Nepal Physics Olympiad

(Pre-selection Test for IPhO-43)

Saturday, December 10, 2011

Time: 3 hrs + 15 mins

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 question which you can easily do first and then come back to attempt seemingly difficult ones. Final answer is not only important step .Every correct step in your solution carries marks for the step. Originality in approach will be rewarded. You are advised to draw figures and sketches with proper labeling wherever necessary.

1. A (i) (a) If a rocket is in gravity free outer space has the same thrust at all times, is its acceleration constant, increasing or decreasing?

   (b) If the rocket has the same acceleration at all times, is the thrust constant, increasing or decreasing? Give reasons to your answers. (2.5)

(ii) If the mass of each members of a binary stars were the same as that of the Sun, and their distance apart were equal to the Sun – Earth distance, what would be their period of revolution? (2.5)

B. (i) Rank the following gases in order from highest to lowest rms speed of molecules (a)Oxygen (M = 32.0 g /mol) at 300 K ,(b) Nitrogen (M = 28.0 g/mol) at 300 K (iii) Oxygen at 330 K & (iv) Nitrogen at 330 K. (2.5)

(ii) A particular metal has a cubical expansion $6 \times 10^{-5}\ K^{-1}$, and ions are about 0.1 nm apart. What is the change in their mean separation when the temperature increases by 100 K? (2.5)

C. (i) Can a virtual image be photographed by exposing a film at the location of the image ? Explain. (2.5)

(ii) The water droplets on a green leaf have radius of curvature R and index of refraction 1.33.Can they form an image of the Sun on the leaf ? (2.5)

D. (i)The electrical potential at a point is given by $V = A + Bx + Cx^2$ where A, B and C are positive constants. Sketch the electric field E as a function of x. (2.5)

(ii) The inner surfaces of two close parallel insulating plates are each given a uniform charge of + Q. What force is required to hold the plates together? (2.5)

E. (i) You are given a large complex electrical circuit containing a lot of resistors and other passive elements and wishes to determine the resistance of a particular resistor in the circuit without unsoldering it (i.e. without taking it out of the circuit). A battery, an ammeter, a voltmeter and connecting wires of negligible resistances are given. How would you carry out the measurement? (2.5)

(ii)A solar cell generates a potential difference of 0.1 V when a 500 Ω resistor is connected across it and a potential difference of 0.15 V when a 1000 Ω resistor is substituted. What are (a) the internal resistance and (b) the emf of the solar cell? (2.5)

2. A (i) Consider the circular motion of an artificial satellite of mass m in orbit around the Earth (mass M) at a distance r from its centre.
   a) Derive the relation for the kinetic energy of the satellite in terms of mass m, M and r
   b) Derive a similar relation for the potential energy of the satellite in the gravitational field of the Earth.
   c) Hence write down the total energy of the satellite.
   d) Real satellite lose energy through various processes during orbit .Use your answer in(c)

to explain whether the satellite as it loses its energy ,will fall towards the Earth or fly away to greater distance. (6)

A(ii) In olden times people used to think that the Earth is flat .Imagine it is and estimate thickness (H) of the Earth to allow same g as on the surface of actual Earth which is assumed to be spherical. Take the density of the flat Earth to be equal to that of the spherical Earth.

Hints: You may use the analogy between gravitational and electrostatic fields, and consider the electric field strength of an infinitely large disc with homogeneous charge distribution. (6.5)

B (i) The compass of an aero-plane indicates that it is headed due North and its air speed indicator shows that it is moving through the air at 300Km/hr. If there is a wind of 100Km/hr from West to East. What is the velocity of the aero-plane relative to the Earth. In what direction should the pilot head to travel due North?. (4)

B(ii) In the film "Spiderman" a man has to climb up the corner formed by the intersection of two vertical perpendicular walls. (a) Draw a clearly labeled free body diagram for the spider-man. (b) Find the minimum force with which he had to push on the walls whilst climbing. (8.5)

3 A (i) In a cylinder sealed with a piston, you rapidly compress 3.00 L of N_2 gas initially at 1.00 atm. pressure and 0.00 ^{0}C to half of its original volume. Assume the N_2 behaves like an ideal gas (ratio of heat capacities = 1.4)

(a) Calculate the final temperature and pressure of the gas.
(b) If you now cool the gas back to 0.00 ^{0}C without changing the pressure, what is its final volume? (5)

A(ii) The steady rate of flow of the liquid is 20 gs^{-1} and the electric heating element dissipates 0.15KW.Under these conditions the outflow temperature of the liquid is 3.0 K higher than the inflow temperature. When the rate of flow is halved, the power required to maintain the same temperature difference is 81 W. Calculate

a. the specific heat of the liquid and
b. the power loss to the surroundings (7.5)

3 B The following is a set of measurements of angles made by a light beam with the normal in air and water respectively

Θ_a(in degrees)	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0
Θ_w (in degrees)	7.75	15.0	22.1	28.8	35.1	40.6	45.3	48.2

(a) Draw a graph of θ_a (y-axis) against θ_w .

(b) Draw another graph of $\text{Sin}\theta_a$ against $\text{Sin}\theta_w$ and comment.

(c) From your graph find the relative refractive index of water, and a value for the critical angle for these media.

(12.5)

4.A (i) Drops of impure water of radius 1.0 mm fall from a metal tube maintained at a potential of 50 V, and they fill a spherical conducting vessel of negligible thickness and radius 10 mm . Calculate

(a) the charge on each drop
(b) the total charge on the vessel when full
(c) the electric potential energy carried by each drop
(d) the electrostatic potential energy of the full vessel (6)

A(ii) Two horizontal metal plates each of area A separated by a distance d is used as a parallel plate capacitor. The lower half of the space between the plates is filled with material of dielectric constant k_1 and upper half with that of k_2 .Find the resulting capacitance. (6.5)

B (i) The uniform wire of a meter bridge has a resistance 10.0Ω, and is soldered at both ends. Known resistances of 4.0Ω and 6.0Ω are fitted into the arms, and give a balance point 390 mm from one end when the resistors are interchanged the new balance point is 610 mm from the same end. Calculate the resistances of the soldered contacts at the ends of the wire (Assume there are no other errors). (5)

B(ii) In the lower atmosphere of the Earth there are negative and positive ions created by radioactive elements in the soil and cosmic rays from space. In a certain region, the atmospheric electric field strength is 120 Vm^{-1} ,directed vertically downward .Due to this field, singly charged positive ions, 620 per cm^3 , drift downward and singly charged negative ions, 550 per cm^3, drift upward. The measured conductivity is $2.70 \times 10^{-14}\ \Omega^{-1}m^{=1.}$.
Assuming the same drift speed for positive and negative ions, calculate

(a) the ion drift speed
(b) the current density (7.5)

Electronic charge,e = 1.6×10^{-19}C

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