National Physics Olympiad, Nepal, 2007

(Pre-selection test, 2007)

Saturday, 17th February, 2007
Time: 3 hours + 15 minutes
Full marks: 100

Attempt all questions. Mark for each question or a part of a question is given in the right margin. You are advised to answer the questions which you can easily do first and then come back to attempt seemingly difficult ones. Final answer is not the only important step. Every correct step in your solution carries marks for that step. Originality in approach will be rewarded. You are advised to draw figures and sketches with proper labeling where necessary.

Data Sheet

Mass of the Earth	$5.98*10^{24}$ kg
Mass of moon	$7.36*10^{22}$ kg
Radius of the Earth	$6.38*10^{6}$ m
Radius of moon	$1.74*10^{6}$ m
Distance between the Earth and moon	$3.8*10^{8}$ m
Gravitational constant (G)	$6.673*10^{-11}$ Nm^2kg^{-2}

Question 1

(a) (i) You are given only an ordinary ruler which has been divided into cm and mm. Describe how you would measure the thickness of a sheet of paper. [2.5]

(ii) Suppose that you are watching a movie 'Jurrasic park' from a DVD. The information is stored on a DVD in a coded pattern of tiny pits. The pits are arranged in a track that spirals outward towards the rim of the disc. As the disc spins inside a player, the track is scanned at a constant linear speed. Will the rotation speed of the disc increase or decrease as the player's scanning head moves over the track? Give reasons. [2.5]

(b) (i) Two bodies made of the same material have the same external dimensions and appearance, but one is solid and the other is hollow. When their temperature is increased, is the overall volume expansion the same or different? Give reasons. [2.5]

(ii) A block of wood and a block of iron are at the same temperature. A person touches the blocks. When the blocks feel cold, the iron block feels colder than the wood; when the blocks feel hot, the metal block feels hotter than the wood. Explain. At what temperature will the blocks feel equally cold or hot? [2.5]

(c) (i) If you walk directly towards a plane mirror at a speed u, at what speed does your image approach you? [2.5]

(ii) Does the apparent depth of a tank of water change if viewed obliquely? If so, does the apparent depth increase or decrease? [2.5]

(d) (i) During lightning you are safer inside a house than under a tree? Why? [2.5]

(ii) Why metals cannot be used as a dielectric in a capacitor? [2.5]

(e) (i) Electrons are continuously in motion within a conductor, but there is no current in it, unless some source of potential is applied across its ends. Explain briefly with reasons. [2.5]

(ii) Water boils in an electric-kettle in 15 minutes after being switched on. Using the same mains supply, should the length of the heating element be increased or decreased if the same quantity of water is to boil in 10 minutes? Why? [2.5]

Question 2

(a) There is a point on the line joining the centers of the earth and moon, where the gravitational forces add to zero. (i) Determine the location of this point. (ii) With what speed would a body have to be launched at the surface of the earth in order to just reach this point with zero velocity? (iii) If a body is given a velocity just slightly greater than that found in (ii), what is its speed just as it reaches the surface of the moon? [12.5]

(b) On an inclined plane of 30° a block, mass m_2 = 4 kg, is joined by a light cord to a solid cylinder, mass m_1 = 8 kg, radius r = 5 cm (Fig.1). Find the acceleration if the bodies are released. The coefficient of friction between the block and the inclined plane μ = 0.2. You may assume that the moment of inertia (I) of the solid cylinder about its center is given by, $I = (1/2)\, m_1 r^2$. Friction at the bearing and rolling friction are negligible. [12.5]

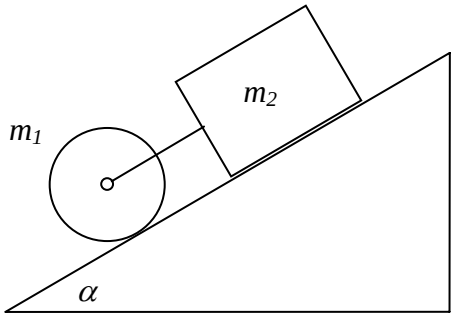


Fig. 1

Question 3

(a) In a solar water heater, energy from the sun is gathered by a rooftop collector, which circulates water through tubes in the collector. The solar radiation enters the collector through a transparent cover and warms the water in the tubes; this water is pumped into a holding tank. Assuming that the efficiency of the overall system is 20%, (80% of the incident solar energy is lost from the system), what collector area is necessary to raise the temperature of 100 liters of water in the tank from 25 to 40^0 C in 2.0 hour? The intensity of incident sunlight is 700 W/m^2. (Specific heat capacity of water =4200 J kg^{-1} K^{-1}. You may assume that the density of water =1 g/cm^3) . [12.5]

(b) A ray of light AB (Fig. 2) is incident at an angle *i* on face of prism LMN and is refracted along BC. This ray, after refraction at face LN travels along CN at grazing emergence. If θ is angle of the prism, show that the refractive index of the material of prism is given by, $n = \sqrt{1+\left(\frac{\sin i + \cos\theta}{\sin\theta}\right)^2}$. [12.5]

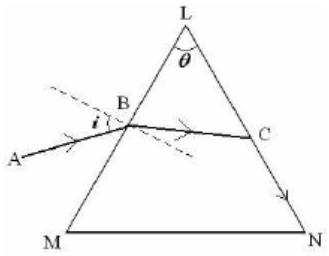
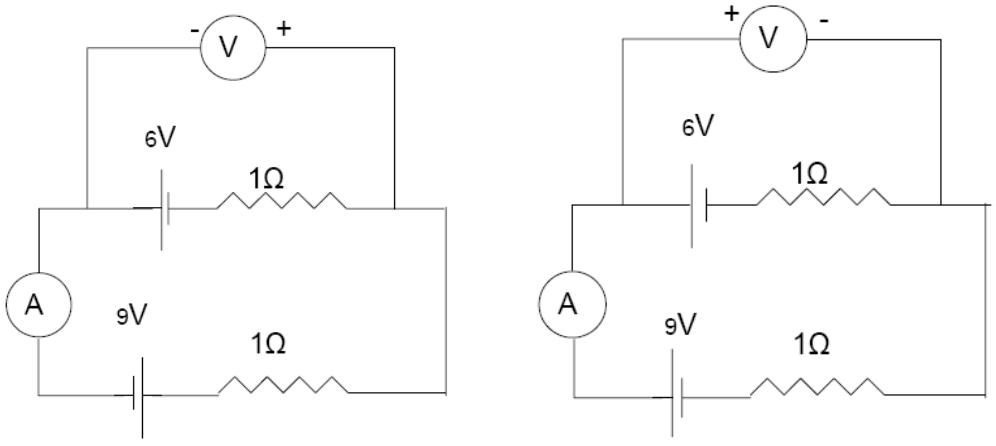


Fig. 2

Question4

(a) Two identical charged spheres are suspended in air by strings of equal lengths and make an angle of 30^0 with each other. When suspended in liquid of density 0.8 g/cm^3, the angle remains the same. What is the dielectric constant of the liquid? (Density of the material of the spheres =1.6 g/cm^3). [12.5]

(b) Consider an ideal ammeter A and an ideal voltmeter V in the following circuits (Fig. 3 (i) and (ii)). The connections with the circuit elements are as shown. Both the meters have zero in the middle. Redraw the circuit diagrams. Label the polarity of the ammeter and indicate the readings of the voltmeter and ammeter in each case. [12.5]



(i) (ii)

Fig. 3

GOOD LUCK!!!