National Physics Olympiad, Nepal, 2010

(Pre-selection Test, 2010)

Saturday, March 06, 2010
Time: 3 Hours
Full Marks: 100

Answer all questions, giving appropriate reasons for your answer in each.

Marks for each question or a part of a question are 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.

1 (a) (i) Calculate the density in kg/m^3 of a spherical body of mass 15.0 gm and radius 12 mm. Round off your answer to the appropriate significant figures. (2.5)

(ii) A bucket with holes in the bottom is attached to the end of a rope and water is continuously poured into the bucket. The bucket is displaced from its equilibrium and the system swings as a pendulum. Explain how the swinging motion changes as water leaks out from the bottom of the bucket. (2.5)

(b) (i) The same amount of heat is transferred to two identical rectangular blocks. One of the blocks lies on a heat insulating plate, while the other one hangs from a heat insulating thread. After a short time has elapsed, explain which one of the blocks is at higher temperature. (2.5)

(ii) A heat insulating vessel is divided in two parts of equal volumes by a heat conducting fixed partition. One part of the vessel is filled with one mole of $^{20}Ne_{10}$, and the other is filled with one mole of $^{4}He_{2}$. At the initial moment, root mean squared speed of Ne atoms is two times greater than that of He atoms. Find the ratio of He pressure to Ne pressure at the state of thermal equilibrium. (2.5)

(c) (i) A short sighted person reading notice on a notice board takes his glasses off and looks at the notice through it. Explain how the size of the image changes as he moves the glass further and further from his eyes. (2.5)

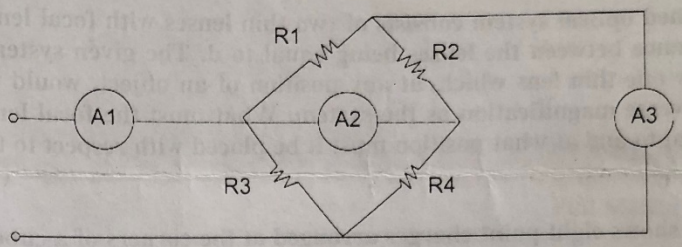
(ii) Is there any dispersion of white light refracted through a rectangular glass slab? Explain. Would you expect a beam of white light to disperse on passing through a hollow prism made of thin glass? Explain. (1.25+1.25)

(d) (i) What do you mean by equipotential surface? Can two different equipotential surfaces of a charge intersect? Explain. (2.5)

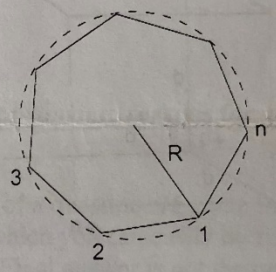
(ii) A 4-μF capacitor and an 8- μF capacitor are connected in series to a source of emf E volts. Which has the greater amount of stored energy? What if the capacitors are connected in parallel? Explain. (2.5)

(e) (i) A constant electric field is maintained inside a piece of semiconductor. What happens to the current density in the semiconductor if its temperature is lowered? How does the behaviour of the current density change if the semiconductor is replaced by a metal ? (2.5)

(ii) Three identical ammeters are connected in a bridge circuit as shown in figure. What are the readings of A1 and A2 provided that resistance of resistors are R1=R2=R, R3=R4=2R. (2.5)



2 (a) Point particles each of mass m are at rest in the corners of a regular n-sided polygon. How does the system of particles move if the only force acting between them is gravity? How much time elapses before the bodies collide if n=2, 3 and 10? Estimate the time in the case when n is very very large number. (m=M0/n; M0 is the given total mass). (12.5)



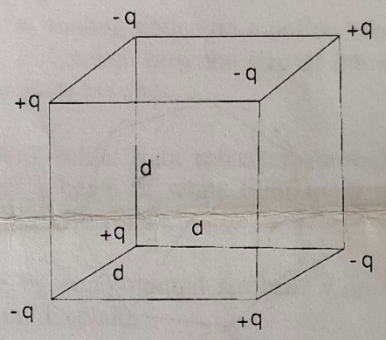
(b) (I) A particle of mass m1 experienced a perfectly elastic collision with a stationary particle of mass m2. What fraction of the kinetic energy does the striking particle lose, if(i) it recoils at right angles to its original direction of motion; (ii) the collision is a head-on one? (7.5)

(II) What is the minimum work that has to be performed to bring a spaceship of mass $m=2.0X10^3$ kg from the surface of the Earth to the Moon? (5)

3(a) A solid cylindrical copper rod 0.20 m long has one end maintained at a temperature of 20.00 K. The other end is blackened and exposed to thermal radiation from surrounding walls at 500 K. The sides of the rod are insulated, so no energy is lost or gained except at the ends of the rod. When steady state is reached, what is the temperature of the blackened end? (Thermal conductivity (K)= 1670 W/m K, □=$5.67X10^{-8}W/m^2 K^4$)). (12.5)

(b) An aligned optical system consists of two thin lenses with focal lengths f1 and f2, the distance between the lenses being equal to d. The given system has to be replaced by one thin lens which, at any position of an object, would provide the same transverse magnification as the system. What must the focal length of thin lens be equal to and at what position must it be placed with respect to the two lens system? (12.5)

4(a) Figure shows eight point charges arranged at the corners of a cube with sides of length d. The values of the charges are as shown in figure. This could serve as a simplified model of unit cell of a cubic ionic crystal where positive and negative charges are placed alternatingly. (i) Calculate the potential energy, U, of this arrangement. (b) Use your results to explain the stability of such ionic crystals. (12.5)



(b) A three-way light bulb has three brightness settings (low, medium and high), but only two filaments. (a) A particular three-way light bulb connected across a 220 V line can dissipate 60W, 120W or 180 W. Describe how the two filaments are arranged by drawing appropriate circuit diagram in the bulb, and calculate the resistance of each filament. (b) Suppose the filament with the higher resistance burns out. How much power will the bulb dissipate on each of the three brightness settings? What will be the brightness (low, medium or high) on each setting? (c) Repeat (b) for situation where it is the filament with the lower resistance that burns out. (12.5)