PHYSICS 2

MARKING SCHEME

1. (a) (i) Write down the Bernoulli's equation for the fluid flow in a pipe. Indicate the disappearing term when the fluid flow is stopped. **(3 marks)**

Solution

$$P + \frac{1}{2}\rho V^2 + mgh = constant$$

where p =pressure
ρ = density
V = velocity
h = height

Is $\frac{1}{2}\rho V^2$ this is due to its motion and therefore if it doesn't move then v=o and the relation above disappear

(ii) Water flows into a tank of large cross-sectional area at a rate of 2×10^{-4} m^3/s, but flows out from a hole of area 2 cm^2 which has been punched through the base so that students can get some water for drinking, How high does the water rise in the tank? **(4 marks)**

Solution

For the height too be constant

Input rate= out put rate

$A_1V_1 = A_2V_2$ recall $V=\sqrt{2gh}$

Then $A_1\sqrt{2gh_1} = A_2\sqrt{2gh_2}$

Rate 1= $2x10^{-4} = A_2\sqrt{2gh_2}$

Then h= $\frac{(2x10^{-4})2}{A_2^2\ 2xg}$

H= $\frac{2x10^{-4}x2x10^{-4}}{2x10^{-4}x2x9.8}$

Then height will be 1.02×10^{-5} m

(b) (i) Write down the formula for 'viscous drag force' on a sphere falling in a fluid as stated by Stokes. All symbols should carry their usual meaning. **(3 marks)**

Sol.

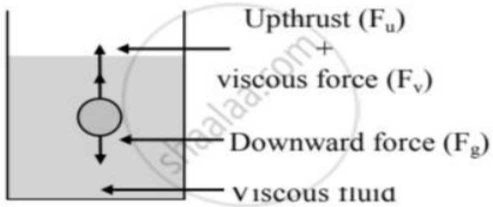
The viscous darg force is expressed using the strokes law where

$$F = 6\pi n r v$$

Where F= viscous darg force
n= coefficient of viscousity of fluid
r= radius os sphere
v= velocity of fluid in a sphere

(ii) When a Child drops a metal sphere in a liquid and sphere starts to move from rest, what are the magnitude, the direction of the forces acting on it and the relationship between the forces acting on it ? (3 marks)

Consider the forces acting on a spherical ball



at equilibrium

$$F_U + F_V = F_g$$
$$F_u = mg\ (\rho v g)$$
$$F_g = mg(\sigma v g)$$
$$F_V = 6\pi \eta r v$$

Then $mg\ (\rho v g) + 6\pi \eta r v = mg(\sigma v g)$

$$\frac{4}{3}\pi r^3 \rho g + 6\pi \eta r v = \frac{4}{3}\pi r^3 \sigma g$$

where σ is the density of spherical ball and *ρ is the density of the fluid*

(c)(i)

Solution

From the poisuiles equation

Rate of flow Q=$\frac{\pi P R^4}{8\eta L}$ **at a constant flow Q1=Q2**

Case 1 Q1= $\frac{\pi P R^4}{8\eta L}$

condition if the L is doubled and R is halved then

Q2== $\frac{\pi P (R^4/2)}{8\eta(2L)}$

then Q1 /Q2 is expressed as

Q1/Q2 = $\frac{\pi P R^4}{8\eta L} \,/\, \frac{\pi P (R^4/2)}{8\eta(2L)}$

Q1 = 32Q2

Then the new rate (Q2) is $\frac{Q1}{32}$

where q1 is the initisl rateand q2 is the final rate

(ii) Here are **four ways** to compare the viscosity of two liquids:

a) **Falling Ball Method**: Drop identical spheres in both liquids and measure the time taken to fall a fixed distance. The slower fall indicates higher viscosity.
b) **Capillary Flow Method**: Use capillary viscometers to measure the time taken by equal volumes of liquids to flow through a capillary under gravity.
c) **Rotational Viscometer**: Measure the torque required to rotate a spindle at a constant speed in both liquids. Higher torque corresponds to higher viscosity.
d) **Bubble Rise Method**: Observe the rise time of an air bubble through the liquids. A slower bubble rise indicates higher viscosity.

2. (a) Given Length of pipe L = 1.7 m
Speed of wave, v = 340 m/s.
Number of nodes, n = 4.

(i) Number of nodes, n = 4
Hence the pipe is vibrating in the fourth mode (i.e., In the third overtone or seventh harmonic)

(ii) Wave length $\lambda_n = \frac{4L}{(2n-1)}$

For fundamental mode n = 1

$$\therefore \quad \lambda_1 = \frac{4 \times 1.7}{(2 \times 1 - 1)} = \frac{4 \times 1.7}{1} = 6.8 \text{ m}$$

(iii) Fundamental frequency of vibration

$$f_1 = \frac{v}{\lambda_1} = \frac{340}{6.8} = 50 \text{ Hz}$$

[Alternatively, $f_n = \frac{(2n-1)v}{4L}$]

(iv) When vibrating with four nodes, n = 4

Wavelength of vibration,

$$\lambda_n = \frac{4L}{(2n-1)} = \frac{4 \times 1.7}{(2 \times 4 - 1)} = \frac{6.8}{7} = 0.971 \text{ m}$$

(v) n = 4

$\therefore$ frequency of vibration

$$f_n = \frac{v}{\lambda_n} = \frac{340}{0.971} = 350 \text{ Hz}$$

[Alternatively, $f_n = (2n-1)f_1$,

$f_4 = (2 \times 4 - 1)f_1 = 7f_1$ (seventh harmonic)

$= 7 \times 50 = 350$ Hz

(vi) First overtone frequency,

$f_2 = (2n-1)f_1$

$= (2 \times 2 - 1)\, f_1 = 3f_1$ (third harmonic)

$= 3 \times 50 = 150$ Hz

(b) Doppler effect is the apparent change of frequency heard by the observer due to relative motion of the source, observer or both of them.

Applications of Doppler effects:

(a) RADAR for determining the speeds of aeroplanes and automobiles.
(b) SONAR for determining the speeds of submarines.
(c) tracking satellites by the Earth stations.
(d) determining the speed of rotation of Sun about its axis by observing the Doppler effect of light coming from its diametrically opposite ends.
(e) medical diagnostics

(c).

$$f_1 = \left(\frac{v - v_L}{v}\right)f = \left(\frac{330 - 2}{330}\right)330 = 328 \text{ Hz}$$

$$f_2 = \left(\frac{v + v_L}{v}\right)f = \left(\frac{330 + 2}{330}\right)330 = 332 \text{ Hz}$$

Beat frequency = $(f_2 - f_1) = 332 - 328 = 4$ Hz

(d). The waves, produce transverse as well as lateral vibrations in the particles of the medium. The water molecules at the surface move up and down and back and forth simultaneously describing nearly circular paths. As the wave passes, water molecules at the crests move in the direction of the wave will those at the through move in the opposite direction.

(e). Gases cannot sustain shearing stress as in case of transverse wave propagation, the medium must have property of sustaining shearing.So, gases cannot support transverse wave Propagation.

3. (a)(i) The difference in the angle of contact arises from the balance between **cohesive forces** (forces between molecules of the same substance) and **adhesive forces** (forces between molecules of different substances).

1) **Mercury with Glass (Obtuse Angle)**:
   - Mercury molecules have strong cohesive forces due to metallic bonding, which dominate over the adhesive forces between mercury and glass.
   - This causes mercury to minimize contact with the glass surface, leading to an obtuse angle of contact (>90°).
2) **Water with Glass (Acute Angle)**:
   - Water molecules exhibit strong adhesive forces with the polar glass surface (silica in glass is hydrophilic), which dominate over the cohesive forces within water.
   - This causes water to spread more on the glass, resulting in an acute angle of contact (<90°).

(ii) Mercury molecules (which make an obtuse angle with glass) have a strong force of attraction between themselves and a weak force of attraction toward solids. Hence, they tend to form drops. On the other hand, water molecules make acute angles with glass. They have a weak force of attraction between themselves and a strong force of attraction toward solids. Hence, they tend to spread out.

(iii) Surface tension is the force acting per unit length

at the interface between the plane of a liquid and any other surface. This force is independent of the area of the liquid surface. Hence, surface tension is also independent of the area of the liquid surface.

(iv) Water with detergent dissolved in it has small angles of contact (θ). This is because for a small θ, there is a fast capillary rise of the detergent in the cloth. The capillary rise of a liquid is directly proportional to the cosine of the angle of contact (θ). If θ is small, then cos θ will be large and the rise of the detergent water in the cloth will be fast.

(v) A liquid tends to acquire the minimum surface area because of the presence of surface tension. The surface area of a sphere is minimum for a given volume. Hence, under no external forces, liquid drops always take spherical shape.

(b)

Radii of mercury droplets, $r_1 = 0.1\text{cm} = 1 \times 10^{-3}\text{m}$

$r_2 = 0.2\text{cm} = 2 \times 10^{-3}\text{m}$

Surface Tension, $T = 435.5 \times 10^{-3}$ N/m

Let V_1 and V_2 be the volume of the droplets and V of the resulting drop, and R be the radius of big drop formed by collapsing.

Then $V = V_1 + V_2$ or $\frac{4}{3}\pi R^3 = \frac{4}{3}\pi r_1^3 + \frac{4}{3}\pi r_2^3$

or $R^3 = r_1^3 + r_2^3 = (0.001 + 0.008)\ \text{cm}^3 = 0.009\ \text{cm}^3$

$\therefore R = 0.21$ cm

Change in surface area, $\Delta A = 4\pi[R^2 - (r_1^2 + r_2^2)]$

$\therefore$ Energy released, $\Delta U = T\Delta A = 4\pi T\left[R^2 - \left(r_1^2 + r_2^2\right)\right]$

$= 4 \times 3.14 \times 435.5 \times 10^{-3}$

$[(0.21)^2 \times 10^{-4} - (1 \times 10^{-6} + 4 \times 10^{-6})]$

$= 435.5 \times 4 \times 3.14\ [4.41 - 5] \times 10^{-6} \times 10^{-3}$

$= -32.23 \times 10^{-7}$ J

$\therefore \quad = 3.22 \times 10^{-6}$ J energy will be absorbed.

(c)

For a force F on a wire of length L elongated by ΔL ; the Young's modulus $Y = \frac{FL}{A\,\Delta L}$. As A (cross–sectional area) and L are constants; therefore

$\frac{F}{\Delta L} = \frac{YA}{L} = \text{constant}$ or $\Delta L \propto F$. Therefore $(\ell_1 - L)$ and $(\ell_2 - L)$ are directly proportional to T_1 and T_2; i.e.

$$\frac{\ell_1 - L}{\ell_2 - L} = \frac{T_1}{T_2}$$

$$\text{or } \ell_1 T_2 - L T_2 = \ell_2 T_1 - L T_1$$

$$L(T_2 - T_1) = \ell_1 T_2 - \ell_2 T_1$$

$$\therefore \quad L = \frac{\ell_1 T_2 - \ell_2 T_1}{T_2 - T_1}$$

4.

4. a) Limitation of Coulomb's law

- It is only applicable for point charges at rest.
- It is only applicable in those cases where inverse square law is obeyed. 02
- It's difficult to apply the law when charges are arbitrary shape because radius cannot be determined
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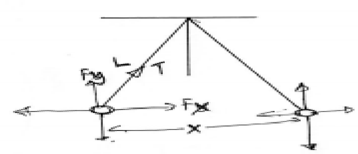
(ii) Consider the figure.



$T_y = T\cos\theta$ —— (1)

$T_x = T\sin\theta$ —— ii

At equilibrium.

$F_y = Mg = T\cos\theta$

$F_x = \frac{q^2}{4\pi\varepsilon_0 x^2} = T\sin\theta.$ 01

$T\sin\theta = \frac{q^2}{4\pi\varepsilon_0 x^2}$ —— iii

$T\cos\theta = Mg$ iv. 01

divide equation iii by iv

$\frac{T\sin\theta}{T\cos\theta} = \frac{q^2}{4\pi\varepsilon_0 x^2} \times \frac{1}{Mg}$

$\tan\theta = \frac{q^2}{4\pi\varepsilon_0 x^2 Mg}$ 01

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4a (ii) $\sin\theta = \frac{x/2}{L} = \frac{x}{2L}$ for small angle $\sin\theta \approx \tan\theta$

$$\frac{x}{2L} = \frac{q^2}{4\pi\varepsilon_0 x^2 Mg}$$

$$x^3 = \frac{q^2 2L}{4\pi\varepsilon_0 Mg}$$ 01

$$x^3 = \frac{q^2 L}{4\pi\varepsilon_0 Mg}$$

$$x = \left(\frac{q^2 L}{4\pi\varepsilon_0 Mg}\right)^{\frac{1}{3}}$$ 01

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b(i) Electric potential at a point of ~~metre~~ in a electric field is the amount of work done in moving a unit positive charge from infinity to that point against the electrostatic force. While Electric potential energy of system of point charges is the work done needed to bring the charges from infinite separation to their final position 02

(ii) Given $q_1 = +12\times10^{-9}$
$q_2 = -12\times10^{-9}c$
$d = 10$ cm
$q_3 = +4\times10^{-9}c$

1b (iii) Potential Energy at a due to q_1 and q_2 — 01

$$(V_1 + V_2) q_3 \qquad V_1 = \frac{kq_1}{r_1}$$

$$V_2 = \frac{kq_2}{r_2}$$

$$\text{Energy} = \left(\frac{q_1}{4\pi\varepsilon_0 r_1} + \frac{q_2}{4\pi\varepsilon_0 r_2}\right) q_3$$ 01

$$\text{Energy} = \left(\frac{12\times10^{-9}}{4\pi\varepsilon_0 \times 0.04} + \frac{-12\times10^{-9}}{4\pi\varepsilon_0\times 0.04}\right)\times 4\times10^{-9}$$

$$= 0 \text{ J/C}$$

Therefore the potential at a = 0

the potential energy at b due to q_1 and q_2. 01

$$(V_2 + V_1)\, q_3 = \left(\frac{12\times10^{-9}}{4\pi\varepsilon_0 \times 0.06} + \frac{-12\times10^{-9}}{4\pi\varepsilon_0 \times 0.1}\right) 4\times10^{-9}$$

$$= 6.47\times10^{-6} \text{ J/C}$$

the potential at c due to q_1 and q_2 is given by 01

$$(V_1 + V_2)\, q_3 = \left(\frac{12\times10^{-9}}{4\pi\varepsilon_0\times 0.1} + \frac{-12\times10^{-9}}{4\pi\varepsilon_0 \times 0.1}\right) 4\times10^{-9}$$

$$= 0 \text{ J/C}$$ 01

Energy at b is zero 1:

4(c)(i) Given $C_1 = 20\,uF$

Charged by a potential difference of 1000V connected to another capacitor of capacity C_2 5uF.

i Original charges on the System.

$$Q = CV$$
$$= 20uF \times 1000$$
$$= 0.02\,C$$ 02

(ii) The final potential difference.

Charge is conserved if $Q_1 = Q_2$ 01

$$\Rightarrow Q_1 = (C_1 + C_2)V$$

$$V = \frac{Q_1}{C_1 + C_2} = \frac{0.02}{(20+5)\times10^{-6}}$$

$$= 800V$$ 01

Therefore the final potential difference = 800V

and charges across each capacitor

(iii) Charge $Q = CV$

$$Q_1 = C_1V = 20\times10^{-6}\times800 = 0.016C$$

$$Q_2 = C_2V = 5\times10^{-6}\times80 = 0.004C$$ 01

$$Q_1 = 0.016C$$

$$Q_2 = 0.004C$$

13

The final energy of the system

$$\text{Energy } E = \frac{1}{2}CV^2$$

$$= \frac{1}{2}(C_1+C_2)V^2$$

$$= \frac{1}{2}(20+5)\times10^{-6}\times 800^2$$

$$= 8\ J$$

01

(iv) The decrease of energy when capacitors are connected

$$\Delta E = E_i - E_f$$

$$= \frac{1}{2}C_1V^2 - \frac{1}{2}(C_1+C_2)V^2$$ 01

$$\Delta E = \frac{1}{2}\times 20\times10^{-6}\times1000^2 - \frac{1}{2}(20+5)\times10^{-6}\times800^2$$

$$= 10-8 = 2J.$$

The decrease in Energy is 2 J. 01

5.

5

a) i) Magnetic field of magnet exerts Magnetic force on the electron beam of Tv tube. 02

ii) The body will be lifted upward.

This is because the direction of current in each turn of the spring will be same. Since parrallel currents in the same direction attract each other then turns comes closser as a result the body will be lifted upward 02

iii) Because: the aligning process is counteracted by the tendency of the dipole to be randomly oriented due to thermal motion 02

b) Required Magnitude and direction of B.

From $F = BIl$.

$F = B \times 5 \times 0.15$.

$F = 0.75\,B$. 01

Weight of wire is $Mg = \frac{\text{Mass}}{\text{length}} \times \text{length} \times g$

$= 3 \times 10^{-3}\,\text{kg/m}^{-1} \times 0.15 \times 9.8\,\text{m s}^{-1}$

$W = 4.41 \times 10^{-3}\,N$ 02

But In equillibrium force (F.) = $0.75B = 4.41 \times 10^{-3}$

$$0.75B = 4.41 \times 10^{-3}$$ 01

$$B = \frac{4.41 \times 10^{-3}}{0.75}$$

$$= 5.88 \times 10^{-3}\ T$$ 01

the directn is vertically downward.

Required the torque (τ)

For solenoi $n_1 = 500$ turns

$I_1 = 3A$ 01

For coil $n_2 = 10$ turns

$I_2 = 0.4A$

From the magnetic field at the middle of solenoid

01

$$B = \mu_0 n I_1$$

$$= 4\pi \times 10^{-7} H/m \times \frac{500}{0.4} \times 3A \quad \text{where } \frac{?}{L}$$

01

$$= 4.71 \times 10^{-3}\ T.$$

Also from the Torque on the Coil placed within solenoi $\tau = MB \sin\alpha$ $\quad M = n_2 I_2 A$ 01

$=$ $\quad = n_2 I_2 \pi r^2.$

5

$$T = 10 \times 0.4 \times \pi \times (0.02)^2 \times 4.91 \times 10^{-3} \times \sin 30$$

$$T = 2.366 \times 10^{-5} \text{ Nm.}$$ 01

d. Required : the Magnitude Induced EMF is,

length of spoke $l = r = 0.6$

Frequency $= 100 \frac{rev}{min} = \frac{100}{60} = \frac{5}{3} s^{-1}$

01

From $E = Blv = Brv$

$v = \omega r$.

Average Linear velocity $= \frac{\omega r}{2}$ 01

$E = Br\left(\frac{\omega r}{2}\right)$ But $\omega = 2\pi f$ 01

~~$E = Br^2 2\pi f$~~

$E = Br^2 \frac{\omega}{2}$

$= Br^2 \pi f$.

$E = 0.3 \times 10^{-4} \times (0.6)^2 \times 3.14 \times \frac{5}{3}$

$E = 5.65 \times 10^{-5}$ V 01

Since all spokes are connected in parallel as the result of Emf between the rim and the axle. Is equal to the emf across the ends of each pole. 01

Therefore the Induced Emf is 5.65×10^{-5} V 02

6 (a) (i) Half-life is the time during which half of atom of radioactive substance will disintegrate. **(01)**

(ii) Activity is the rate of disintegration of radioactive substance. **(01)**

(iii) From $N = (\frac{Mass}{Mr})$ NA

$$N = \frac{1}{235} \times 6.02\times10^{23}$$

$N = 2.5617 \times10^{23}$ particles **(01)**

$$A = A\lambda$$

$$\lambda = \frac{A}{N}$$

$$\lambda = \frac{\ln 2}{t^1/_2}$$

$$A = \frac{\ln 2}{t^1/_2}N$$ **(02)**

$$A = \frac{\ln 2 \times 2.5617\times10^{21}}{4.5\times10^9 \times365\times60\times60}$$

$$A = 300293.410\ S^{-1}$$

$A = 3.0\times10^5$ disintegration /second. **(01)**

(b) (i) Nuclear Fusion is the process of combining two light nuclei to form a heavy nucleus with release of huge amount of energy due to mass defect. **(02)**

(ii) Nuclear Fission is the process of splitting of heavy nucleus into two medium mass nuclei in a nuclear reaction with a release of huge amount of energy due to mass defects. **(02)**

(iii) Chain reaction is the nucleus fission which once started donlimass till all the atoms of the fashionable materials are disintegrated. **(02)**

(iv) Critical mass – is the mass of fissionable material for which the neuron multiplication factor $K = 1$. **(02)**

(6) (c). Mass of U-234 $= 2.65\times10^{-6}$kg

$Na = 6.02\times10^{23}\text{Mol}^{-1}$

Number of U -234 nuclei N $= \frac{NAm}{A}$

$$= \frac{6.02\times10^{23}\times2.65\times10^{-6}}{234} = 6.82\times10^{15}$$

Activity of U-234 $R = 604S^{-1}$

But $R = \lambda N$ and hence $\lambda = \frac{R}{N}$

$$= \frac{604}{6.82\times10^{15}} = 8.85\times10^{-14}s^{-1}$$

Half-life $\frac{T_1}{2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{8.86\times10^{-14}} = 7.92\times10^{12}S$

Half-life in years $= \frac{7.82\times10^{12}}{365\times60\times60}$

$= 2.48\times10^{5}$ years.