National Physics Olympiad, Nepal, 2013

(Pre-selection test, 2013)

Saturday, 12th January, 2013

Time: 3 hours + 15 minutes

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.

Q1A (I) An airplane's velocity is doubled. What happens to its momentum? Is the law of conservation of momentum obeyed? Explain. (2.5)

(II) A pendulum clock is in an elevator that descends at a constant velocity. Explain whether it keeps correct time. The same clock is in an elevator in free fall. Does it keep correct time? Explain. (2.5)

B(I) Gas molecules have velocities comparable with those of rifle bullets, yet we all know that a gas with a strong odour, such as chlorine, takes several seconds to diffuse through a room. Explain. (2.5)

(II) On a concrete road, how large should the expansion joints be between sections if each section is 15 m long? Consider temperature range of 0^0 C to 40^0 C and linear expansivity of concrete $\alpha = 12\times10^{-6}/\ ^0C$. (2.5)

C(I) The relative refractive indices for light of wavelengths 405 nm and 770 nm passing into vitreous silica are respectively 1.470 and 1.454. Calculate the speeds of the two wavelengths, and the difference of their speeds. What colours are represented by these wavelengths? [speed of light = 3.00×10^8 m s^{-1}] (2.5)

(II) You may have noticed the warnings "Objects in the mirror are closer than they appear" in the side view mirrors of vehicles. What feature of the mirror requires this warning? What is the advantage of using such a mirror? (2.5)

D(I) If the electric field of a point charge were proportional to $1/r^3$ instead of $1/r^2$, would Gauss law still be valid? Explain. (2.5)

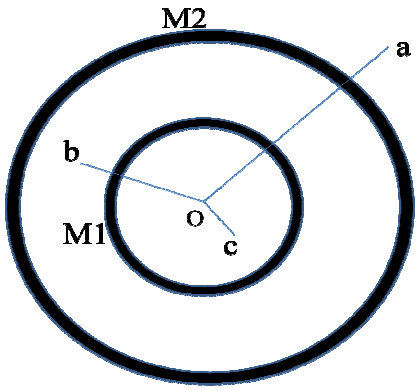
(II) If the electric field at a certain point is zero, does the electric potential at that point have to be zero? Explain. (2.5)

E(I) The energy that can be extracted from a storage battery is always less than the energy that goes into it while it is being charged. Explain. (2.5)

(II) Bends in a pipe slow down the flow of water through it. Do bends in a wire increase its electrical resistance? Explain. (2.5)

Q2A(I) A solid cylinder rolls from rest down an inclined plane 1.2 m high without slipping. What is its linear velocity at the foot of the plane? [acceleration due to gravity =10 m s^{-2}] (5.0)

(II) Two concentric spherical shells of uniform density having masses M1 and M2 are situated as shown in figure. Find the force on a particle of mass *m* when the particle is located at (i) *r* =a (ii) *r* = b (iii) *r* = c. The distance *r* is measured from the center (O) of the shells. (7.5)



B. Following table gives the position of a particle along the meter stick at different times.

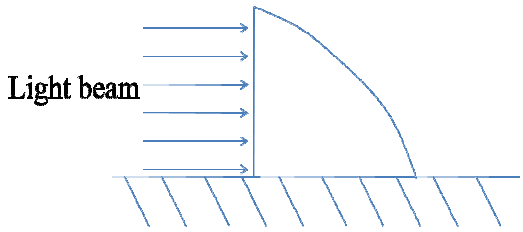
Time (t in sec)	0	5	10	15	20	25	30	35	40	45	50	55	60
Position (s in cm)	0.0	4.1	7.9	12.1	16.0	16.0	16.0	18.0	20.1	21.9	24.0	22.1	20.0

(i).Draw position (*s*) versus time (*t*) graph. (ii) Prepare an appropriate table for velocity (*v*) and time (*t*) and plot the velocity (*v*)–time (*t*) graph. (iii) Also prepare an appropriate table for acceleration (*a*) and time (*t*) and plot the acceleration (*a*)-time (*t*) graph. (12.5)

3A(I) An accurate thermometer of heat capacity 20 J/K reads 18.0 ^{0}C. It is then placed in 0.25 kg of water and both reach the same final temperature of 50.0 ^{0}C as recorded by the thermometer. Assuming that there are no other heat exchanges, calculate the temperature of the water before the thermometer was placed in it. Point out the significance of your result. [specific heat capacity of water = 4200 J kg^{-1} K^{-1}] (5.0)

A(II) In the troposphere, the part of the atmosphere that extends from earth's surface to an altitude of about 11 km, the temperature is not uniform but decreases with increasing elevation. Show that if the temperature variation is approximated by the linear relationship $T = T_0 - \alpha y$, where T_0 is the temperature at the earth's surface and T is the temperature at height *y*, the pressure *p* at height *y* is given by; $\ln(p/p_0) = (Mg/\alpha R) \ln((T_0 - \alpha y)/T_0)$, where p_0 is the pressure at the earth's surface and M is molar mass of air. (7.5)

B(I) A glass prism with a shape of a quarter cylinder lies on a horizontal table. Its vertical plane surface is lit by a uniform, horizontal light beam as shown in figure. Where can a light patch be seen on the table after the cylinder if the radius of the cylinder is R= 5 cm and the refractive index of its material is n =1.5? (5.0)



B(II) A luminous point is moving at speed v_o towards a spherical mirror with radius of curvature *r*, along the central axis of the mirror. Show that the image of this point is moving at speed $v_i = -\left(\frac{r}{2u-r}\right)^2 v_o$, where u is the distance of the luminous point from the mirror at any given time. (7.5)

4A(I) In one design of capacitor thin sheets of metal of area 80 mm × 80 mm sandwich between ×them a piece of paper whose thickness is 40 µm. The relative permittivity of the paper is 4.0 and its dielectric strength is 20 MV m^{-1}. Calculate (i) its capacitance (ii) the maximum potential difference which could be applied to it. [permittivity of free space = 8.85×10^{-12} F m^{-1}] (5.0)

A(II) Two spherical spheres of lead of mass 6.0 kg lie with their centers 1.0 m apart. They are each given a charge Q (which may be assumed to be distributed with spherical symmetry) such that each exerts a zero resultant force on the other. (i) What is their mutual gravitational attraction? (ii) What is the value of Q? (iii) How many electrons should be removed from each sphere to achieve this result? [G= 6.67×10^{-11} N m^2 kg^{-2} and e = 1.6×10^{-19} C] (7.5)

B(I) Two batteries in parallel, one of emf 6 V and internal resistance 0.5 Ω and the other of emf 8 V and internal resistance 0.6 Ω are connected to an external 10 Ω resistor. Draw the circuit diagram. Find (i) the current drawn from each battery and (ii) the power dissipated in the external resistor. (5.0)

B(II) You are given a number of 10 Ω resistors each capable of dissipating only 1.0 W without being destroyed. What is the minimum number of such resistors that you need to combine in series or parallel combinations to a 10 Ω resistor that is capable of dissipating at least 5.0 W? Draw the circuit diagram showing the arrangement you propose to achieve the above result. (7.5)