National Physics Olympiad, Nepal, 2011

(Pre-selection test, 2011)

Saturday, 12 February, 2011
Time: 3 hours + 15 minute
Full marks: 100

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

Marks 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.

Question 1 : Give reasons for each answer.

(A) (i) A car is driven up a steep hill at constant speed. Discuss all the forces acting on the car. What pushes it up the hill? Explain. (1.25+1.25)
(ii) Suppose an astronaut landed on a planet where g= 19.6 m/s^2. Compared to earth, would it require more or equal or less energy for him to walk around? Would it be easier or harder or just as easy for him to catch a ball that is moving horizontally at 12 m/s? Explain. (1.25+1.25)

(B) (i) You take a block of ice at 0° C and add heat to it at a steady rate. After a time t, the block of ice has been converted completely to steam at 100° C. At time t/2, what is the phase? (2.50)
(ii) A brass rod is 185 cm long and 1.60 cm in diameter. What force must be applied to each end of the rod to prevent it from contracting when it is cooled from 120° C to 10° C? (Coefficient of linear expansion of Brass =$2.0X10^{-5}$ K^{-1} and Young's modulus of Brass = $9.0X10^{10}$ N/m^2.) (2.50)

(C) (i) Devise a system using minimum number of plane mirrors that will let you see the back of your head. Trace the rays to illustrate your answer. (2.50)
(ii) A spherical air bubble in water can behave as a lens. Is it a converging or diverging lens? How is its focal length related to its radius? Explain. (2.50)

(D) (i) All particles having mass are gravitationally attracted toward the earth. As a result, the sediment settles to the bottom of the river. Do free electrons in a metal settle to the bottom of the conductor? Explain. (2.50)
(ii) Two equal point charges exert equal and opposite forces on each other. But if one charge is twice the other, do they still exert equal forces on each other or does one exert twice the force than the other? Explain. (2.50)

(E) (i) If the filament of an electric bulb burns out, it does so mostly when you just turn on the light and rarely when it is shining. Explain. (2.50)
(ii) Two batteries of 3V and 5V, having an internal resistance of 0.1Ω and 1Ω respectively, are connected in parallel and the combination is connected to a 15Ω load resistance. Determine the current drawn from each battery. (2.50)

Question 2

(A) The potential energy of a particle in a certain one-dimensional field has the form $U(r)=a/r^2 - b/r$, where *a* and *b* are positive constants, *r* is the distance from the center of the field. Find: (i) the value of r_0 corresponding to the equilibrium position of the particle; examine whether this a position of stable equilibrium; (ii) the maximum magnitude of the attraction force; sketch U(r) and F(r), where F(r) is the force. (12.5)

(B) (i) A projectile is thrown from a point P. It moves in such a way that its distance from P is always increasing. Find the maximum angle above the horizontal with which the projectile could have been thrown. (Ignore air resistance.) (5.0)
(ii) A ball is hanging from a long string that is tied to the ceiling of a train car that is travelling eastward on horizontal tracks and speeding up. An observer inside the train car sees the ball hang motionless. Draw a clearly labelled free-body diagram for the ball. Is the net force on the ball zero? Explain. (7.5)

Question 3

(A) (i) You are designing an electronic circuit element made of 25 mg of silicon. The electric current through it adds energy at the rate of 7.5 mW. If your design allows heat transfer of 2.5 mW out of the element, at what rate does its temperature increase? (Specific heat of silicon = 700 J/Kg-K). (5.0)

(ii) The surface of the sun has a temperature of 5800 K and consists largely of hydrogen atoms. (a) Find the root mean squared speed of a hydrogen atom at this temperature (the mass of a hydrogen atom is $1.67X10^{-27}$ kg). (b) Can appreciable amount of hydrogen escape from the sun? Can any hydrogen escape? Explain. (You may need the following data: Mass of the sun (M) = $2X10^{30}$ kg; Gravitational constant (G) = $6.674X10^{-11}$ Nm^2/kg^2; Radius of the sun (R) = $6.96X10^8$ m). (7.5)

(B) (i) A man standing on the edge of a swimming pool looks at a stone lying on the bottom. The depth of the swimming pool is equal to *h*. At what distance from the surface of water is the image of the stone formed if the line of vision makes an angle θ with the normal to the surface? (5.0)

(ii) a) For a lens with focal length *f*, find the smallest distance possible between the object and its real image. b) Sketch the distance between the object and real image as a function of the distance of the object from the lens. (7.5)

Question 4

(A) (i) A point charge q is located at the center of a thin ring of radius R with uniformly distributed charge –q. Find the magnitude of the electric field strength at the point lying on the axis of the ring at a distance x from its center, if x>>R. (6.5)

(ii) Two concentric spherical conducting thin shells are separated by a medium of dielectric constant K. The inner shell has total charge +Q and radius r_a and the outer shell has charge –Q and radius r_b. Find the capacitance of this spherical capacitor. (6.0)

(B) (i) The gap between the plates of a parallel-plate capacitor is filled up with an inhomogeneous poorly conducting medium whose conductivity varies linearly in the direction perpendicular to the plates from $\sigma 1 = 1.0X10^{-12}$ $(\Omega m)^{-1}$ to $\sigma 2 = 2.0X10^{-12}$ $(\Omega m)^{-1}$. Each plate has an area A= 230 cm^2 and the separation between the plates is d = 1.0 mm. Find the current flowing through the capacitor due to a potential difference of 300 V. (7.5)

(ii) Two identical light bulbs are to be connected to a source with E=8V and negligible internal resistance. Each light bulb has a resistance R = 2Ω. Find the current through each bulb, the potential difference across each bulb, and the power delivered to each bulb and to the entire network if the bulbs are connected a) in series b) in parallel. c) Suppose one of the bulbs burns out, that is its filament breaks and current can no longer flow through it. What happens to the other bulb in the series case? In the parallel case? (5.0)