NTNU
Institutt for Fysikk

Contact during the exam: Tor Nordam
Telephone: 47022879 / 73593648

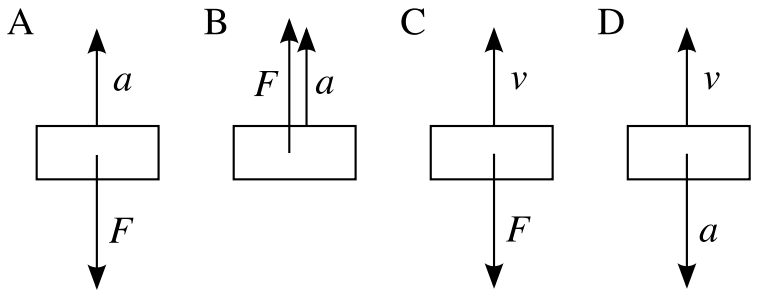
Final exam

FY0001 Brukerkurs i fysikk
Friday May 29, 2009

Duration: 4 hours (09.00 - 13.00)
Allowed help: *Tabeller og formler i fysikk 2FY og 3FY* (Gyldendal undervisning)
Pocket calculator HP30S or Citizen SR-270X

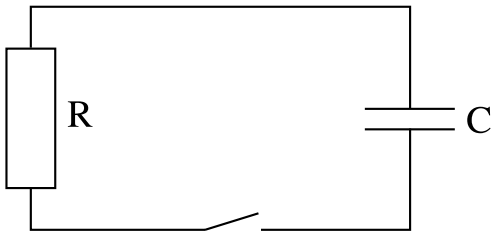
Problem 1

a) The figure shows four objects, and two physical quantities for each. F is the sum of the forces acting upon the object, v is the speed of the object, and a is its acceleration. Which of these drawings depict(s) an impossible physical situation? Give a very short explanation.



b) What is the Doppler effect? Explain how we can use this effect to determine if a far away star is moving towards us or away from us.

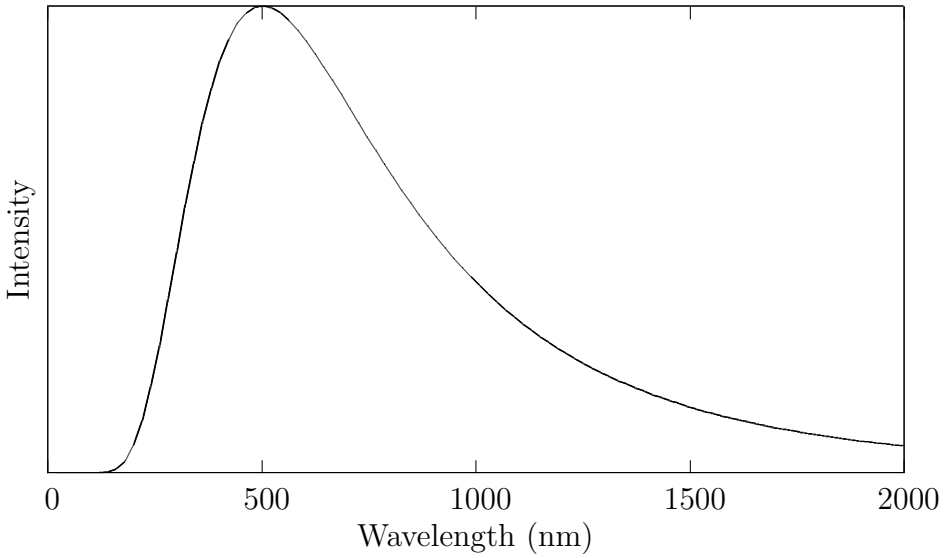
c) The figure shows a circuit with a capacitor with capacitance $5 \cdot 10^{-6}$ F and a resistor with resistance $1.2 \cdot 10^{6}$ Ω. The capacitor is charged to a voltage $V_0 = 50$ V. Draw a figure which shows approximately how the current in the circuit will change as a function of time, after the switch is closed. When the voltage over the capacitor has dropped below 1% of V_0, we say the capacitor is discharged. Will this take about half a second, half a minute or half an hour?



d) Laser light with the wavelength 632.8 nm is sent onto a double slit. After passing through the slit, the light creates an interference pattern on a screen which is located 3 m away from the slit. You measure a distance of 19 mm from the zeroth to the first order maximum. Calculate the distance between the slits.

e) Polonium-210 ($^{210}_{84}$Po) is a radioactive material with a half-life of 138 days. Assume that we have a sample consisting of 0.1 g of pure polonium-210. How much of the polonium remains after 690 days? How long does it take before only 1 % of the original amount remains?

Problem 2



In this problem, we will assume that the Sun acts like a black body. The figure shows the Sun's radiated intensity as a function of wavelength.

a) Explain how you can use information from the figure to obtain an approximate value for the surface temperature of the Sun.

b) The surface temperature of the Sun is 5778 Kelvin, and the total radiated power of the Sun is $3.846 \cdot 10^{26}$ W. Calculate the radius of the Sun.

c) The distance from the Earth to the Sun is $1.496 \cdot 10^{11}$ m. How large, measured in Watts per square meter, is the intensity of the sunlight that hits the Earth?

d) Assume that all the energy radiated by the Sun is produced in the reaction

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He}$$

Deuterium ($^2_1$H) has an atomic mass of 2.01355 u, and helium ($^4_2$He) has an atomic mass of 4.00260 u. Calculate the amount of energy which is released in this reaction.

e) Calculate how many deuterium atoms are converted to helium each second in the Sun. How many kilos of deuterium does this correspond to?

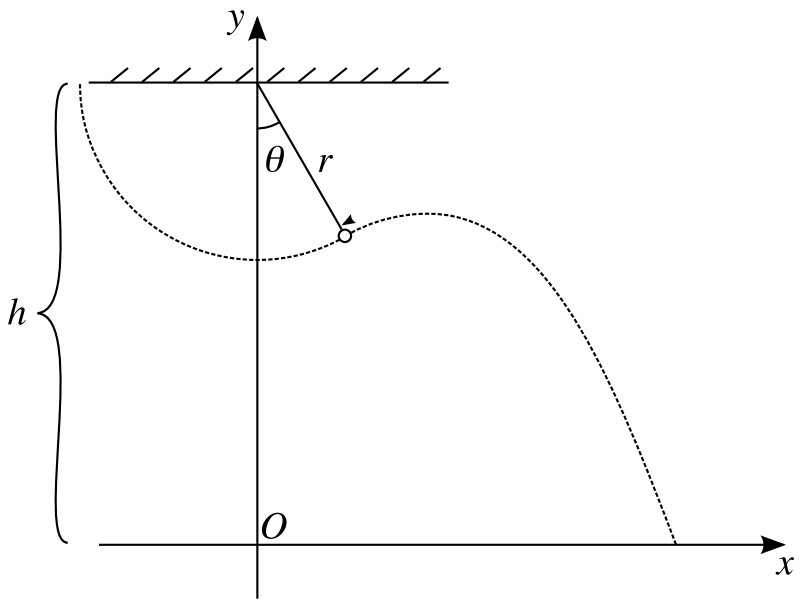
Problem 3

The Moon takes 27 days, 7 hours and 43 minutes to complete one orbit around the Earth. Assume that the Moon follows a circular orbit, in a distance of $3.831 \cdot 10^8$ m from the Earth.

a) Calculate the orbital speed of the Moon.

b) Show that the mass of the Earth is $M_\oplus = 5.97 \cdot 10^{24}$ kg.

Problem 4



We have a pendulum, where the length of the pendulum is $r = 0.6$ m. The distance from the pivot point to the floor is $h = 1.5$ m. A knife is mounted in such a way that it will cut the cord of the pendulum when it has reached an angle θ past the lowest point. In this problem, you can ignore air resistance, and you can assume that no kinetic energy is lost as the cord is cut.

Assume that the knife is placed so that $\theta = 20°$, i.e. that the cord is cut when the bob has moved a little past the lowest point.

a) The bob is lifted so that the pendulum points horizontally to the left, and released. Use conservation of energy to show that the speed of the bob as the cord is cut is

$$v = \sqrt{2gr\cos 20^\circ},$$

and calculate the x and y components of the velocity.

b) Calculate the time from the cord is cut to the bob hits the floor.

c) Find the x coordinate of the point where the bob hits the floor.

Formulæ

Acceleration in uniform circular motion	$a = \frac{v^2}{r}$
Doppler effect, moving emitter	$f' = f\left(\frac{1}{1 \pm V_E/v}\right)$
Doppler effect, moving receiver	$f' = f\left(1 \pm V_R/v\right)$
Kinetic energy	$E_k = \frac{1}{2}mv^2$
Law of gravitation	$F_g = G\frac{m_1 m_2}{r^2}$
Mass - Energy equivalence	$E = mc^2$
Newton's 2. law	$\vec{F} = m\vec{a}$
Ohm's law	$\Delta V = RI$
Potential energy in constant gravitational field	$E_p = mgh$
Radioactive decay	$N(t) = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$
Stefan-Boltzmann law	$I = \sigma T^4$
Wien's displacement law	$\lambda_{max} = \frac{b}{T}$

Constants

Acceleration of gravity	$g = 9.81\ \mathrm{m/s^2}$
Atomic mass unit	$1u = 1.6605 \cdot 10^{-27}\ \mathrm{kg}$
Avogadro's number	$N_A = 6.02 \cdot 10^{23}\ \mathrm{mol^{-1}}$
Gravitational constant	$G = 6.67 \cdot 10^{-11}\mathrm{m^3kg^{-1}s^{-2}}$
Speed of light	$c = 299792458\ \mathrm{m \cdot s^{-1}}$
Stefan-Boltzmann constant	$\sigma = 5.6704 \cdot 10^{-8}\ \mathrm{Js^{-1}m^{-2}K^{-4}}$
Wien's displacement constant	$b = 2.8978 \cdot 10^{-3}\ \mathrm{m \cdot K}$