Short questions

Q1. A a) The acceleration a_x of a body increases linearly with time t. Sketch the nature of the velocity v_x versus time t graph. (2.5)

b) The potential energy of a pair of hydrogen atoms separated by a distance x is given by $U(x) = -C_o/x^6$ where C_o is a positive constant. What is the force that one atom exerts on the other? (2.5)

Q1.B a) A quantity of ideal gas undergoes an expansion that increases its volume from V_1 to $V_2 = 3\,V_1$. The final pressure of the gas is P_2. What is the work done by the gas if the expansion is i) isobaric ii) isothermal? (2.5)

b) You design an engine that takes 2.5×10^4 J of heat at 650 K in each cycle and rejects heat at a temperature of 350 K. The engine completes 240 cycles in 1 minute. What is the maximum power output of your engine? (2.5)

Q1.C a) A glass plate 2.00 mm thick, with an index of refraction 1.50 is placed between a screen and a point source of light with wavelength 475.0 nm. If the distance between the source and the screen is 1.80 cm, how many wavelengths are there between them? (2.5)

b) A horizontal ray of light passes through a prism of refractive index 1.50 and apex angle 3° and then strikes a vertical mirror as shown in Fig.1.Through what angle must the mirror be rotated if after reflection the ray is to be horizontal. (2.5)

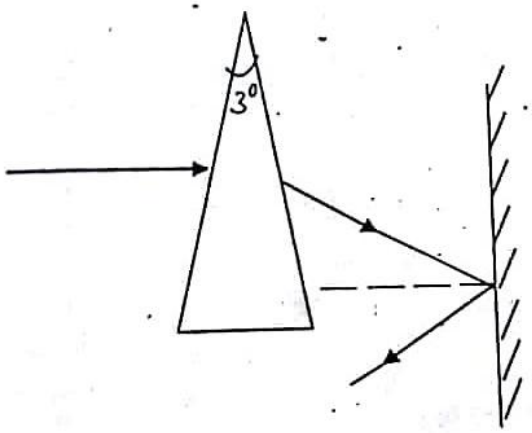

Fig.1

Q1.D a) A certain charge Q is divided into two parts q and (Q-q). How are the charges Q and q related f q and (Q-q) to experience maximum electrostatic force of repulsion when placed at a certain distance apart. (2

b) An infinite number of charges each equal to q are placed along the x- axis at x=1, x=2, x=4 x=8, x=16 .....units and so on. Find the potential at the point x=0 due t set of charges. (2.5

Q1.E a) A copper wire of diameter d carries a constant current I. What is the effect of doubling the diameter of the wire on drift velocity of the charge carriers in it, if the current remains the same? (2.5)

b) Two 220-V light bulbs one 25 W and one 200 W are connected in series across a 360- V line. Which of the two bulbs is likely to burn out? (2.5)

Long questions

Q2.A a) Fish can inflate themselves using a sac (called swim bladder) located under their spinal column. This sac can be filled with oxygen-nitrogen mixture that comes from the blood. In an aquarium, it is observed that fish are able to remain at any depth in water. i) What this observation tells you about the density of the fish? ii) If a 2.75 kg fish in fresh water inflates itself and increases its volume by 10%, find the force exerted by the water on the fish. iii) What is the net force on the fish? Your answer should include a free-body diagram showing all the forces acting on the fish (5)

b) Suppose a spacecraft of mass m_0 and cross-sectional area A is coasting with velocity v_0 when it encounters a stationary dust cloud of density ρ. Solve for the subsequent motion of the spacecraft assuming that the dust sticks to its surface and that A is constant over the time. (7.5)

Q2.B a) A small particle rests on top of a frictionless sphere. The particle is given an infinitesimal kick and slides downward. At what point does it lose contact with the sphere. (5)

b) A firecracker placed inside a coconut shell of mass M, initially at rest on a frictionless floor, blows the coconut into three pieces that slide across the floor. The third piece of mass $m_3 = 0.30M$ moves with final speed $v_{f3} = 5.0\ ms^{-1}$. The first piece has mass $m_1 = 0.50M$. The first piece moves at an angle 100° from the third and the second mass moves at 130° both from the third and the first mass.

i) Draw a sketch for the situation showing the velocities. ii) Find the speed of m_2. iii) Find the speed of m_1 (7.5)

Q3. A a) A mono-atomic ideal gas that is initially at a pressure of 1.5×10^5 Pa and has a volume of 0.0800 m^3 is compressed adiabatically to a volume of 0.0400 m^3. i) What is the final pressure? (b) How much work is done by the gas? (c) What is the ratio of the final temperature of the gas to its initial temperature? Is the gas heated or cooled by this compression? (5)

b) A frictionless piston of mass m is a precise fit in the vertical cylindrical neck of a large container of volume V. The container is filled with a gas and there is a vacuum above the piston. The cross-sectional area of the neck is A.

i) Calculate the pressure of the gas in the container when the piston is in equilibrium.

ii) Assuming that the pressure and volume of the gas is related by Boyle's law, calculate the restoring force on the piston when it is displaced by a small distance x.

iii) Assuming that the motion of the piston is slow enough for Boyle's law to be valid, obtain the differential equation for small displacement of the piston about its equilibrium position.

iv) Obtain an expression for the angular frequency of oscillation ω.

v) Calculate ω for V= 2000.0 liters and A= 1.0×10^{-4} m^2 (7.5)

Q3.B a) An object is placed at a distance 20.0 cm in front of a convex lens. The image is formed on the same side as the object at a distance of 30.0 cm from the lens.

i) Draw a ray diagram.
ii) Write the nature and size of the image
iii) Find the focal length of the lens
iv) The error in measurement of the object distance u and image distance v is ±0.1 cm in each case. Calculate the error in the focal length. (5)

b) The dependence of refractive index μ on the material of the lens and the color of light is given below:

	μ_{blue}	μ_{red}	μ_{yellow} (mean)
Crown glass	1.521	1.510	1.517
Flint glass	1.665	1.645	1.655

You a given equiconvex lens of a crown glass of radius of curvature 30.0 cm.

i) Find the focal length and dispersive power of this lens.
ii) It is desired to make an achromatic combination using the above lens. State the type of the glass needed for the second lens.
iii) What would be the focal length of the second lens?
iv) Find the radii of curvature of the second lens provided the lenses are in perfect contact, without any air gap between them.
v) Sketch the combination.
vi) Calculate the effective focal length of the combination. (7.5)

Q4. A a) A charge of 28.0 nC is placed in a uniform electric field that is directed vertically upwards and has a magnitude of 4.00×10^{4} Vm^{-1}. What work is done by the electric force when the charge moves,

i) 0.450 m to the right?
ii) 0.670 m upward?
iii) 2.60 m at an angle of 45° downward from the horizontal? (5)

b) In the circuit shown in Fig.2 E_1 =3.0 V, E_2=2.0 V, E_3=1.0 V and r= r_1 = r_2= r_3= 1Ω

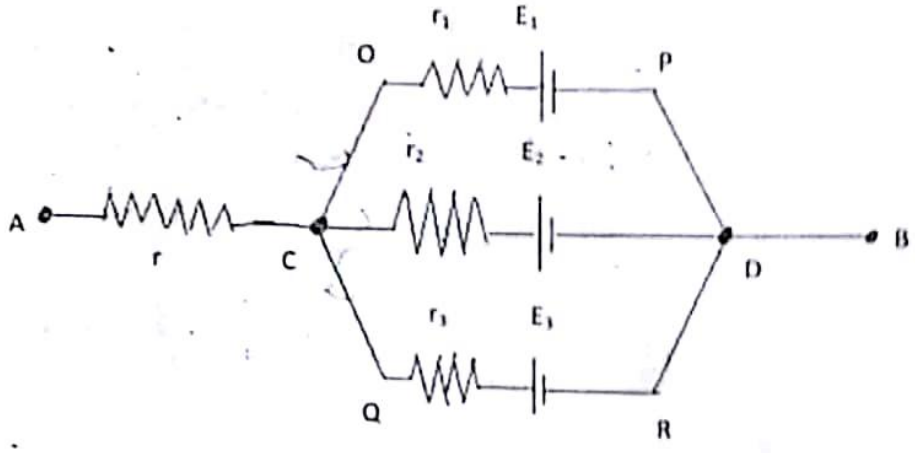

Fig.2

i) Find the potential difference between the point A and B and the current through each branch.
ii) If r_2 is short circuited and the point A is connected to point B. Find the currents through E_1, E_2, E3 and the resistor r.

(7.5)

Q4. B The voltage V across a charged capacitor is found to decay with time according to the relation

$$V = \alpha \exp(-t/T)$$

where, α and T are constants.

i) How would you modify the relation to obtain a straight line for the dependence of V on t
The table below gives an experimental data for V and t

t/sec	0.0	1.0	2.0	3.0	4.0	5.0	6.0
V/volt	4.3	2.8	1.8	1.2	0.8	0.5	0.3

ii) Copy the table and include the processed data to obtain a single line graph
iii) Plot the process data and fit to a straight line
iv) Estimate the value of α and T from your graph

(12.5)