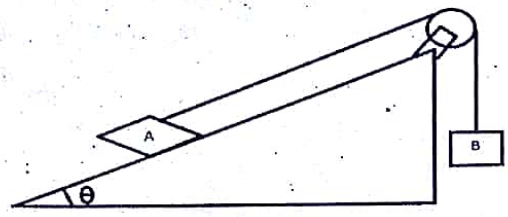
Q1. 12.5

Body A in figure weighs 102 N and body B weighs 32 N. The coefficients of friction between A and the incline are $\mu_s = 0.56$ and $\mu_k = 0.25$. Angle θ is 40^0. Sketch the free body diagram and find the acceleration of A if it is initially (a) at rest, (b) moving up the incline, and (c) moving down the incline. ($g = 10\ m/s^2$)



Q2. 6.5

A. A body of mass m is moving in one dimension under the influence of a conservative force with a potential energy U(x).

(a) Show that the body, when displaced slightly from a point of stable equilibrium at $x = x_o$, will experience a restoring force proportional to its displacement, the force constant being $\left[\frac{d^2U(x)}{dx^2}\right]_{X=X_o}$.

(b) The potential energy is given by the expression $U(x) = \frac{-cx}{x^2+a^2}$, where c and a are positive constants.

i. Sketch this potential energy and the force resulting from it.

ii. Find the position of stable equilibrium.

iii. Calculate the angular frequency of small oscillations about this position.

B. A body of mass m_1 collides elastically with a stationary mass m_2. After the collision the bodies move making angles θ_1 and θ_2 with the original direction of m_1. Consider the events in the center of mass frame or otherwise.

(a) Find the relation between θ_1 and θ_2 when $m_1 = m_2$.

(b) If $m_1 > m_2$ what would be the maximum value of θ_1?

Your answer should include appropriate diagram/s in each case. 6.0

Q3.

A. A diffraction grating has 12000 rulings uniformly spaced over 25 mm. It is illuminated by yellow light from a sodium vapor lamp. This light contains two closely spaced emission lines (known as sodium doublet) of wavelengths 589.00 nm and 589.59 nm.

(a) At what angle does the first order maximum occurs on either side of the center of the diffraction pattern for the wave length 589.00 nm?

(b) Using the dispersion of the grating calculate the angular separation between the two lines in the first order.

(c) What is the least number of rulings a grating can have to be able to resolve the sodium doublet in the first order? 6.5

B. There is a small air bubble inside a glass cube of size 24 cm. When viewed from one of the vertical faces, the bubble appears to be at a distance 10 cm from it. When viewed from the opposite face, it appears at 6 cm from it. Find the position of the bubble and the refractive index of the glass. 6.0

Q4.

A. You kick a soccer ball, compressing it suddenly to 2/3 of its original volume. In the process, you do 450 J of work on the air (assumed to be an ideal gas) inside the ball.

(a) What is the change in the internal energy of the air inside the ball due to being compressed?

(b) Does the temperature of the air inside the ball rise or fall due to being compressed? 6.5

B. A physics student immerses one end of a copper rod in boiling water at 100° C and the other end in an ice –water mixture at 0° C. The sides of the rod are insulated. After steady state has been achieved in the rod, 0.175 kg of ice melts in a certain time interval. For this time interval, mixture; (c) the total energy change of the entire system. 6.0

Find a) Entropy change of the boiling water

b) Entropy change of ice water mixture

Q5.

A. Point charges $q_1 = -5.0$ nC and $q_2 = +5.0$ nC are separated by 3.2 mm forming an electric dipole.

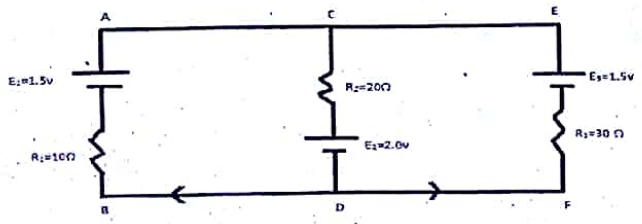
(a) Find its dipole moment. Is dipole a vector quantity?

(b) The dipole is located in a uniform electric field whose direction makes an angle 41.3° with the line connecting the charges. Draw a diagram and show the directions of the dipole, the electric field and the torque acting on the dipole.

(c) The torque exerted on the dipole is found to have a magnitude 4.5×10^{-9} Nm. Calculate the magnitude of the field.

(d) Calculate the potential energy of the dipole in the electric field. 6.0

B. In the circuit shown and with the values of emf of the batteries and resistances given, find the current flowing through R_1 and the potential difference across points CD. Neglect internal resistances of the batteries. 6.5



Q6.

A. The density of a stationary cubic body is equal to ρ_o. Find the velocity of an observer for whom the density of the body measures 20% more. How would your answer differ if the body is spherical in shape? 6.5

B. High energy cosmic rays interact with atoms in the atmosphere and create unstable particles called muons. A muon's mean life time in its rest frame is measured to be 2.20×10^{-6} s. Muons created in the upper atmosphere, typically at a height of 5.0 km from earth's surface, have been detected in labs.

(a) Assume a typical non-relativistic velocity 300 km/s for the muon and calculate the distance travelled by the muon before it decays. Is the muon detected on earth's surface relativistic or non-relativistic?

(b) Calculate the typical speed of muons detected on earth's surface. 6.0

Q7.

A. An electron is confined within a region of width 1.2×10^{-10} m.

(a) Estimate the uncertainty in the x-component of the momentum.

(b) Assume that the electron has momentum equal to the uncertainty found in part (a). What is its kinetic energy? Express the result in Joules and in electron-volt.

(c) A certain electron's kinetic energy is twice your answer in (b). Estimate the size of the box it is confined within.

[Given: $\hbar = 6.626 \times 10^{-34}$ J.s; $m_e = 9.109 \times 10^{-31}$ kg; $e = 1.6 \times 10^{-19}$ C] 6.5

B. A torsional wire of radius r and length l is fixed at one end and subjected to a couple of moment C at the other end. The angular displacement φ is given by

$$\varphi = \frac{2lc}{n\pi r^4}$$, where n is modulus of rigidity of the wire's material.

A measurement yields the following values:

$\frac{\varphi}{c} = 4.00 \pm 0.12$ rad.N^{-1}.m^{-1}.

r= 1.00 ± 0.02 mm.

l = 500 ±1 mm.

Calculate the values of n and the maximum permissible error. 6.0

Q8. 12.5

The dependence of refractive index (μ) of a prism on the wavelength (λ) of light is given by the expression

$$\mu = a + \frac{b}{\lambda^2}$$, where a and b are constants.

In an experiment the following results were obtained.

SN	Wavelength λ (nm)	Refractive Index μ
1	400	1.725
2	450	1.595
3	500	1.500
4	550	1.430
5	600	1.375
6	650	1.340

(a) Explain that μ vs λ^{-2} graph would give a straight line.

(b) Suitably complement the table.

(c) Plot a graph of μ vs λ^{-2}.

(d) From the graph find the values of a and b with proper units.