The University of Nottingham Ningbo China

Centre for English Language Education

Sample end-of-semester exam-solutions

Foundation Physics

Time allowed: **TWO HOURS**

Candidates may complete the front cover of the answer book and sign the attendance card.

Candidates must NOT start writing their answers until told to do so.

There are 6 Questions. Answer any FOUR Questions.
All questions are worth 25 marks.

No electronic devices except for approved calculators ***(e.g. Casio FX82 Series)*** *can be used in this exam.*

Dictionaries are not allowed with one exception: those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination.
Subject-specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries and mobile phones, may be used.

DO NOT turn the examination paper over until instructed to do so.

All answers must be written in the Answer Sheet

ADDITIONAL MATERIALS:
All students should be provided with a copy of the Foundation Physics Formula Sheet

INFORMATION FOR INVIGILATORS:

Please collect the examination paper and the answer booklets at the end of the exam.
A 15-minute warning should be announced before the end of the exam.

 Turn Over

Q.1 (25 Marks)

Answer each of the following questions.

(a) Define speed and velocity. Which of these quantities can be negative? [3 marks]

Speed is a scalar quantity and is defined as the rate of change in distance. (1)

Velocity is a vector quantity and is defined as the rate of change in displacement. (1)

Velocity can be negative because it has both magnitude and direction. (1)

(b) Define distance and displacement. Which of these quantities can be negative? [3 marks]

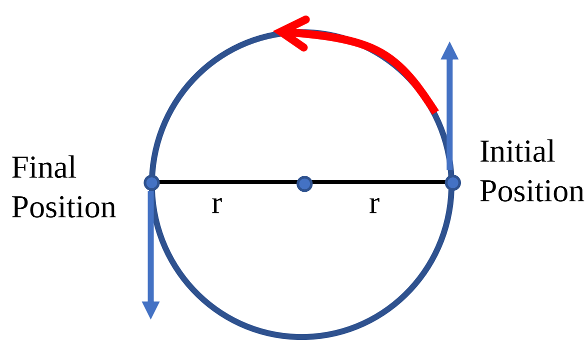
Distance is a scalar quantity and is the actual path length traveled by an object in the given interval of time during the motion. (1)

Displacement is a vector quantity and is the difference between the final and initial positions of the object in a given interval of time. (1)

Or

Displacement is the shortest distance from your initial position to your final position.

(c) An object moves in a circle with a radius of 3 m, as shown in the figure below. It takes the object 4 seconds to complete one revolution.



i. What is the average speed and the average velocity of the object after it completes one cycle/revolution? [4 marks]

$speed = \frac{\sum distance}{\sum time} = \frac{2\pi R}{t} = \frac{2 \times 3.14 \times 3\ m}{4s} = \frac{18.84\ m}{4\ s} = 4.71\ m/s$ (2)

$velocity = 0\ m/s\ (the\ final\ and\ initial\ displacement\ of\ the$ (1)

$$object\ is\ the\ same\ so\ \Delta x = 0\ m) \qquad (1)$$

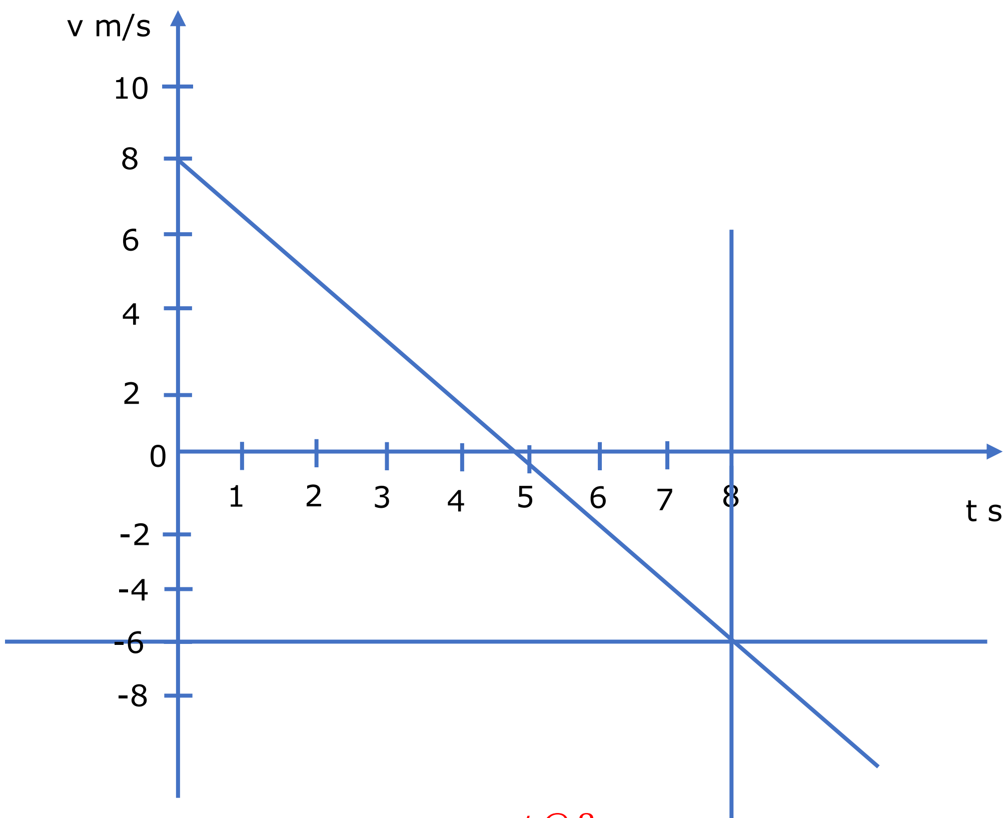
ii. What is the average speed and the average velocity of the object after it completes one-half or 0.5 cycle/revolution? [4 marks]

$$speed = \frac{\sum distance}{\sum time} = \frac{\frac{2\pi R}{2}}{t} = \frac{\frac{2\times 3.14\times 3\ m}{2}}{2\ s} = \frac{9.42\ m}{2\ s} = 4.71\ m/s \quad (2)$$

$$velocity = \frac{\sum dispalcement}{\sum time} = \frac{2(3)\ m}{2\ s} = 3\ m/s\ \ west \quad (2)$$

(d) The particle is at x = −10 m initially. Find d, s, x, v and a at t = 8 s. where: t is time (s), x is position, d is total distance travelled (m), s is displacement (m), v is velocity (m/s^2), and a is acceleration (m/s^2). [6 marks]

(1)



$$t\ @\ 8\ s$$

$$d = \frac{1}{2}\times 5\times 8 + \frac{1}{2}\times 3\times 6 = 29\ m \qquad (1)$$

$$s = \frac{1}{2}\times 5\times 8 - \frac{1}{2}\times 3\times 6 = 11\ m \quad (1)$$

$$x = -10 + 11 = 1\ m \quad (1)$$

$$v = -6\ m/s \quad (1)$$

$$a = \frac{v}{t} = -\frac{8}{5} = -1.6\ m/s^2 \quad (1)$$

(e) A marble is dropped from a height of 15 m above the ground, and at the same time a stone is projected vertically upwards from a height of 5 m above the ground. They pass each other after 1.0 s. Find the speed of projection of the stone. [5 marks]

Initially the marble is 10 m above the stone.

$$In\ 1.0\ s\ the\ marble\ has\ fallen\ s = ut + \frac{1}{2}at^2 = (0\ m/s)(1.0\ s) + \frac{1}{2}(9.81)(1.0\ s)^2 = 4.9\ m$$
(1)

$$the\ stone\ has\ risen\ 10 - 4.9 = 5.1\ m \quad (1)$$

$$s = ut + \frac{1}{2}at^2 = 5.1\ m = u(1.0\ s) + \frac{1}{2}(-9.81\ m/s^2)(1.0\ s)^2 \quad (1)$$

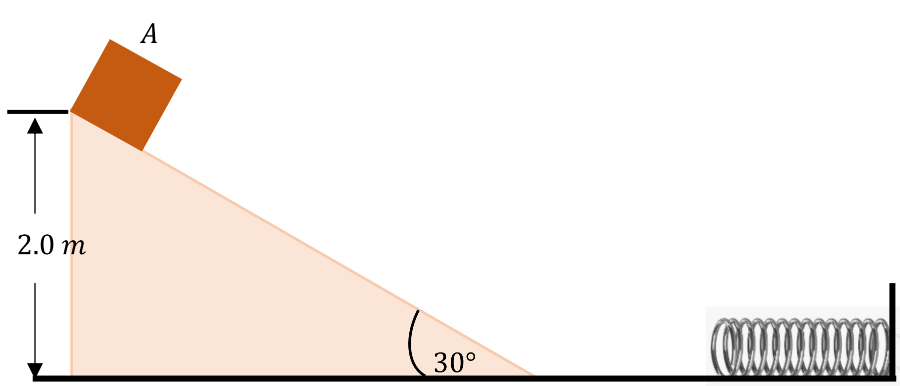
$$u = \frac{5.1\ m + \frac{1}{2}(9.81 m/s^2)(1.0\ s)^2}{(1.0\ s)} \quad (1)$$

$$u = +10\ m/s$$
$$speed = 10\ m/s \quad (1)$$

Q.2 (25 Marks)

Answer each of the following questions.

(a) An object of mass 10 kg is released at point A, slides to the bottom of the 30° incline starting from a height of 2 m above the spring, then collides with a horizontal massless spring, compressing it to a maximum distance of 0.75 m as shown below. The spring constant is 500 N/m, the height of the incline is 2.0 m, and the horizontal surface is frictionless.



i. What is the speed of the object at the bottom of the incline? [3 marks]

So, in the final point, both energies are the same, the kinetic and the elastic potential energy, which we express like this:

$$K_f = U_f$$

$$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \qquad (1)$$

$$mv^2 = kx^2$$

$$v = \sqrt{\frac{kx^2}{m}} \qquad (1)$$

$$v = \sqrt{\frac{(500)(0.75)^2}{10}}$$

$$v = 5.30\, m/s \qquad (1)$$

ii. What is the work of friction on the object while it is on the incline? [3 marks]

work due to friction is what slows down the mass, subtracting its potential energy from the initial point, giving as a result the final potential energy:

$$U_f = U_i - W_f$$

$$\frac{1}{2}kx^2 = mgh - W_f \qquad (1)$$

$$W_f = mgh - \frac{1}{2}kx^2$$

$$W_f = (10 \cdot 9.81 \cdot 2) - \frac{1}{2}(500 \cdot 0.75^2) \qquad (1)$$

$$W_f = 196.2 - 140.62$$

$$W_f = 55.57\, J \qquad (1)$$

iii. The spring recoils and sends the object back toward the incline. What is the speed of the object when it reaches the base of the incline? [2 marks]

As nothing slow the mass down because the trajectory is frictionless. The speed in the horizontal part is the same as:

$$v = \sqrt{\frac{(500)(0.75)^2}{10}} \qquad (1)$$

$$v = 5.30\, m/s \qquad (1)$$

iv. What distance does it move back up the incline? [2 marks]

$$d = \frac{2}{sin(30°)} \qquad (1)$$

$$d = 4\, m \qquad (1)$$

(b) In the cartoon movie Pocahontas runs to the edge of a cliff and jumps off, showcasing the fun side of her personality.

i. If she is running at 3.0 m/s before jumping off the cliff and she hits the water at the bottom of the cliff at 20.0 m/s, how high is the cliff? Assume negligible air drag in this cartoon. [4 marks]

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f$$

$$\frac{1}{2}v_i^2 + gh_i = \frac{1}{2}v_f^2 + gh_f \qquad (1)$$

$$\frac{1}{2}v_i^2 + gh_i = \frac{1}{2}v_f^2$$

$$v_i^2 + 2gh_i = v_f^2 \qquad (1)$$

$$h_i = \frac{v_f^2 - v_i^2}{2g}$$

$$h_i = \frac{(20)^2 - (3)^2}{2(9.81)} \ (1)$$

$$h_i = 19.9\, m \qquad (1)$$

ii. If she jumped off the same cliff from a standstill, how fast would she be falling right before she hit the water? [3 marks]

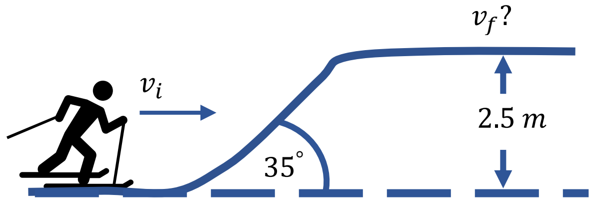
$$h_i = \frac{v_f^2 - v_i^2}{2g} \qquad (1)$$

$$19.9 = \frac{v_f^2 - 0}{2(9.81)} \qquad (1)$$

$$v_f = \sqrt{19.9 \cdot 2(9.81)}$$

$$v_f = 19.7\, m/s \qquad (1)$$

(c) A 60.0 kg skier with an initial speed of 12.0 m/s coasts up a 2.50 m high rise as shown below. Find her final speed at the top, given that the coefficient of friction between her skis and the snow is 0.80. [8 marks]



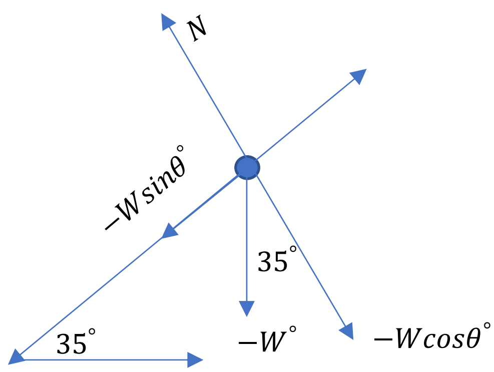
$W_{nc} = E_f - E_i$ (1)

$W_f = E_f - E_i$

$F_f \cdot d \cdot cos\theta = [PE_f + KE_f] - KE_i$ (1)

$F_f = \mu N$ $\quad PE = mgh$ $\quad KE = \frac{1}{2}mv^2$

Free body diagram of the object on the slope



(1)

$F_f = \mu_k mgcos\theta$ (0.5) $\quad d = \dfrac{2.5}{sin(35°)}$ (0.5)

$$(\mu_k mgcos\theta) \cdot \left(\frac{2.5}{sin(35°)}\right) \cdot cos(180°) = \left[(mgh)_f + \left(\frac{1}{2}mv^2\right)_f\right] - \left(\frac{1}{2}mv^2\right)_i \quad (1)$$

$$(\mu_k gcos\theta) \cdot \left(\frac{2.5}{sin(35°)}\right) \cdot cos(180°) = \left[(gh)_f + \left(\frac{1}{2}v^2\right)_f\right] - \left(\frac{1}{2}v^2\right)_i$$

$$v^2{}_f = \frac{\left(\frac{1}{2}v^2\right)_i - (gh)_f + (\mu_k gcos\theta) \cdot \left(\frac{2.5}{sin(35°)}\right) \cdot cos(180°)}{\frac{1}{2}} \quad (1)$$

$$v_f = \sqrt{\frac{\left(\frac{1}{2}v^2\right)_i - (gh)_f + (\mu_k g cos\theta)\cdot\left(\frac{2.5}{sin(35°)}\right)\cdot cos(180°)}{\frac{1}{2}}}$$

$$v_f = \sqrt{\frac{\left(\frac{1}{2}12^2\right)_i - (9.81\cdot 2.5)_f + (0.8\cdot 9.81\cdot cos35)\cdot\left(\frac{2.5}{sin(35°)}\right)\cdot cos(180°)}{\frac{1}{2}}} \quad (1)$$

$$v_f = 6.23\ m/s \qquad (1)$$

Q.3 (25 Marks)

Answer each of the following questions.

(a) A certain battery has a 12.0 V emf and an internal resistance of 0.10 Ω. What is the terminal voltage when connected to a 10.0 Ω load? [4 marks]

$$V = \varepsilon - Ir \quad (1)$$

$$IR = \varepsilon - Ir$$

$$IR + Ir = \varepsilon$$

$$I(R + r) = \varepsilon \quad (1)$$

$$I = \frac{\varepsilon}{(R + r)}$$

$$I = \frac{12.0\ V}{(10 + 0.1)\ \Omega}$$

$$I = \frac{12.0\ V}{10.1\ \Omega} = 1.188\ A \quad (1)$$

$$V = \varepsilon - Ir$$

$$V = 12.0\ \Omega - (1.188\ A)(0.1\ \Omega)$$

$$V = 11.9\ \mathrm{V} \quad (1)$$

(b) A filament lamp is operating at normal brightness. The potential difference across the lamp is 6.0 V. The current in the filament is 0.20 A. For the filament of this lamp, calculate:

i. the resistance. [2 marks]

$$R = \frac{V}{I} = \frac{6.0}{0.2} = 30\ \Omega \quad (2)$$

[1 mark for formula and 1 for final answer]

ii. the power dissipated. [2 marks]

$$P = VI = 6.0 \times 0.2 = 1.2\,W \quad (2)$$

[1 mark for formula and 1 for final answer]

(c) A resistor made from a metal oxide has a resistance of 1.5 Ω. The resistor is in the form of a cylinder of length 2.2 × 10⁻² m and radius 1.2 × 10⁻³ m. Calculate the resistivity of the metal oxide. [2 marks]

$R = \rho \frac{L}{A}$ *, where R is resistance, L is the length, A is the cross − sectional area and ρ is the resistivity of the material*

$$\rho = R\frac{A}{L} \quad (1)$$

$$\rho = \frac{(1.5 \times \pi(1.2 \times 10^{-3})^2)}{(2.2 \times 10^{-2})}$$

$$\rho = 3.1 \times 10^{-4}\ \Omega m \quad (1)$$

(d) A 500 Ω resistor, an uncharged 1.50 μF capacitor, and a 6.16 V emf are connected in series.

i. What is the initial current? [2 marks]

$$V = IR \quad (1)$$

$$I = \frac{V}{R} = \frac{6.16}{500}$$

$$I = 0.0123\,A \quad (1)$$

ii. What is the RC time constant? [2 marks]

$$\tau = RC \quad (1)$$

$$\tau = (500)(1.5 \times 10^{-6})$$

$$\tau = 7.50 \times 10^{-4} s \quad (1)$$

iii. What is the current after one time constant? [4 marks]

$$V_t = V_0 e^{\left(-\frac{t}{RC}\right)} \quad (1)$$

$$V = IR$$

$$I_t R_t = I_0 R_0 e^{\left(-\frac{t}{RC}\right)} \quad (1)$$

$$R_t = R_0$$

$$I_t = I_0 e^{\left(-\frac{t}{RC}\right)} \quad (1)$$

$$I_t = (0.0123\,A)e^{\left(-\frac{7.50\times10^{-4}s}{7.50\times10^{-4}s}\right)}$$

$$I_t = (0.0123\,A)e^{(-1)}$$

$$I_t = 4.52 \times 10^{-3} A \quad (1)$$

iv. What is the voltage on the capacitor after one time constant? [3 marks]

$$V_t = V_0 e^{\left(-\frac{t}{RC}\right)} \quad (1)$$
$$V_t = V_0 e^{\left(-\frac{7.50\times10^{-4}s}{7.50\times10^{-4}s}\right)}$$
$$V_t = V_0 e^{(-1)} \quad (1)$$
$$V_t = (6.16)e^{(-1)}$$

$$V_t = 2.26\,V \quad (1)$$

(e) ECG monitor must have an RC time constant less than 1.0 μs to be able to measure variations in voltage over small time intervals. If the resistance of the circuit (due mostly to that of the patient's chest) is 1.0 kΩ, what is the maximum capacitance of the circuit? [4 marks]

$$\tau = RC = 1\times10^{-6}s \quad (1)$$

$$R = 1000\,\Omega$$

$$C = \frac{1\times10^{-6}s}{1\times10^{3}\,\Omega} \quad (1)$$

$$C = \frac{\tau}{R} \quad (1)$$

$$C < 1\times10^{-9}F \quad (1)$$

Q.4 (25 Marks)

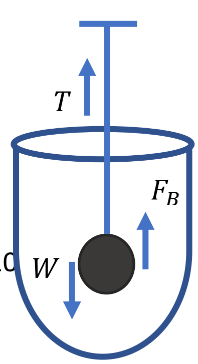
Answer each of the following questions.

(a) State Archimedes' principle and the State the law of floatation. [3 marks]

Archimedes principle states that when a body is wholly or partially immersed in a fluid, it experiences an up thrust, which is equal to the weight of the fluid displaced. (2)

A floating body displaces its own weight of the fluid in which it floats. (1)

(b) A ball bearing of mass 180 g is hung on a thread in oil of density 800 kg/m^3. Calculate the tension in the string if the density of the ball bearing is 8000 kg/m^3. [8 marks]



$$Volume\ of\ the\ ball\ bearing = \frac{mass\ f\ the\ ball\ bearing}{density\ f\ the\ ball\ bearing} \quad (1)$$

$$Volume\ of\ the\ ball\ bearing = \frac{0.180\ kg}{8000\ kg/m^3}$$

$$Volume\ of\ the\ ball\ bearing = 2.25\ \times 10^{-5} m^3$$

$$Volume\ of\ oil\ displaced = 2.25\ \times 10^{-5} m^3 \quad (1)$$

$$mass\ of\ oil\ displaced = volume \times Desnsity$$

$$mass\ of\ oil\ displaced = 2.25\ \times 10^{-5} m^3 \times 800 kg/m^3$$

$$mass\ of\ oil\ displaced = 0.018\ kg \quad (1)$$

$$Buoyancy\ force = mass\ of\ oil\ displaced \times g$$

$$Buoyancy\ force = 0.018\ kg \times 9.81\ m/s^2 \quad (1)$$

$$Buoyancy\ force = 1.77\ N\ (upward\ force) \quad (1)$$

$$Weight\ of\ ball\ bearing = 0.18\ kg \times 9.81\ m/s^2$$

$$Weight\ of\ ball\ bearing = 1.77\ N\ (downward\ force) \quad (1)$$

$$Tension = Weight - Bouyancy\ force$$

$$Tension = 1.77 - 0.177 \quad (1)$$

$$Tension = 1.6\ N \quad (1)$$

(c) A jet plane flying at 600 m/s experiences an acceleration of 4.0 g when pulling out of a circular dive. What is the radius of the curved path in which the plane is flying? [4 marks]

$$a = \frac{v^2}{r} \quad (1)$$

$$4.0\ g = \frac{(600)^2}{r}$$

$$4.0\ (9.81) = \frac{(600\ )^2}{r} \quad (1)$$

$$r = \frac{(600\ )^2}{4.0\ (9.81)} \quad (1)$$

$$r = 9174.3\ m \quad (1)$$

(d) A liquid of density 1.17×10^3 kg/m^3 flows steadily through a pipe of varying diameter and height. At location 1 along the pipe the flow speed is 9.47 m/s and the pipe diameter is 1.11 cm. At location 2 the pipe diameter is 1.77 cm. At location 1 the pipe is 9.45 m higher than it is at location 2. Ignoring viscosity, calculate the difference between the fluid pressure at location 2 and the fluid pressure at location 1. [10 marks]

$$\textit{From the equation of continuity:} \quad A_1 v_1 = A_2 v_2 \quad (1)$$

$$\textit{Where the Areas of the pipe :} \quad A_1 = \frac{\pi (d_1)^2}{4} \quad \textit{and} \quad A_2 = \frac{\pi (d_2)^2}{4} \quad (1)$$

$$v_2 = \left(\frac{A_1}{A_2}\right) v_1$$

$$v_2 = \left(\frac{\frac{\pi (d_1)^2}{4}}{\frac{\pi (d_1)^2}{4}}\right) v_1$$

$$v_2 = \frac{(d_1)^2}{(d_2)^2} v_1 = \left(\frac{d_1}{d_2}\right)^2 v_1 \quad (1)$$

$$\textit{Use Bernoulli's equation:}$$

$$P_2 + \rho g z_2 + \frac{1}{2}\rho v_2^2 = P_1 + \rho g z_1 + \frac{1}{2}\rho v_1^2 \quad (1)$$

$$(P_2 - P_1) + \rho g (z_2 - z_1) + \frac{1}{2}\rho (v_2^2 - v_1^2) = 0$$

$$(P_2 - P_1) = \rho g (z_1 - z_2) + \frac{1}{2}\rho \left(v_1^2 - \left(\frac{d_1}{d_2}\right)^4 v_1^2\right) \quad (2)$$

$$(P_2 - P_1) = \rho g (z_1 - z_2) + \frac{1}{2}\rho v_1^2 \left(1 - \left(\frac{d_1}{d_2}\right)^4\right) \quad (1)$$

$$(P_2 - P_1) = (1.17 \times 10^3)(9.81)(9.45) + \frac{1}{2}(1.17 \times 10^3)(9.47)^2 \left(1 - \left(\frac{1.11}{1.77}\right)^4\right) \quad (2)$$

$$(P_2 - P_1) = 1.53 \times 10^5\ Pa = 153\ kPa \quad (1)$$

Q.5 (25 Marks)

Answer each of the following questions.

(a) A ray of light is travelling from glass to air. The angle of incidence in the glass is 30^0 and angle of refraction in air is 60^0. What is the refractive index of glass w.r.t air? [3 marks]

Applying Snell's law

$$n_1 sin(\theta_1) = n_2 sin(\theta_2) \quad (1)$$
$$n_1 sin(30°) = 1 sin(60°) \quad (1)$$

$$n_1 = \frac{1 sin(60°)}{sin(30°)}$$

$$n_1 = 1.73 \quad (1)$$

(b) A water tank appears to be 4 m deep when viewed from the top. If the refractive index of water is 4/3, what is the actual depth of the tank? [5 marks]

$$n sin(i) = n sin(r) \quad (1)$$

$$n sin(i) = sin(r)$$

$$n = \frac{sin(r)}{sin(i)} \quad (1)$$

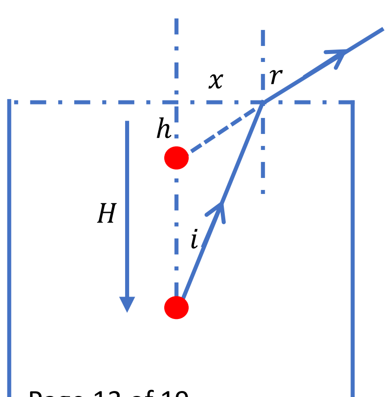
$$n = \frac{real\ depth}{apparent\ depth} = \frac{H}{h} \quad (1)$$

$$n = \frac{4}{3}$$

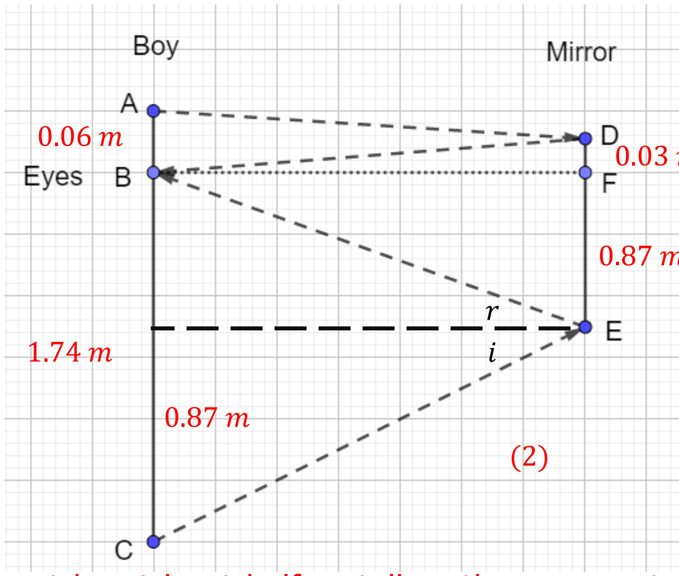
$$\frac{4}{3} = \frac{H}{4} \quad (1)$$

$$H = \frac{4 \times 4}{3}$$

$$H = 5.3\ m \quad (1)$$



(c) A boy 1.80 m tall stands in front of a plane mirror. What is the minimum height of the mirror, and how high must its lower edge be above the floor for the person to be able to see his whole body? The boy's eyes are 6.0 cm below the top of the head. [5 marks]

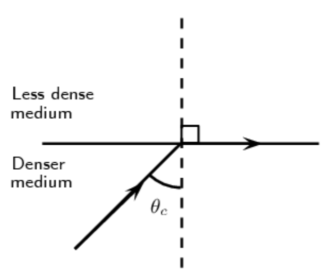


The mirror must be at least half as tall as the person standing in front of it. Since the person is 1.80 m tall, the vertical dimension of the mirror must be at least 0.9 m (1). The lower edge of the mirror must be at a height that is half the distance between his feet and eyes (1). Since the eyes are located 0.06 m from the top of his head which means it is at a height of 1.74 m from his feet, the lower edge of the mirror must be 0.87 m from the ground (1).

(d) Define critical angle and total internal reflection with diagram. [6 marks]

Critical angle

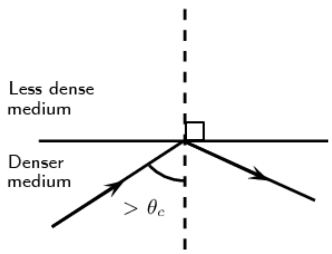
The critical angle is the angle of incidence where the angle of refraction is 90° (1). The light must travel from an optically denser medium to an optically less dense medium (1).



(1)

Turn Over

If the angle of incidence is bigger than this critical angle, the refracted ray will not emerge from the medium, but will be reflected back into the medium. This is called **total internal reflection**. (2)



(1)

(e) A beam of light is incident from air on the surface of a liquid. If the angle of incidence is 30^0 and the angle of refraction is 22^0, find the critical angle for the liquid when surrounded by air. [6 marks]

Using Snell's law, the index of refraction of the liquid is found to be:

$$n_{liquid} sin(\theta_r) = n_{air} sin(\theta_i) \quad (1)$$

$$n_{liquid} = \frac{n_{air} sin(\theta_i)}{sin(\theta_r)} \quad (1)$$

Thus, the critical angle for light going from this liquid into air is:

$$\theta_c = sin^{-1}\left(\frac{n_{air}}{n_{liquid}}\right) \quad (1)$$

$$\theta_c = sin^{-1}\left(\frac{n_{air}}{\frac{n_{air} sin(\theta_i)}{sin(\theta_r)}}\right) \quad (1)$$

$$\theta_c = sin^{-1}\left(\frac{sin(\theta_r)}{sin(\theta_i)}\right)$$

$$\theta_c = sin^{-1}\left(\frac{sin(22°)}{sin(30°)}\right) \quad (1)$$

$$\theta_c = 48.5° \quad (1)$$

Turn Over

Q.6 (25 Marks)

Answer each of the following questions.

(a) A hollow metal sphere with a diameter of 10 cm has a net charge of 4 μC distributed uniformly across its surface. What is the magnitude of the field a distance 2.0 m from the center of the sphere? [4 marks]

$$E = \frac{kq}{r^2}\ (electric\ field\ of\ point\ charge) \quad (1)$$

$$q = 4 \times 10^{-6}\ C$$

$$r = 2m + 0.05\ m = 2.05\ m$$

$$k = 8.91 \times 10^9\ \frac{Nm^2}{C^2}$$

$$E = \frac{\left(8.91\times10^9\ \frac{Nm^2}{C^2}\right)(4\times10^{-6}\ C)}{(2.05m)^2} \quad (1)$$

$$E = \frac{36000\ N}{4.2\ C}$$

$$E = 8.6 \times 10^3\ \frac{N}{C} \quad (2)$$

(b) Two infinite parallel conducting sheets each have positive charge density σ. What is the magnitude and direction of the electric field to the right sheet? [4 marks]

$$E = \frac{\sigma}{2\varepsilon_0}\ (electric\ field\ due\ to\ infinite\ plane) \quad (1)$$

Electric field is additive; in other words, the total electric field from the two planes is the sum of their individual fields:

$$E_{total} = E_1 + E_2 \quad (1)$$

$$E_{total} = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$E_{total} = \frac{\sigma}{\varepsilon_0} \quad (1)$$

The direction of the electric field is away from positive source charges. Thus, to the right of these positively charged planes, the field points away to the right. (1)

(c) A proton moves in a straight line for a distance of 5 m. Along this path, the electric field is uniform with a value of $2 \times 10^7 V/m$. Find the potential difference created by the movement. [4 marks]

Potential difference is given by the change in voltage

$$V_a - V_b = \frac{W}{q} \quad (1)$$

Work done by an electric field is equal to the product of the electric force and the distance travelled. Electric force is equal to the product of the charge and the electric field strength.

$$\Delta V = V_a - V_b = \frac{W}{q} = \frac{Fd}{q} = \frac{qEd}{q} = Ed \qquad (1)$$

$$\Delta V = Ed = \left(2 \times 10^7 \frac{V}{m}\right)(5m)$$

$$\Delta V = 1 \times 10^8\, V \qquad (2)$$

(d) A negative charge of magnitude 9.0 nC is placed in a uniform electric field of $3 \times 10^4\, N/C$, directed upwards. If the charge is moved 1.0 m upwards, how much work is done on the charge by the electric field in this process? [4 marks]

$$\Delta V = Ed$$

$$W = q\Delta V \qquad (1)$$

$$E = 3 \times 10^4 \frac{N}{C}$$

$$d = 1.0\, m$$

$$q = -9nC = -9 \times 10^{-9}\, C$$

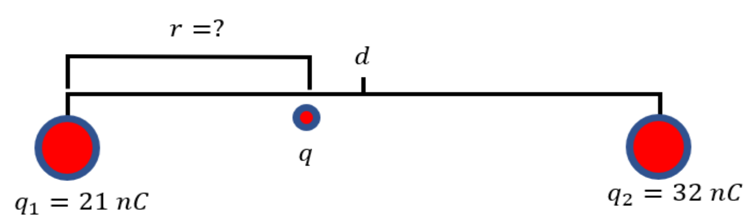
First, find the potential difference between the initial and final positions:

$$\Delta V = \left(3 \times 10^4 \frac{N}{C}\right)(1.0\, m) = 3 \times 10^4 \frac{N}{C} m \qquad (1)$$

$$W = (-9 \times 10^{-9}\, C)\left(3 \times 10^4 \frac{N}{C} m\right)$$

$$W = -2.7 \times 10^{-4}\, J \qquad (2)$$

(e) Two positive point charges of q_1 and q_2 are place at a distance 1000 μm away from each other, as shown below. If a positive test charge, q, is placed in between, at what distance away from q_1 will this test charge experience zero net force? [9 marks]



To find the location at which the test charge experience zero net force, write the net force equation as $F_{net}=F_1-F_2=0$, where F_1 is the force on the test charge from q_1, and F_2 is the force on the same test charge from q_2. Using Coulomb's law, we can rewrite the force equation and set it equal to zero.

$$F=\frac{kq_1q_2}{d^2},\quad F_1=\frac{kq_1q}{r^2},\quad F_2=\frac{kq_2q}{(d-r)^2}\qquad (1)$$

$$F_{net}=\frac{kq_1q}{r^2}-\frac{kq_2q}{(d-r)^2}=0\qquad (1)$$

$$\frac{kq_1q}{r^2}=\frac{kq_2q}{(d-r)^2}\qquad (1)$$

In this equation, the distance, r, is how far away the test charge is from q_1, while (d−r) represents how far away the test charge is from q_2. Now, we simplify and solve for r.

Cross-multiply.

We can cancel k and q. We do not need to know these values in order to solve the question.

$$\frac{kq_1q}{r^2}=\frac{kq_2q}{(d-r)^2}$$

$$kq_1q(d-r)^2 = kq_2q(r^2)$$

$$q_1(d-r)^2 = q_2(r^2)\qquad (2)$$

$$\sqrt{q_1(d-r)^2} = \sqrt{q_2(r^2)}$$

$$\sqrt{q_1}(d-r) = \sqrt{q_2}(r)$$

$$\sqrt{q_1}(d)-\sqrt{q_1}(r) = \sqrt{q_2}(r)$$

$$\sqrt{q_1}(d) = \sqrt{q_2}(r)+\sqrt{q_1}(r)$$

$$\sqrt{q_1}(d) = (r)\left(\sqrt{q_2}+\sqrt{q_1}\right)$$

$$r=\frac{\sqrt{q_1}(d)}{(\sqrt{q_2}+\sqrt{q_1})}\qquad (2)$$

Now that we have isolated r, we can plug in the values given in the question and solve.

$$r=\frac{\sqrt{21\times10^{-9}C}(1000\times10^{-6}\,m)}{(\sqrt{32\times10^{-9}C}+\sqrt{21\times10^{-9}C})}\qquad (1)$$

$$r=4.5\times10^{-4}\,m\qquad (1)$$

All answers must be written in the Answer Sheet