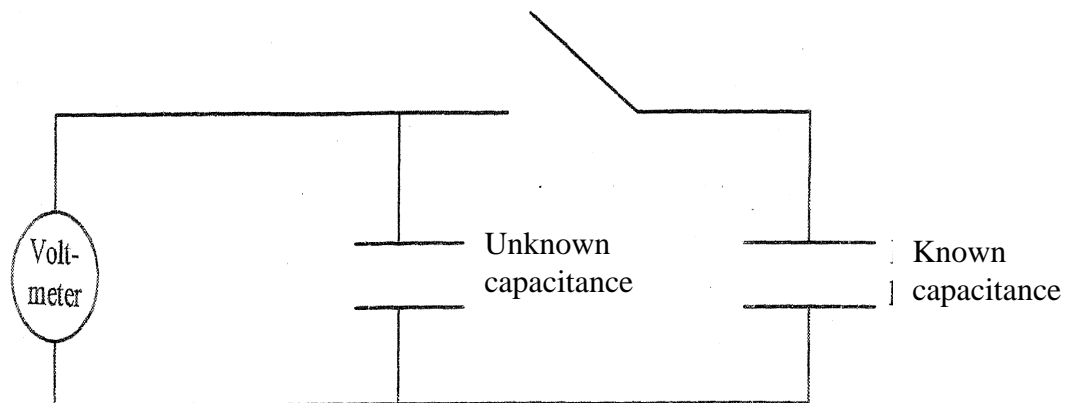
3. At equinox the day is 8 minutes longer than the night due to the bending of light in the atmosphere. What does this tell us about the dielectricity constant in the atmosphere as a function of height?

Justify your answer.

4. A conical-shaped tube has different cross-sectional radii at each of its two ends. Both cross-sectional radii are much smaller than the length of the tube. Oil flows through the tube. What is the relation between the pressure fall over the tube and the amount of oil that flow through the tube?

Justify your answer.

5.



A capacitor of unknown capacitance is connected to a voltmeter as shown in the figure above. The capacitor is charged with an unknown amount of charge with the contact open. Then the contact is closed. This can be used to determine the unknown capacitance from the known capacitance. How?

Roskilde University

Written test, module 2, Problem Solving in Physics II

To be held Tuesday, June 16, 2009, 10:00-14:00

NO AIDS ALLOWED, except one sheet of A4 paper with notes on each side of your own choice

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A small piece of aluminium foil is placed on the lower plate of a plate capacitor. The voltage over the capacitor is slowly increased. Find the voltage at which the aluminium foil is released from the plate. Justify your answer.
2. Two satellites orbit the Sun at the same distance. One is equipped with very large solar panels. What is the difference between the periods of revolutions of the two satellites? Justify your answer.
3. As a rule of thumb, large fish swim faster than small fish of the same shape. Explain why.
4. In 1913, Niels Bohr was led to his model for the hydrogen atom by noting that it is not possible to form a characteristic length corresponding to the size of the atom from the constants of nature m_e , the mass of the electron, and $\frac{e^2}{4\pi\epsilon_0}$, the constant of Coulomb's law, which are the only constants of nature that can enter into the result of a classical calculation. If h , Planck's constant, is used, a characteristic length of the right order of magnitude appears. How is the Bohr radius given in terms of m_e , h , $\frac{e^2}{4\pi\epsilon_0}$?
5. CdSe nanocrystals of varying sizes from 200 to 1000 atoms have band gap that depends on the size. A solution of such CdSe nanocrystals changes color according to the size of the crystals. Explain why.

Roskilde University

Written test, module 1, Problem Solving in Physics I

To be held Friday, January 22, 2010, 10:00-14:00

NO AIDS ALLOWED, except one sheet of A4 paper with notes on each side of your own choice

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A child sitting in a bus holds a helium-filled balloon in a string. How does the direction of the string depend on how the bus moves?

Justify your answer.

2. A part of a chain hangs over the edge of a table. How large a fraction of the chain can hang over the edge without the chain falling to the floor?

Justify your answer.

3. An iron lump has the size of the Earth. What is the order of magnitude of the time that it will take for the heat in the lump to be distributed uniformly if the lump has a heated interior?

A somewhat old textbook on thermal physics by E. S. Johansen gives the following data for iron: Density of mass at 18°C: 7.86 g cm^{-3} , linear coefficient of expansion between 0°C and 100°C: $0.0000125 \text{ degree}^{-1}$, heat capacity at 18°C: $0.111 \text{ cal g}^{-1} \text{ degree}^{-1}$ and thermal conductivity at 18°C: $0.20 \text{ cal degree}^{-1} \text{ cm}^{-1} \text{ s}^{-1}$. Justify your answer.

4. How does the width of the water column flowing from a water tap depend on the length of the fall?

Justify your answer.

5. A bat is moved towards a table tennis ball thrown into the air for a serve.

Using a relativistic calculation, find the speed of the table tennis ball immediately after it has been hit by the ball.

Justify your answer.

Roskilde University

Written test, module 2, Problem Solving in Physics II

To be held Monday, June 14, 2010, 10:00-14:00

NO AIDS ALLOWED, except one sheet of A4 paper with notes on each side of your own choice

Please solve 4 out of the below 5 problems. It should be clear which problem that is deselected.

1. A steel wire is swung in a horizontal circle. How much is the steel wire prolonged by being swung?

Justify your answer.

2. How does the temperature of a wire in a turned-on toaster depend on the voltage drop per unit wire length?

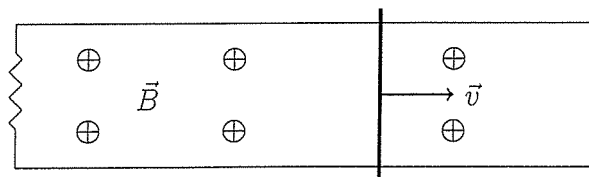
Justify your answer.

3. At room temperature, gases of different diatomic molecules do not have the same molecular heat capacity. Does the heavy or the light gases have the highest heat capacity?

Justify your answer.

4. A metal rod is pulled to the right on a pair of smooth metal tracks placed in a magnetic field as indicated in the figure. How does the velocity of the rod change with time when we stop holding the rod?

Justify your answer.



5. What power does the engine of a helicopter have to deliver to keep the helicopter in the air? Justify your answer

Roskilde University

Written test, module 1, Problem Solving in Physics 1

To be held Friday, January 21, 2011, 10:00-14:00

4 out of 5 of the problems below are to be answered. It should appear which of the problems that are discarded.

Remedies are **not** allowed, except for a sheet of A4 paper filled out on each side of the student's own choosing.

1. An unstable particle is produced in a high energy process. How does its length of flight depend on its momentum. Justify your answer.
2. For short wavelengths the surface tension rather than gravitation is governing the behavior of surface waves. How does the velocity of propagation of these so-called capillary waves depend on their wavelengths? Justify your answer.
3. Human beings can run 100m in about 10s. How high can human beings jump in pole vault (using a rod to assist the jumping)? Justify your answer.
4. When the wind is blowing you feel colder when outdoors than when no wind is blowing. Why does the wind have no impact on the reading of an outdoor thermometer? Justify your answer.
5. An almost vertically positioned ladder with a person at the top starts falling. What should the person do in order to be less hurt: Let go of the ladder or stick to the ladder during the fall? Justify your answer.

Roskilde University

Written test, module 2, Problem Solving in Physics 2

To be held Friday, June 24, 2011, 10:00-14:00

4 out of 5 of the problems below are to be answered. It should appear which of the problems that are discarded.

Remedies are **not** allowed, except for a sheet of A4 paper filled out on each side of the student's own choosing.

1. A roundabout is put in motion while a person is standing on it. How large does the coefficient of friction between the disk of the roundabout and the person's shoes have to be in order to ensure that the person does not slip? Justify your answer.

2. Why do charged particles on their way towards the earth from outer space spiral along the earth's magnetic field lines? Justify your answer.

3. For car driving, how do the fuel consumption and the CO₂ emission per driven kilometer depend on the velocity of the car? Justify your answer.

4. A long-lived α -preparation is placed in the middle of a spherical block of concrete. How does the temperature vary throughout the block? Justify your answer.

5. For photoluminescence, i.e., the delayed emission of absorbed energy of energy, the wave length of the emitted light is almost always larger than the wave length of the absorbed light. Explain this so-called Stokes' rule.

Written test, module 1, Problem Solving in Physics 1, Monday January 16th 2012, 10.00 – 14.00.



4 out of the following 5 problems have to be answered. It must be clearly stated in your answer which problem you have excluded.

Remedies are **not** allowed, except for a sheet of paper (size A4) where you on both sides of the sheet are free to write whatever you like.

1. How does the buoyancy (lift) on a hot air balloon depend on the temperature of the hot air in the balloon? Justify your answer.

2. By how much is the stress on the tracks of a railroad switch increased if the speed of the trains is increased by 10%? Justify your answer.

3. A particle moving at $4/5$ of the speed of light collides with an identical particle at rest. The two particles merge to one particle in the collision. What is the speed of this new particle? Justify your answer.

4. A drop of water oscillates between having an orange-like shape () and a lemon-like shape (). How does the oscillation time depend on the size of the drop? Justify your answer.

5. When a train brakes to stop at the platform, a jerk (pull) is felt at the end of the stopping. What does this fact say about how the speed of the train is decreased? Justify your answer

END OF PROBLEMS

Written test, module 2, Problem Solving in Physics II, Monday, June 25, 2012, 10:00-14:00.

4 out of 5 of the problems below are to be answered. It should appear which of the problems that are discarded.

Remedies are **not** allowed; except for a sheet of A4 paper filled out on each side of the students own choosing.

1. The space between the plates of a parallel-plate capacitor filled with a gas adjust itself in such a way that the pressure inside the capacitor is equal to the pressure outside the capacitor. How can the capacitor be used as an instrument for measuring pressure?
Justify your answer.
2. How big is the angular acceleration of a roller coaster train in a vertical circular loop in an amusement park?
Justify your answer.
3. A CD can reflect light resolving it in all the colors of the rainbow. What is the distance between the grooves in a CD?
Justify your answer.
4. The rotation of the Earth about its own axes is slowed down due to the tide caused by the Moon. Coupled to this the distance between the Earth and the Moon changes. Does the distance decrease or increase?
Justify your answer.
5. In general the molar heat capacity of solids is three times the gas constant R at room temperature. But diamond differ, having smaller and temperature dependent heat capacity about room temperature. Why diamond and not e.g. lead?
Justify your answer.

Written test, module 2, Problem Solving in Physics II, Tuesday, August 28, 2012, 10:00-14:00.

4 out of 5 of the problems below are to be answered. It should appear which of the problems that are discarded.

Remedies are **not** allowed; except for a sheet of A4 paper filled out on each side of the students own choosing.

1. A stick, ruler or the like is placed on two fingers, one from each hand of a person. When the fingers are moved towards each other the stick/ruler to begin with only glides on one of the fingers, then later only glides on the other finger, then again only on the first, then again only on the second etc. Explain how and why.
2. In metals the electrical conductivity is decreasing when the temperature is increasing. In materials, where the electrical conductivity is not due to the motion of electrons but due to the motion of ions, the electrical conductivity usually is increasing when the temperature is increasing. Explain the difference.
3. How much power is needed in order to make a stick stay rotating about its own axes in a big container of oil? Justify your answer.
4. As it is well known electrons and light exhibits the same kind of interference patterns when passing a double slit. The double slit experiment has now been carried out with ions of C_{60} molecules. Assume that we use the same double slits and the same potential difference accelerating both the C_{60} ions and the electrons. How would the angular resolutions using C_{60} and electrons respectively then be in comparison? Justify your answer.
5. Ticket-collectors on merry-go-rounds in amusement parks sometimes have to collect tickets while the merry-go-round is rotating. Do they then prefer to walk on the merry-go-around in the same direction as the merry-go-round is rotating or in the opposite direction? Justify your answer.

Written examination, module 1, Problem Solving in Physics I,
Friday, January 18, 2013, 10.00-14.00

4 out of 5 of the problems below are to be answered. It should be evident from your paper which of the problems you choose **not** to answer.

Remedies are **not** allowed except for a sheet of A4 paper filled out on both side; the text is of the student's own choosing.

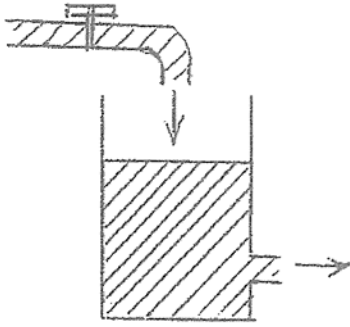
1. In combustion chambers of coal-fired power stations, the smaller combustion particles rise upward with the ascending air, while the larger particles land at the floor. What is the threshold size? Justify your answer.
2. The orbit of Mars is just outside the orbit of the Earth. The Earth takes about 365 days to orbit the Sun, while it takes Mars 687 days. How long time passes between the instant where Mars, as seen from the Earth, is in opposition to the Sun to the instant where Mars is again in opposition? Justify your answer.
3. How does your speed at the bottom of a valley of a roller coaster track depend on where you sit in the train of the roller coaster? Justify your answer.
4. After some time with frosty weather, how does the thickness of the ice on a lake depend on how cold it is? Justify your answer.
5. A large cola bottle, half-filled with water, is shaken up and down. How large should the accelerations be for bubbles to form in the water? Justify your answer.

Written examination, module 1, Problem Solving in Physics I,
Thursday, February 28, 2013, 10.00-14.00

4 out of 5 of the problems below are to be answered. It should be evident from your paper which of the problems you choose **not** to answer.

Aids are **not** allowed except for a sheet of A4 paper filled out on both side; the text is of the student's own choosing.

1. What is the relation between the radius of a soap bubble and the pressure difference between the interior and the exterior of the bubble?
Justify your answer.
2. How does the temperature fall with time in a house after the heater is broken?
How does this depend on whether the house is made of stone or wood?
Justify your answers.
3. A simple device for measuring reaction time consists of a sheet of cardboard. An assistant holds the sheet vertically by holding it at the top. Initially, the test person whose reaction time is to be measured, holds the pointing finger and the thumb around each side of the sheet at the lower edge. The person doesn't touch the sheet. When the assistant, without prior notice, let go of the sheet, the test person should grab the sheet as quickly as possible. How should the scale on the sheet be made in order to allow for the reaction time to be read immediately from the position where the sheet was grabbed?
Justify your answer.
4. An ultra fast light source approaches an observer and passes by the observer with constant velocity. How can the observer by measuring the frequency of the light source determine the speed of the light source as well as the frequency that we would measure if we moved with the light source?
Justify your answer.



5. The figure shows the principle of a so-called Danaide water meter. After the water tap has been opened we read the height difference between the outlet and the surface area of the water meter, when the water meter has reached equilibrium. At what height does the water level settle as a function of the water flow through the device?

Justify your answer.

ROSKILDE UNIVERSITY

PHYSICS

Written Eksamen, module 2, Problem Solving in Physics II, Thursday,
June 20, 2013, kl. 10.00-14.00.

4 out of the five problems below are to be answered. It should be evident from the submitted papers which of the problems that is deselected.

Aids are **not** allowed, except for a sheet of A4 paper with writings of your own choosing

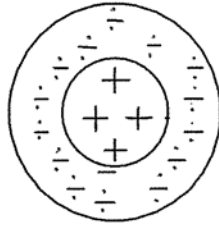
1. An ice hockey puck in motion on ice collides with a similar puck at rest. The pucks can be rotating before and after the collision, their rotational energies can change in the collision, and heat and internal oscillations can be produced within the pucks. How does the angle between the directions of motion of the two pucks after the collision depend on whether the total translational kinetic energy is increased, unchanged or decreased in the collision? Justify your answer.
2. How does the line broadening behind an optical grating depend on the density of the rulings? Justify your answer.
3. Why are the nuclei unstable for Uranium and heavier elements?
4. By how much does the temperature decrease per 100 meters ascension in air that quickly ascends in the atmosphere? Justify your answer.
5. How does the self-inductance for a coil of a given size depend on the number of windings? Justify your answer.

Written exam, module 2, Problem Solving in Physics II, Friday August 23, 2013, 10.00-14.00

4 out of the 5 problems below are to be answered. It should be evident from the submitted papers which of the problems that is deselected.

Aids are **not** allowed, except for a sheet of A4 paper with writings of your own choosing on both sides.

1. How does the time you can suck on (not chew) a piece of hard candy depend on its size? Justify your answer.
2. A miniature golf ball is rolling towards a vertical loop. What is the minimum speed required for it to roll through the loop without falling down? Justify your answer.
3. So-called single domain magnetic particles used for data storage typically have a preferred axis, where the energy is smallest for magnetisation along the two directions of the axis. It requires extra energy proportional to the volume of the particles to magnetize them perpendicular to the axis. How does the time where the data storage can be considered undisturbed by thermal fluctuations depend on the volume of the particles? Justify your answer.
4. When ^{235}U -nuclei undergo fission in nuclear reactors due to the capture of a neutron, other neutrons are released which in turn may be captured and hence lead to other fission reactions. In order to make the chain reaction as efficient as possible, the neutrons are slowed down to lower speeds during the process. Why is the probability of capture higher for slow neutrons than for fast ones? Justify your answer.
5. In the figure, a crude model (not related to the previous problem) of the neutron is given:



In the central part, there is a even distribution of positive charge that in total equals the elementary charge. This part is surrounded by an even distribution of negative charge that in total numerically equals the elementary charge. The charge densities of the two areas are numerically equal. How does the electrical field according to the model vary throughout the neutron? Justify your answer.

THE END

ROSKILDE UNIVERSITY

PHYSICS

Written exam, module 1, Problem Solving in Physics I, Wednesday,
January 15, 2014, 10.00-14.00.

Please solve 4 of the 5 problems below. It should be clear from the submitted paper which of the problems that is deselected.

Aids are **not** allowed, except for a sheet of A4 paper with writings of your own choosing on both sides.

-
1. How large is the force exerted on a demonstrator by a water jet cannon directed towards the demonstrator by the police? Justify your answer.
 2. To make a balloon, a bag is filled with a light gas until the bag is unfolded; then the bag is tied up. How does the lift force on the balloon depend on the molar mass of the gas? Justify your answer.
 3. Should an exterior door open inwards or outwards in order to prevent the door from opening in stormy weather? Justify your answer.
 4. On the night sky, Venus can only be seen either in the morning or in the evening because it is an internal planet relative to the Earth. What is the maximum number of hours that it can be seen during one night? Justify your answer.
 5. A K-meson moves with a speed of $\frac{2}{3}c$ relative to the laboratory. It decays to two similar π -mesons; in the rest frame of the K-meson each of the π -mesons gets a speed of $\frac{4}{5}c$. What is the maximum speed of the π -mesons relative to the laboratory that can be observed? Justify your answer.

Written Examine, module 1, Problem Solving in Physics I, Monday, June 23, 2014, kl. 10.00-14.00.

Four out of the five problems below are to be answered. It should be clear from the submitted papers which of the problems that is deselected.

Aids are **not** allowed, except for a sheet of A4 paper with writings of the student's own choosing.

1. A bucket partially filled with liquid slides down a icy hill. What angle with the horizontal line does the surface of the liquid form after the liquid has quiet down? Justify your answer.

2. How does the liquid height due to capillary action in narrow tubes depend on the tube radius? Justify your answer.

3. A particle decays into two smaller identical particles. What is the speed of the two smaller particles in the rest frame of the original particle? Justify your answer.

4. If you stand on the escalator at the Copenhagen Central Station, you arrive at the top at the same time as those who take the ordinary staircase next to the escalator. What portion of the work required to lift you do you have to deliver yourself if you walk at the escalator compared to if you stand on it? Justify your answer.

5. Which of the material constants of a liquid do the speed of sound in the liquid depend on? How does it depend on them? Justify your answers.

Written Examine, module 2, Problem Solving in Physics II, Tuesday, June 10, 2014, kl. 10.00-14.00.

Four out of the five problems below are to be answered. It should be clear from the submitted papers which one of the problems you have deselected.

Aids are **not** allowed, except for a sheet of A4 paper with writings of the student's own choice

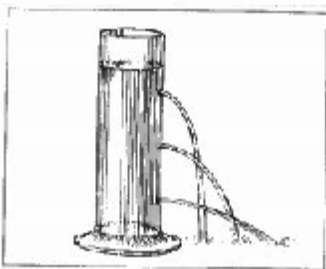
1. If the combustion chamber cannot endure temperatures above 3000°K , what is the highest exhaust velocity that can be obtained in a rocket engine using chemical fuel? Justify your answer.
2. A freely falling bar rod with direction towards the center of the Earth is so long that the gravitational field varies from one end of the rod to the other. What is the magnitude of the acceleration of the rod towards the Earth? Justify your answer.
3. The band gaps of insulators are larger than the band gaps of semiconductors. But they are not orders-of-magnitude larger. Then why is it that the specific conductivities of insulators and semiconductors differ from each other by many orders-of-magnitude? Justify your answer.
4. Rainbows are due to reflections of sun light in water drops in the air. Why is the light split into its color components? Justify your answer.
5. When charges move through a conductor placed in a homogeneous magnetic field perpendicular to the conductor, a potential difference builds up between the two sides of the conductor in the direction of the magnetic field, the so-called Hall effect. Assume that the conductor has a rectangular cross-section. How does the potential difference depend on the magnetic field strength and the current through the wire? Justify your answer.

Written Exam, Problem Solving in Physics Ib, Tuesday June 9th, 2015,
10.00-14.00

4 out of the 5 problems below are to be answered. It should be clear which of the 5 problems is not answered.

No aids are allowed except for one sheet of A4 paper with the student's notes on each side.

1. In the autumn of 2014, the space ship Rosetta was put in a small altitude orbit around a comet of the size of Mont Blanc. What is the ratio between the period of Rosetta and the period of satellites orbiting the Earth at small altitudes? Justify your answer.
2. How large is the relative increase of pressure of a cold car tire when the tire is heated during the drive? Justify your answer.
3. The following figure can be found in Grimsehl's "Lehrbuch der Physik" of 1914:



The figure is wrong. How should the correct figure be? Justify your answer.

4. A particle at speed $\frac{3}{5}c$ merges in a collision with an identical particle at rest. How large a fraction of kinetic energy is transformed into mass in the process? Justify your answer.
5. How does the power consumption of a ventilator with a rotating propeller depend on the diameter and the rotation frequency of the propeller? Justify your answer.

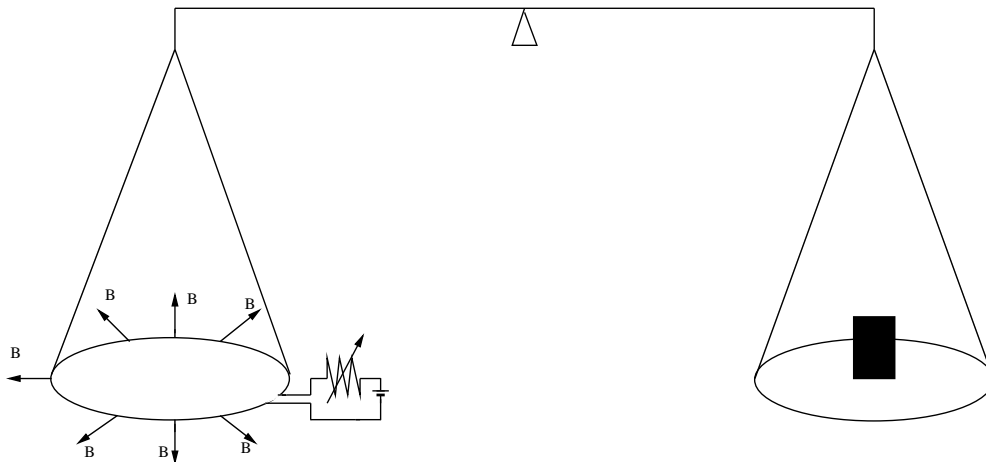
END

Written Exam, Problem Solving in Physics II, Thursday June 4th, 2015,
10.00-14.00

4 out of the 5 problems below are to be answered. It should be clear which of the 5 problems is not answered.

No aids are allowed except for one sheet of A4 paper with the student's notes on each side.

1. How large a plane mirror do you need to see yourself in full length? Justify your answer.
2. The figure shows a principle sketch of a so-called Watt-balance. One of the scales contains a mass, while the other scale is replaced by a circular, horizontal circuit. In the plane of the circuit there is a magnetic field; the magnetic field is directed out of the center of the circuit and is of the same strength at all points in the circuit.



We adjust the current of the circuit so that the balance is balanced. What is the relationship between the current and the mass in the scale? Justify your answer.

3. A barrel shaped like a cylinder has been left at the platform of a truck. The barrel is placed against the cabin of the truck and its axis is perpendicular to the travelling direction of the truck. The truck speeds up to drive. How far does the truck get before the barrel rolls out of the open, rear end of the platform of the truck? Justify your answer.

CONTINUES

4. One side of a hall has two closely spaced doors each leading into a smaller room; the two smaller rooms are not connected. Disturbing speech can be heard from one of the rooms. Is it easiest to determine which of the rooms the disturbing speech is coming from by listening to the female voices or the male voices? Justify your answer.

5. In 1913, H. G. J. Moseley studied the so-called characteristic x-rays that are produced in the following process in elements of atomic number higher than two: First an outside electron knocks out of the atom one of the two electrons at lowest energy level, so a vacancy, so to speak, is formed. When one of the electrons from the next energy level jumps to the vacancy an x-ray is emitted. Moseley plotted the frequencies of these x-rays as a function of atomic number for several elements. What should we expect the curve to look like? Justify your answer.

THE END

ROSKILDE UNIVERSITET

PHYSICS

Written Exam, Problem Solving in Physics II, Wednesday 19th August, 2015, 10.00-14.00.

Four out of the five problems below are to be answered. It should be clear from the submitted papers which one of the problems you have deselected.

Aids are **not** allowed, except for a sheet of A4 paper with writings of the student's own choice

1. By choosing the right height for a horizontal hit with the cue on the billiard ball, you can give the ball a pure roll without sliding immediately after the hit. What is the right height?

Justify your answer.

2. A spinning top on a scale weighs more the faster it rotates. How fast does it have to rotate for this effect to be measured?

Justify your answer.

3. A conducting bar that is parallel to a wire is moved away from the wire with a constant velocity perpendicular to the wire. How does the voltage difference between the two ends of the bar depend on the current in the wire?

Justify your answer.

4. Gas diffusion is a method used for separating isotopes of a substance. After the substance is put on gas form, it diffuses through a number of semi-permeable membranes that allows diffusion in one direction, but not the other. After the passage through a membrane the number of heavy isotopes has decreased relative to the light ones. If the isotopes were in the same proportion initially, how does the ratio of the isotope numbers after the passage through a membrane depend on the molecular masses of the isotopes?

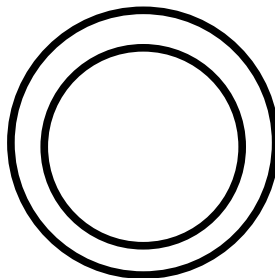
Justify your answer.

5. Atom nuclei in the universe that are heavier than hydrogen, helium and lithium are assumed to be formed in fusion processes, if they are lighter than the atomic nucleus of iron. If they are heavier than the atomic nucleus of iron, they are assumed to be formed by neutron capture in lighter nuclei with subsequent beta decay. Explain why.

Four out of the five problems below are to be answered. It should be clear from your submitted paper which one of the problems you have deselected.

Aids are **not** allowed, except for a sheet of A4 paper with writings of the student's own choice

1. How does the density of mass influence how fast a planet can rotate about itself without exploding? Justify your answer.
2. Using dimensional analysis, derive the constant in Compton's equation for the relation between change of wavelength and change of direction for X-ray scattering on electrons.
3. A capacitor consists of two long metal tubes, a small tube within a large tube. The figure shows a cross section of the capacitor



What is the capacity of capacitor? Justify your answer.

4. By what percentage does the blood pressure have to be increased to ensure the same blood flow in a blood vein if the inner diameter of vein is reduced by 5% due to the deposit of calcified mass on the inside of the vein? Justify your answer.
5. A wall consists of two layers. How does the isolation capacity of the walls depend on the layers? Justify your answer.

THE END

Written exam, Problem Solving in Physics II, Wednesday 17th of February 2016, 10.00-14.00

4 out of the 5 problems below are to be answered. It should be clear which problem has been deselected.

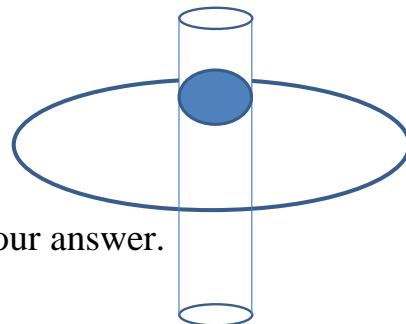
No aids are allowed, except for a sheet of A4 paper with writings of the student's choice on both sides

1. In Bohrs model of the atom, contrary to the later quantum mechanics, it is meaning full to specify position and momentum of the circling electrons simultaneously. Never the less the model is pointing forward to the wave quality of particles, since the circumference of the n'th orbit of the Bohr atom is n times the de Broglie wavelength, $\lambda = h/p$. Prove that.

2. In district heating, how does the temperature of the hot water in the pipeline between the heat plant and the houses depend on the distance from the heat plant? Justify your answer.

3. By how much does the Earth deviate from a spherical shape? Justify your answer.

4. A positively charged ball in a smooth tube moves back and forth through a negatively charged ring, as shown in the sketch.



What is the oscillation period of the ball? Justify your answer.

5. A new radio astronomical telescope system is being built; it consists of a cluster of telescopes in Australia whose signal is added to the signal of a cluster of telescopes in Africa. Why are the two clusters of the system distributed over more than one continent? Justify your answer.

THE END

Danish Exam Problems

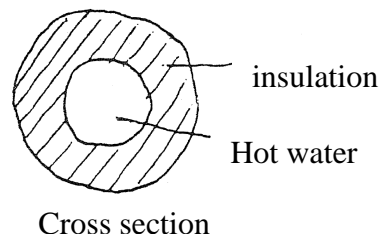
The exam in the breadth module of the graduate studies in physics at Roskilde University center, summer 1987

First written test in the breadth module of physics (1st module), to be held Wednesday, June 10, 1987, 10:00-14:00

No aids are allowed. Please solve 6 out of the below 8 problems. It should be clear which 2 of the problems that are deselected.

1. In what position does the rope of a swing break if it breaks?
What happens?
Justify your answers

2. How does the heat loss in district heating pipelines depend upon the insulation?
Justify your answer.



3. In the chain of radioactive decays from ${}^{238}_{92}\text{U}$ to ${}^{206}_{82}\text{Pb}$, α and β radiation is emitted. Does the β radiation consist of electrons or positrons?
Justify your answer

4. The spectral lines emitted by luminous hydrogen can be described by the equation

$$\nu_{n,m} = R \left(\frac{1}{m^2} - \frac{1}{n^2} \right)$$

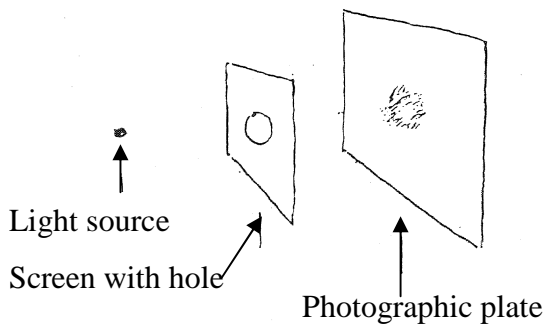
On which fundamental quantities does the constant R depend and how does it depend on them?
Justify your answers

5. If an electric device is turned off by pulling the plug of the socket, a spark may occur. This doesn't happen if it is turned on by putting the plug into the socket.
Explain why.

6. So called gravimeters, used for measuring gravitational fields, measure so accurately that they register the difference between being placed on a table and on the floor next to it.
How accurate is that?

. A 2 .
Danish Exam Problems

7.



At what size of the hole does the smearing spot become the smallest in the sketched arrangement?

Justify your answer.

8. In windy weather paper and leaves in the street are typically stirred up rather than pressed down to the Earth.

Explain why.

(end of problem set)

Second written test in the breadth module of physics (1st module), to be held Wednesday, June 10, 1987, 10:00-14:00

No aids are allowed. Please solve 6 out of the below 8 problems. It should be clear which 2 of the problems that are deselected.

1. Who slips the easiest on a slope, a child or an adult?

Justify your answer.

2. Experience indicates that viscosity of liquids typically varies as $\exp(+T_0/T)$ with

temperature T (T_0 is a constant). Does this seem reasonable from a microscopic perspective?

Justify your answer.

3. In connection with the latest observed super nova explosion, a strong neutrino flux was recorded here on Earth. The event in the course of the explosion that caused the neutrino emission was also optically observed. According to the observational material, the arrival of the neutrinos at the Earth was at most 1 hour compared to the arrival of light. The distance to the super nova is 170 000 light years.

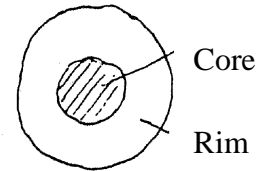
What upper limit on the order of magnitude of the rest mass of the neutrinos can be derived from this?

4. A beer can is 16 cm tall. It can contain 320 g beer and weighs itself 40 g. What is the lowest position of the center of gravity for can and beer combined for varying beer content?

Danish Exam Problems

5. Optical glass fibers for signal transmission are built up of a core and a rim, both of which are of glass, but with different refractive indices:

The light signals are transmitted through the core. Is the refractive index of the core larger or smaller than the index of the rim? Justify your answer



Cross section

6. To protect the door hinges, carpenters typically place the door stop at a distance of two thirds of the door width from the support of the door. Why at precisely this distance?

7. Stefan-Boltzmann's law, that the energy density of black body radiation is equal to a universal constant times the absolute temperature to the fourth power, can be derived from electrodynamics and thermodynamics. The magnitude of the universal constant, however, is explainable only from more fundamental constants of nature within the framework of quantum mechanics, which suggests a relation between quantum mechanics and thermodynamics.

What is the relation between the constant in Stefan-Boltzmann's law and more fundamental constants of nature?

Justify your answer.

8. In a house heated by electricity, the risk of breaking the fuse is the largest in the case where all the electricity radiators are cold and turned on simultaneously. Why?

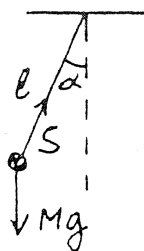
(end of problem set)

"Solutions"

"Solutions" is in inverted commas, because the character of the problems means that definite, clear-cut and authorized answers to them do not always exist. Moreover, due to lack of space the explanations given here are less elaborate than expected from the students' answers. "The solutions" are brief presentations of what I essentially had in mind when I posed the problems. My thoughts are not necessarily correct.

First set

1.



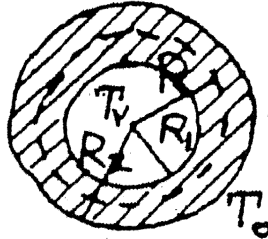
The rope breaks in the position, where the tension, S , is largest.

$$\text{From: } S - Mg \cos \alpha = M \frac{V^2}{l} \text{ and}$$

$$Mgl(1 - \cos \alpha) + 1/2 MV^2 = Mgl(1 - \cos \alpha_{\max})$$

we get $S = Mg(3 \cos \alpha - 2 \cos \alpha_{\max})$. S is largest when $\alpha=0$, hence the rope breaks when in the bottom position, if it breaks. Hence, the person on the swing will be thrown in the parable of projectile motion with an initial velocity that is horizontal, if the rope breaks.

2.



The heat flow density is given by

$j = -\chi \frac{dT}{dR}$ where χ is the thermal conductivity of the insulating material. In a stationary situation, the heat loss per unit length, K , is independent of R and given by $K = 2\pi R \cdot j(R)$;

hence $-2\pi\chi dT = K \cdot \frac{dR}{R}$, which by integration yields

$$K = \frac{2\pi\chi(T_v - T)}{\ln(R_2 / R_1)}$$

Thus it is the ratio R_2 / R_1 rather than the thickness of the insulation that together with χ determine the heat loss.

3. The number of α decays is $(238-206)/4=8$. This decreases the charge of the nucleus by 16, thus 6 more than the registered number. Thus the transformation of another 6 neutrons to 6 protons with the emission of 6 electrons is required. Hence, the β radiation consists of electrons.

4. R can be derived from Bohr's semi-classical model; the constants of nature that enter into this model is m_e , e , h and ϵ_0 . How R depends on the constants of nature can be found using dimensional analysis.

As $[R]=T^{-1}$, $[m_e]=M$, $[e]=Q$, $[h]=ML^2T^{-1}$ and $[\epsilon_0]=Q^2M^{-1}L^{-3}T^2$, the *ansatz* $R=\text{dimensionless constant} \cdot m_e^\alpha \cdot e^\beta \cdot h^\gamma \cdot \epsilon_0^\delta$ necessitates

$$-1 = -\gamma + 2\delta; \quad 0 = \alpha + \gamma - \delta; \quad 0 = \beta + 2\delta; \quad \text{and} \quad 0 = 2\gamma - 3\delta$$

Hence

$$\alpha = 1, \quad \beta = 4, \quad \gamma = -3 \text{ and } \delta = -2, \text{ i.e. } R \propto \frac{m_e \cdot e^4}{h^3 \cdot \epsilon_0^2}$$

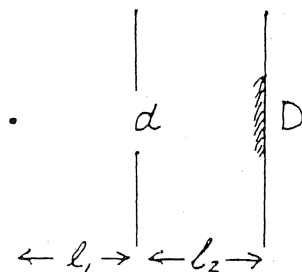
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5. When the plug is pulled, the self inductance in the apparatus can lead to large voltage drops across the developed spark gap due to the quick change in current intensity. At the same time the gap is small in the beginning. When the plug is put into the socket, the current no longer changes as long as there is a gap.

$$6. \quad g(r) = G \cdot \frac{M}{r^2}; \quad dg = -2G \frac{M}{r^3} \cdot dr; \quad \frac{dg}{g} = -2 \frac{dr}{r}$$

As $\frac{dr}{r} \approx \frac{1m}{6000m} \approx 2 \cdot 10^{-7}$, gravimeters apparently can measure with a relative accuracy that is less than or equal to $4 \cdot 10^{-7}$.

7.



For large values of d , the smearing spot will be given geometrically by

$$D = \frac{l_1 + l_2}{l_1} d,$$

For small values of d , it will be given by the smearing of diffraction

$$D \approx \frac{\lambda}{d} l_2$$

The smallest smearing spot is obtained when $\frac{l_1 + l_2}{l_1} d \approx \frac{\lambda}{d} l_2$, i.e.

$$d \approx \sqrt{\frac{\lambda \cdot l_1 \cdot l_2}{l_1 + l_2}}$$

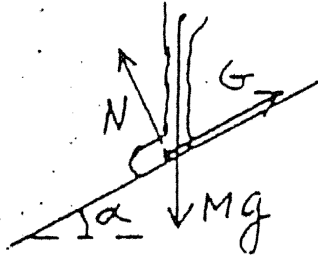
With the orders of magnitude $l_1 \approx l_2 \approx 1 \text{ m}$ and $\lambda \approx 10^{-6} \text{ m}$ we obtain

$D_{\min} \approx 1 \text{ mm}$ for $d \approx 1 \text{ mm}$.

8. The leaf or paper in the street has stagnant air on its underside and moved air on the top side, if there is a wind. According to Bernoulli's equation this implies that there is a relative negative pressure on the top side.

Second set

1.



When the person is standing still: $N = Mg \cos \alpha$; $G = Mg \sin \alpha$,
i.e. $\tan \alpha = G / N$. As $G_{\max} = \mu N$, where μ is the coefficient of
static friction, the condition for standing still is $\tan \alpha \leq \mu$. As the
condition is independent of M , the adult and the child have, in a
first approximation, equal big difficulties with standing firmly
on the slope.

2. Liquids consist of molecules (or atoms) that, like in solid materials, oscillate about some equilibrium positions between the neighboring molecules. When the liquid, in contrast to solid materials, can flow, it is because the molecular configuration allows enough space that a rearrangement of the molecules sometimes can take place at sufficiently large energy fluctuations. The simplest assumption of the frequency of such fluctuations is that it somehow follows from a characteristic activation energy, A , and a corresponding Boltzmann factor ($\exp(-A/(k_B T))$). Hence the temperature dependences of $\exp(-T_0/T)$ for the easy-flowingness and, conversely, of $\exp(T_0/T)$ for the viscosity, seem reasonable.

3. If neutrinos have a rest mass, then $m_0 c^2 = E \cdot \sqrt{1 - v^2/c^2}$, where v is the velocity of the neutrinos. According to the observations we have

$$\frac{v}{c} = \frac{t_{\text{light}}}{t_{\text{neutrino}}} > \frac{170\,000 \text{ year}}{170\,000 \text{ year} + 1 \text{ hour}} \approx 1 - \frac{1 \text{ hour}}{170\,000 \text{ year}}$$

hence

$$\sqrt{1 - v^2/c^2} = \sqrt{(1 + v/c)(1 - v/c)} < \sqrt{2 \cdot 1 \text{ hour} / 170\,000 \text{ year}} \approx 3 \cdot 10^{-5}$$

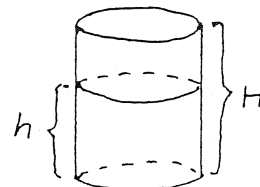
If we set $E \leq 1 \text{ MeV}$ we get $m_0 c^2 < 1 \text{ MeV} \cdot 10^{-4} = 100 \text{ eV}$.

4. The position of the center of gravity above the bottom is given by

$$x = \frac{h/H \cdot 320 \cdot h/2 + 40 \cdot H/2}{40 + h/H \cdot 320} = \frac{H}{2} \frac{1 + 8a^2}{1 + 8a}; \quad a = \frac{h}{H}$$

$$\frac{dx}{da} = 0 \text{ for } 8a^2 + 2a - 1 = 0 \text{ or } a = \frac{1}{4},$$

which plugged into the equation for x , gives $x_{\min} = 4 \text{ cm}$.

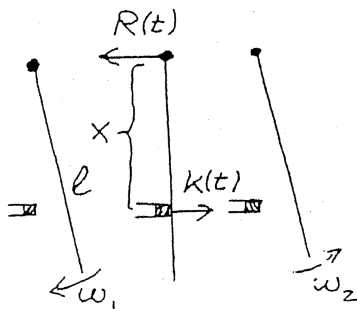


5. We aim for total reflection of the light in core of the interface. According to the law of refraction $n_k \cdot \sin \alpha_k = n_r \cdot \sin \alpha_r$ this is obtained when the angle of incidence α_k is larger than the one given by

$$\sin \alpha_k = \frac{n_r}{n_k} \quad \text{if } n_k > n_r$$

The refraction index of the core should thus be larger than the index of the rim.

6.



The change of momentum in the impact:

$$Ml/2 \cdot (\omega_1 + \omega_2) = \int_0^{\Delta t} (K(t) - R(t)) dt$$

The change of angular momentum in the impact:

$$1/3 \cdot Ml^2 (\omega_1 + \omega_2) = x \cdot \int_0^{\Delta t} K(t) dt$$

From this follows that

$$\int_0^{\Delta t} R(t) dt = 0 \Leftrightarrow x = 2/3 l.$$

7. For dimensional reasons, k_B necessarily has to enter into the constant to the fourth power. The remaining factor then has the dimension: energy/(length³×energy⁴). Of the relevant constants of nature that can yield this dimension, only h and c are possible. The factor $(hc)^{-3}$ gives agreement. Hence the constant in Stefan-Boltzmann's law is given by: dimensionless number · $k_B^4 \cdot (hc)^{-3}$.

8. When the radiators are cold, their electrical resistance is smaller than when they are warm and hence the current through them are larger than when they are warm since the network voltage is constant.

Comments

The Master's degree programs at RUC consist of two years basic studies, possibly one module of work experience, and six modules of graduate studies, each module corresponds to half a year of full time work. The graduate studies are in two subjects on an equal footing, each occupying three out of the six modules.

The graduate studies in physics, which thus corresponds to one and half years of full time work, consists of a breadth module, a depth module and a specialization module.

Half of the breadth module consists of project work, which is finished with a oral exam on the basis of a produced project report. The other half consists of course work that is finished with two written exams like the ones described here.

The work load that in principle is available for the preparation for the two written exams of the breadth module is thus half a semester, i.e. corresponding to something like the size of Physics 1 at the universities in Copenhagen and Århus. The ground that should be covered is, for the moment, defined by the material in Alonso Finn, Physics I, II, III supplemented by books in astrophysics. This disproportion can only be resolved if it is presupposed that the students, one way or the other, through the basic studies in science and parallel engagement with other parts of the physics program have obtained a confident relation with large parts of the syllabus, so that the aim of the course work in the breadth module for the individual student mainly becomes a matter of relating previously acquired partial understandings to each other and "filling holes".

In accordance with this, the two written exams in the breadth module are not orchestrated in the traditional way, which serves to check the students' ability to reproduce and apply a syllabus that has been taught immediately prior to exam. (The written exam in the depth module is orchestrated in this way). It was seen as crucial to find a type of problems that, rather than test mathematical/technical manipulation skills and detailed knowledge, test the students' insight into physics in its entirety, their understanding of central structures of physical concepts and their ability to apply them, so that the exam could function as a "maturity test", where a pedantic repetition for the exam of the insurmountable syllabus is only of limited value.

In addition to these structural reasons for choosing this special kind of problems, the problems are also chosen for more general pedagogical reasons. The problems are devised based on a consideration of the feedback on the previous teaching and learning that exam problems inevitably have.

When devising the problems, it is attempted to meet the following 7 requirements:

- 1) Acceptable processing of the indicated problems should require physical understanding.
- 2) The problem should bear on central structures of concepts and ways of reasoning in physics.

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- 3) The problems should collectively span the syllabus.
- 4) The problems should be solvable using simple calculations.
- 5) It should be possible to formulate the issues in everyday language, so that a central aspect of the problem solving is to make the problems more precise in physical terms.
- 6) The problems should be at a reasonable level of difficulty.
- 7) The problems should concern real, rather than contrived, issues.

That the problem should concern real, rather than contrived, issues is partly to motivate the students, partly to illustrate that the character of physics as a theoretical, explanatory science makes it useful for commanding parts of reality and that physics is not the scholastic, self-determined system, that it, because of its strong theoretical character, often is mistaken to be. That it should be possible to formulate the issues raised in the problems in everyday language is based on the idea that the essential yield of physics teaching can only be obtained through the training of the ability to actively apply acquired concepts and ways of reasoning on not previously known or designed problems. In order to meet this concern, a large part of the problem issues already have been handled in Gymnasium.

It may seem surprising to some that this kind of "easy" problems should be the starting point of university teaching. Experiences show, however, that there is a big difference between the yield of and the difficulties with working on a problem if it is only given in a merely suggested form and disconnected from a particular place in the syllabus and when it is given in a parameterized and precise form as well as connected exposition-wise to the relevant syllabus.

The first exam in the breadth module of physics at RUC was held in the summer of 1976. At that time, a collection of 68 problems existed. The collection has now grown to 292 problems by including the exam problems from the past years. It is available as IMFUFA text 3 and can be bought for the printing expenses at the secretariat, IMFUFA, Roskilde University, P. O. Box 260, 4000 Roskilde

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