HUT, TUT, LUT, UO, ÅA, UT and UW entrance examination in physics for the engineering departments 1.6.2005 — Series A

Write down your name and applicant number on each paper. Solve each problem on a separate sheet of paper and explain briefly the formulas which you use.

A1 The velocities of two cars, A and B, travelling in the same direction are shown in Figure 1. The cars are side by side at time $t = 0$ s.
a) Describe the movement of car A as a function of time. Which car has moved a larger distance in the time interval 0. . .26 s?
b) Determine the next point in time when the cars are again side by side.

A2 A van, which has a mass of 2880 kg, is travelling along a horizontal road with a speed of 55 km/h, when the driver brakes hard and the wheels of the van lock. The driver carries on braking until the van stops. The coefficient of friction between the tyres of the van and the road is 0.50.
a) Determine the braking distance of the van. Air resistance is neglected.
b) Determine the braking distance of the van if the van is fully loaded and the mass of the van is 3930 kg. Air resistance is neglected.
c) Which van, the fully loaded one or the empty one, has a longer braking distance if the air resistance is taken into account? The air resistance is $F_a = Dv^2$, where v is the speed of the van and D is a constant depending only on the shape of the van. Explain.

A3 A piece of ice, which has a mass of 0.100 kg and an initial temperature of 244 K, is heated from time $t = 0$ min with a constant power of 100.0 W in a thermally isolated container. The temperature of the system as a function of time is shown in Figure 2.
a) Explain what happens during the different time periods in Figure 2.
b) Determine the specific heat of fusion and specific heat of water with the help of Figure 2.

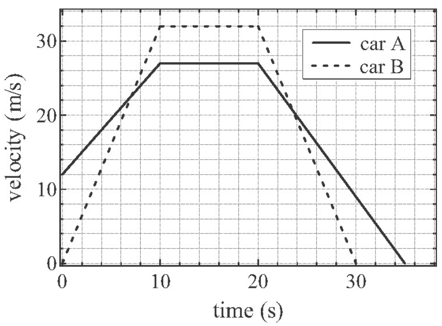

Figure 1

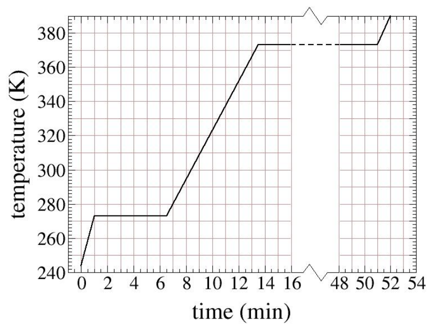

Figure 2

A4 An unknown dielectric material, with a dielectric constant κ, has been placed between the plates of a parallel-plate capacitor. The area of the capacitor plates is $A = 10.0$ cm^2 and the distance between them is $d_1 = 1.00$ mm. A charge Q_1 is placed on the capacitor after which the switch S is opened (Figure 3). At this time the reading on the voltmeter is U_1. The dielectric material between the plates is then removed.

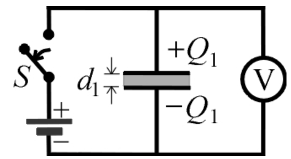

Figure 3

a) In what way are the capacitance, the charge of the capacitor and the voltage between the capacitor plates affected by the removal of the dielectric material? Explain.
b) The distance between the plates is varied until the voltmeter again gives the same voltage U_1 as with the dielectric material between the plates. This distance is measured to be $d_2 = 0.46$ mm. Determine the dielectric constant κ of the material.

A5 A metal rod, with a mass of $m = 0.20$ kg, is placed on two conducting rails which are separated by a distance $L = 0.25$ m (Figure 4). The rod can move without friction in the direction of the rails. A homogenous magnetic field $B = 1.4$ T is directed perpendicularly to the exam sheet and into the sheet. A direct current power source with an electromotive force $\mathcal{E} = 12.0$ V is connected to the rails and the total resistance of the closed circuit is $R = 5.0\ \Omega$. The resistance of the rails is assumed negligible. The switch S is closed at time $t = 0$ s.

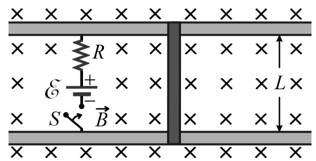

Figure 4

a) Determine the acceleration of the rod (magnitude and direction) immediately after the switch has been closed. Explain.
b) Explain why the velocity of the rod eventually approaches a constant value after the switch has been closed. Determine this constant value.

A6 Carbon dating is a commonly used method for dating organic archeological specimens. The method utilizes the unstable $^{14}_{6}C$ isotope, which decays by β-decay.
a) Write down the decay reaction of the $^{14}_{6}C$ isotope.
b) 155 decay reactions per hour are detected from an archeological specimen which contains 440.0 mg of carbon. Determine the age of the specimen, if one assumes that the activity of atmospheric carbon at the time of the specimen's death was 0.255 Bq per gram of carbon.

CONSTANTS:

Absolute zero point	$T_0 = -273.15$ °C	Normal air pressure	$p_0 = 1.013 \cdot 10^5$ Pa
Elementary charge	$e = 1.6022 \cdot 10^{-19}$ C	Planck's constant	$h = 6.6261 \cdot 10^{-34}$ Js
Avogadro's number	$N_A = 6.0221 \cdot 10^{23}$ mol^{-1}	Acceleration of gravity	$g = 9.807$ m s^{-2}
Dielectric constant of air	$\kappa_a = 1.0006$	Permittivity of vacuum	$\varepsilon_0 = 8.8542 \cdot 10^{-12}$ F m^{-1}
Half-life of $^{14}_{6}C$	$T_{1/2} = 5730$ a	Speed of light in vacuum	$c = 2.998 \cdot 10^8$ m s^{-1}