PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No. 1

PHYSICS & MEASUREMENT

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

PROBLEMS

Q.1 What is the percent uncertainty in the measurement 3.67 ± 0.25 m?

Data:

$x = 3.67$ cm

$\Delta x = 0.25$ cm

Percent uncertainty $= \left(\frac{\Delta x}{x}\right) \times 100 = ?$

Solution:

Percent uncertainty $= \left(\frac{\Delta x}{x}\right) \times 100$

Percent uncertainty $= \left(\frac{0.25}{3.67}\right) \times 100 = 6.8\%$

Q.2 What is the area, and its approximate uncertainty, of a circle with a radius 3.7×10^4 cm $(4.3 \pm 0.11) \times 10^9$ cm^2

Data:

Radius of circle $= r = 3.7 \times 10^4$ cm

The smallest value of radius = 1000cm

The area of circle = A =?

Solution:

Area of the circle is:

$A = \pi r^2$

$A = (3.14)(3.7 \times 10^4)^2$

$A = 4.3 \times 10^9 \text{cm}^2$

The uncertainty in the radius is,

$\Delta r = \pm \frac{\text{The smallest value}}{2}$

$\Delta r = \pm \frac{1000}{2} = \pm 500 \text{cm}$

The fractional uncertainty in area

$A = \pi r^2$

$\frac{\Delta A}{A} = \frac{2\Delta r}{r}$

$\frac{\Delta A}{A} = \frac{2(500)}{3.7 \times 10^4}$

$\frac{\Delta A}{A} = 0.027$

$\Delta A = 0.027 \times A$

$\Delta A = 0.027 \times 4.3 \times 10^9$

$\Delta A = 0.11 \times 10^9 cm^2$

Area of the circle = $A \pm \Delta A = (4.3 \times 10^9 \pm 0.11 \times 10^9)\ cm^2$

Or

Area of the circle = $A \pm \Delta A = (4.3 \pm 0.11) \times 10^9\ cm^2$

Q.3 An airplane travels at 850 km/h. How long does it take to travel 1.00 km?

Data:

V = 850 km/h
S = 1.00 km
t =?

Solution:

$S = Vt$

$t = \frac{s}{v}$

$t = \frac{1.00}{850} = 0.001176\ hr$

$t = 0.00117 \times 3600$

$\boxed{t = 4.23\ s}$

Q.4 A rectangular holding tank 25.0 m in length and 15.0 m in width is used to store water for a short period of time in an industrial plant. If 2980 m^3 water is pumped into the tank, what is the depth of water?

Data:

Length = l = 25.0m
Width = w = 15.0
Volume = V = 2980 m3
Depth = d = ?

Solution:

$V = l \times w \times d$

$d = \frac{V}{l \times w}$

$d = \frac{2980}{25.0 \times 150}$

$\boxed{d = 7.95m}$

Q.5 Find the volume of a rectangular underground water tank that has a storage facility of 1.9 m by 1.2 m by 0.8 m. (1.824 m^3)

Data:

Length = l = 1.9m

Width = w = 1.2m

Depth = d = 0.8m

Volume = V =?

Solution:

$V = l \times w \times d$

$V = 1.9 \times 1.2 \times 0.8 = 1.824 m^3$

Q.6 Two students derive the following equations in which x refers to the distance travelled, v the speed, the acceleration, and t the time, and the subscript (o) means a quantity at time t=0: (a) x = vt2 + 2at and (b) x = v. t + 2at2, which of these could be correct according to the dimensional check?

x = + 2at

$[x] = [v][t^2] + [a][t^2]$

$[L] [LT^{-1}][T^2] + [LT^{-2}] [T^2]$

$[L] = [LT^{-1+2}] + [LT^{-2+2}]$

$[L] = [LT] + [LT^{o}]$

$[L] = [LT] + [L]$

The above equation is dimensionally incorrect.

$x = v t + 2at^2$

$[x] = [v][t] + [a][t^2]$

$[L] = [LT^{-1}] [T] + [LT^{-2}] [T^2]$

$[L] = [LT^{-1+1}] + [LT^{-2+2}]$

$[L] = [LT^{o}] + [LT^{o}]$

$[L] = [L] + [L]$

The above equation is dimensionally correct.

Q.7 One hectare is defined as 10^4 m². One acre is 4 x 10^4 ft². How many acres are there in one hectare?

Data:

One hectare = $10^4 m^2$

One acre = $4\times10^4 ft^2$

One hectare = ?

1m = 3.28ft

Solution:

$$1ft = \frac{1}{3.28} m$$

and,

$$\text{one acre} = 4\times10^4 ft^2$$

$$\text{one acre} = 4\times10^4\left(\frac{1}{3.28}\right)^2 m^2$$

$$\text{one acre} = \frac{4}{(3.28)^2} \times 10^4 m^2$$

$$\text{one acre} = \frac{4}{(3.28)^2} \text{ hectare} \qquad (10^4 m^2 = 1 \text{hectare})$$

Or

$$1 \text{ hectare} = \frac{(3.28)^2}{4} \text{ acre}$$

1 hectare = 2.69 acres

Q.8 A watch factory claims that its watches gain or lose not more than 10 seconds in a year. Find the percentage accuracy of this watch.

Data:

$\Delta t = \pm 10s$

$t = 1 \text{ year} = 3.15\times10^7 s$

Loss or gain in time $= \frac{\Delta t}{t} = ?$

$$\frac{\Delta t}{t} = \frac{10}{3.15\times10^7}\times100$$

$$\frac{\Delta t}{t} = 3.175\times10^{-5}\%$$

Q.9 The diameter of the Moon is 3480 km. What is the volume of the moon? How many moons would be needed to create a volume equal to that of the Earth?

Data:

Diameter of the moon $= D = 3480km$

$$r_m = \frac{D}{2} = \frac{3480}{2}$$

$r_m = 1740km$

Volume of the moon $= V_m = ?$

Number of moons in earth's volume $= n = ?$

Solution:

Volume of the moon

$$V = \frac{4}{3}\pi r_m^3$$

$$V = \frac{4}{3}(3.14)(1740)^3$$

$$V = 2.2\times10^{10} m^3$$

Number of moon = n

$$V_e = nV_m$$

$$\cancel{\frac{4}{3}\pi} r_e^3 = n\times\cancel{\frac{4}{3}\pi} r_m^3$$

$$n = \left(\frac{r_e}{r_m}\right)^3$$

$$n = \left(\frac{6380}{1740}\right)^3$$

$$\boxed{n = 49.3}$$

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PHYSICS

CHAPTER No. 2

KINEMATICS

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

NUMERICALS

Q.1 A helicopter is ascending at a rate of 12 m/s. At a height of 80m above the ground, a package is dropped. How long does the package take to reach the ground?

Solution:

Consider upward motion from B to C.

Initial velocity of package at B = V_i = 12 m/sec

Final velocity of package at C = $V_f = 0$

Time from B to C = t_1 =?

$$a = -g = -9.8 m/s^2$$

Using the equation of motion,

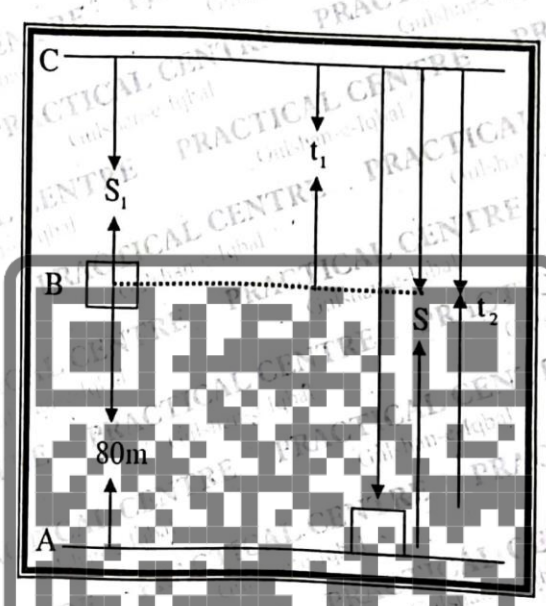
$$V_f = V_i + at$$

$$0 = 12 + (-9.8)\, t_1$$

$$9.8\, t_1 = 12$$

$$t_1 = \frac{12}{9.8}$$

$$\boxed{t_1 = 1.2 \text{ sec}} \text{ Ans.}$$



To calculate the distance from B to C = s_1

$$s = v_i t + \frac{1}{2} g t^2$$

$$s_1 = 12 \times 1.2 + \frac{1}{2} \times (-9.8)\,(1.2)^2$$

$$s_1 = 14.4 - 7.06$$

$$s_1 = 7.34 \text{ m}$$

Consider downward motion from C to A,

$$S = 80 + S_1$$

$$S = 80 + 7.34$$

$$= 87.34 \text{m}$$

$$V_i = 0$$

$$g = 9.8 m/sec^2$$

$$t_2 = ?$$

using the equation of motion,

$$S = v_i t + \frac{1}{2} g t^2$$

$$87.34 = 0 \times t_2 + \frac{1}{2}(9.8)\, t_2^2$$

$$87.34 = 4.9\, t_2^2$$

$$t_2^2 = \frac{87.34}{4.9}$$

$$t_2^2 = 17.82$$

$$\boxed{t_2 = 4.22 \text{ sec}} \text{ Ans.}$$

Hence, the total time the package takes to reach the ground is

$$t = t_1 + t_2$$

$$t = 1.2 + 4.22$$

$$\boxed{t = 5.42 \text{ sec}} \text{ Ans.}$$

Q.2. Two tugboats are towing a ship, each exerts a force of 6000 N and the angle between the ropes is 60°. Calculate the resultant force on the ship.

Given Data:

$F_1 = 6000\ N$

$F_2 = 6000\ N$

$\theta = 60^o$

To Find:

$|\vec{F}| = ?$

Solution:

Magnitude of resultant force

$$|\vec{F}| = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

$$|\vec{F}| = \sqrt{(6000)^2 + (6000)^2 + 2(6000)\ (6000)\cos 60^o}$$

$$|\vec{F}| = \sqrt{36000000 + 36000000 + 72000000 \times 0.5}$$

Ans: $\frac{1}{2}\sqrt{114}$

$\boxed{F = 10392.305\ N}$ Ans.

Q.3. A car starts from rest and moves with a constant acceleration. During the 5th seconds of its motion, it covers a distance of 36 meters. Calculate:

(a) the acceleration of the car

(b) the total distance covered by the car during this time.

From A to C

$v_i = 0$, $t = 5\ sec$

$S_5 = ?$, $a = ?$

Now

$$S_5 = v_it + \frac{1}{2}at^2$$

$$S_5 = 0 \times 5 + \frac{1}{2}a\ (5)^2$$

$S_5 = 12.5a$ --------(1)

and from A to B

$v_i = 0$, $t = 4sec$

$S_4 = ?$

$$S_4 = v_i t + \frac{1}{2} at^2$$

$$S_4 = 0 \times 4 + \frac{1}{2} a (4)^2$$

$$S_4 = 8a \text{ -------(2)}$$

Subtracting Equation2 from Equation1

$$S_5 - S_4 = 36$$

$$12.5\,a - 8a = 36$$

$$a = 8 m/s^2$$

From Equation (1)

$$S_5 = 12.5\,a$$

$$= 12.5\,(8)$$

$$= \boxed{S_5 = 100m}$$

Q.4 Show that the range of projectile at complementary angles are same with examples.

Let us suppose two complementary angles θ and (90 -θ) and find horizontal range for both angels.

$$R_1 = \frac{V_o^2 \sin 2\theta}{g} \text{ ---------- (1)}$$

and

$$R_2 = \frac{V_o^2 \sin 2(90-\theta)}{g}$$

$$R_2 = \frac{V_o^2 \sin(180-2\theta)}{g}$$

As $\sin(a-b) = \sin a \cos b - \cos a \sin b$

So, $\sin(180-20) = \sin 180^o \cos 2\theta - \cos 180^o \sin 2\theta$

$$= 0 \times \cos 2\theta - (-1) \sin 2\theta$$

$$\sin(180-20) = \sin 2\theta$$

Now

$$R_2 = \frac{V_o^2 \sin 2\theta}{g} \text{ ----------(2)}$$

Comparing (1) and (2)

$$R_1 = R_2$$

So, horizontal range is same for two complementary angles.

$$R_{75^o} = \frac{V_o^2}{g}\text{Sin}2(75^o)$$

$$R_{75^o} \frac{V_o^2}{g}\text{Sin}2(150^o)$$

Therefore

$$R_{75^o} \frac{V_o^2}{g}(0.5)$$

and $$R_{15^o} \frac{V_o^2}{g}\text{Sin}2(15^o)$$

or $$R_{15^o} \frac{V_o^2}{g}\text{Sin}30^o$$

Therefore

$$R_{15^o} \frac{V_o^2}{g}(0.5)$$

Hence, the range at 75° & 15° is same.

Q.5 At what angle the does range of projectile become equal to the height of projectile?

Gives:

$H = R$

To Find:

$\theta = ?$

$H = R$

$$\frac{V_o^2 \text{Sin}^2\theta}{2g} = \frac{V_o^2 \text{Sin}2\theta}{g}$$

$$\frac{\text{Sin}\theta\,\text{Sin}\theta}{2} = 2\text{Sin}\theta\,\text{Cos}\theta$$

$$\frac{\text{Sin}\theta}{\text{Cos}\theta} = 4$$

$$\text{Tan}\theta = 4$$

$$\theta = \text{Tan}^{-1}(4)$$

$$\boxed{\theta = 76^o}$$

Q.6. A mortar shell is fired at ground level target 500m distanced with an initial velocity of 90m/s. What is its launch angle?

Given Data:

Range $= R = 500\text{m}$

Initial velocity $= V_o = 90\text{m/s}$

To Find:

(a) Launch angle $= \theta = ?$

Solution:

(a) We know that range of projectile is:

$$R = \frac{V_o^2 \text{Sin}2\theta}{g}$$

$$\text{Sin}2\theta = \frac{R \times g}{V_o^2}$$

$$\text{Sin}2\theta = \frac{500 \times 9.8}{(90)^2}$$

$$\text{Sin}2\theta = 0.6049$$

$$2\theta = \text{Sin}^{-1}(0.6049)$$

$$2\theta = 37.2^\circ$$

$$\theta = \frac{37.2^\circ}{2}$$

$$\boxed{\theta = 18.6^\circ} \text{ Ans.}$$

If the shell is fired with angle $(90 - 18.6) = 71.4^\circ$, then range will also be 500m

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CLASS-XI

PHYSICS

CHAPTER No. 3
DYNAMICS

2023-24

info@practicalcentre.edu.pk
021-34976530
021-34812547
021-34984762
B-14, Block-1,
Gulshan-e-Iqbal, Karachi.
www.practicalcentre.edu.pk

PROBLEMS

Q.1 A car, weighing 9800 N, is moving with a speed of 40 km/h. On the application of the brakes, it comes to rest, after travelling a distance of 50 metres. Calculate the average retarding force.

Given Data:

$W = 9800\ N$

$mg = 9800$

$m = \frac{9800}{9.8}$

$m = 1000\ kg$

$v_i = 40\ km/hr$

$= \frac{40 \times 1000}{60 \times 60}$

$= 11.1111\ m/sec.$

$v_f = 0$

$s = 50\ m$

To Find:

$F = ?$

Solution:

$F = -ma$ ----------(1)

-ve sign shows that force is retarding

Find "a"

$2aS = v_f^2 - v_i^2$

$a = \frac{v_f^2 - v_i^2}{2S}$

$= \frac{0^2 - (11.1111)^2}{2 \times 50}$

$a = -123.456\ m/s^2$

Putting the value of a in eq. (1)

$F = -1000 \times 123.456$

$F = 1234.57\ N$

Q.2 A helicopter weighs 3920 Newtons.
Calculate the force on it if it is ascending at a rate of 2 m/s². What will be force on the helicopter, if it is moving up with the constant speed of 4m/s?

Given Data:

Weight of helicopter = W = 3920 N

(i) Acceleration of helicopter = $a = 2\ m/sec^2$

(ii) Constant velocity of helicopter = $v = 4\ m/sec$

To Find:

(i) Force acting on the helicopter = F = ? (ii) Force acting on the helicopter = F = ?

Solution:

Mass of the helicopter $= m = \frac{w}{g}$

$$m = \frac{3920}{9.8} = 400kg$$

(i) Since the helicopter is ascending up, therefore, the net force on helicopter is

$F - W = ma$

$F = ma + w$

$F = 3920 + 400 \times 2$

$F = 3920 + 800$

$\boxed{F = 4720\ N}$ **Ans.**

(ii) Force on the helicopter when ascending with constant velocity.

$F - W = ma$

In this case, acceleration of helicopter is zero

$F - W = m \times 0$

$F - W = 0$

$F = W$

$\boxed{F = 3920\ N}$ **Ans.**

Q.3 A 100 grams bullet is fired from a 10 Kg gun, with a speed of 1000m/s. what is the speed of recoil of the gun?

Given Data:

Mass of bullet $= m_1 = 100g$

Mass of bullet $= m_1 = \frac{100}{1000} = 0.1\ Kg$

Mass of gun $= m_2 = 10Kg$

velocity of the bullet before firing $= u_1 = 0$

velocity of the gun before firing $= u_2 = 0$

velocity of the bullet after firing $= v_1 = 1000\ m/s$

To Find:

velocity of the gun after firing $= v_2 = ?$

Solution:

According to the law of conservation of linear momentum,

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$0.1x0 + 10x0 = 0.4x1000 + 10\ v_2$$

$$0 + 0 = 100 + 10v_2$$

$$v_2 = \frac{-100}{10}$$

$$\boxed{v_2 = -10\ m/s}$$

Negative sign shows that the direction of the velocity of recoil of the gun, whose magnitude is 10 m /s and the direction of recoil, is opposite to the direction of velocity of bullet.

Q.4 A machine gun fires 10 bullets per second into a target. Each bullet weighs 20gm and has a speed of 1500m/s. Find the force necessary to hold the gun in position.

Given Data:

Mass of the bullet $= m = 20g = \frac{20}{1000} = 0.02kg$

Number of bullets $= 10$

Mass of 10 bullets $= M = 10 \times 0.02 = 0.2kg$

Time $= t = 1s$

Initial velocity of the bullet $= v_i = 0$

Final velocity of the bullet $= v_f = 1500$ m/sec

To Find:

Force $= F = ?$

Solution:

Force necessary to hold the gun = change in momentum of bullets per second.

$$F = \frac{Mv_f - Mv_i}{t}$$

$$F = \frac{0.2 \times 1500 - 0.2 \times 0}{1}$$

$\therefore$ $\boxed{F = 300\ N}$ **Ans.**

Q.5 A 50 grams bullet is fired into a 10kg block, that is suspended by a long cord so that it can swing as a pendulum. If the block is displaced so that its centre of gravity rises by 10cm, what was the speed of the bullet?

Given Data:

Mass of bullet $= m_1 = 50g = \frac{50}{1000} = 0.05Kg$

Mass of block $= m_2 = 10kg$

Height $= h = 10cm = \frac{10}{100} = 0.1m$

Velocity of block before impact $= u_2 = 0$

Velocity of bullet after impact $= v_1 = V$

Velocity of block after impact $= v_2 = V$

To Find:

velocity of bullet before impact $= u_1 = ?$

Solution:

According to the law of conservation of linear momentum,

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$0.05 \times u_1 + 10 \times 0 = 0.05v + 10 \times v$$

$$0.05u_1 = 10.05v$$

$$u_1 = \frac{10.05}{0.05}\, v$$

$$\mathbf{u_1 = 201v} \text{ ———— } \mathbf{(1)}$$

According to the law of conservation of energy,

loss of K.E. = gain of P.E.

$$\frac{1}{2}(\cancel{m_1} + m_2)\, v^2 = (m_1 + \cancel{m_2})\, gh$$

$$\frac{1}{2} v^2 = gh$$

$$v^2 = 2\,gh$$

$$v = \sqrt{2\,gh}$$

$$v = \sqrt{2 \times 9.8 \times 0.1}$$

$$v = 1.4 \text{ m/s}$$

putting the value of v is eq (1),

$$u_1 = 201 \times 1.4$$

$$\boxed{u_1 = 281.4 \text{ m/s}} \text{ Ans.}$$

Q.6 A 70-gram ball collides with another ball of mass 140 gram. The initial velocity of the first ball is 9m/s to right while the second ball is at rest. If the collision was perfectly elastic, what was the velocity of the two balls after the collision?

Given Data:

m_1	= 70g	m_2	= 140kg
	= 0.07kg	m_2	= 0.14kg
u_1	= 9m/Sec.	u_2	= 0

To Find:

$v_1 = ?$ $\qquad$ $v_2 = ?$

Solution:

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2$$

$$v_1 = \left(\frac{0.07-0.14}{0.07+0.14}\right)9 + \left(\frac{2\times0.14\times0}{0.07\times0.14}\right)$$

$$v_1 = \frac{-0.07}{0.21}\times9+0$$

$$\boxed{v_1 = -3m/s}$$

and $$v_2 = \frac{2m_1u_1}{m_1+m_2} + \frac{(m_2-m_1)u_2}{m_1+m_2}$$

$$v_2 = \frac{2\times0.07+9}{0.07+0.14} + \frac{(0.14-0.07)0}{0.07+0.14}$$

$$\boxed{v_2 = 6m/s}$$

Q.7 A truck, weighing 2500 kg and moving with a velocity of 21m/s, collides with a stationary car, weighing 1000 kg. The truck and the car move together after the impact. Calculate their common velocity.

Given Data:

$m_1 = 2500$ kg $\quad m_2 = 1000$kg

$u_1 = 21$ m/s $\quad u_2 = 0$

To Find:

$v_1 = v_2 = v = ?$

Solution:

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$2500 \times 21 + 1000 \times 0 = 2500v + 1000v$

$52500 = 3500\ v$

$$v = \frac{52500}{3500}$$

$$v_1 = \frac{52500}{3500}$$

$$\boxed{v_1 = 15\ m/s}$$

PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No. 5

WORK, POWER & ENERGY

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

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NUMERICALS

Q.1
A man pulls a trolley through a distance of 10m by applying a force of 50N which makes an angle of 60° with the horizontal. Calculate the work done by the man.

Data.

Distance = d = 10m
Force = F = 50N
$\theta = 60°$
Work done =W = ?

Solution:-

$W = Fd \cos\theta$
$W = 50 \times 10 \times \cos 60$
$\boxed{W = 250\ J}$

Q.2 A 100 kg man runs up a long flight of stairs in 9.8 seconds. The vertical height of the stair is 10m. Calculate its power.

Data.

Mass = m = 100 kg
Time = t = 9.8 sec
Height =h = 10 m
Power = P =?

Solution:-

$P = \frac{W}{t}$

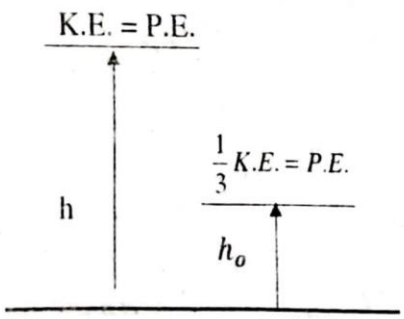
$P = \frac{mgh}{t}$

$P = \frac{100 \times 9.8 \times 10}{9.8}$

$\boxed{P = 1000 watt}$

Q.3 When an object is thrown upwards, it rises to a height 'h'. How high will the object go in terms of 'h', when it has lost one third of its original kinetic energy?

Data.



At height h

K.E. = P.E.

K.E. = mgh---------(1)

At height 'h_o'

$\frac{1}{3}K.E. = P.E.$

$\frac{1}{3}K.E. = mgh_o$

K.E. = $3mgh_o$------- (2)

Compare (1) and (2)

$3mgh_o = mgh$

$3h_o = h$

$$\boxed{h_o = \frac{h}{3}}$$

Q.4 A 70 kg man runs up the hill through a height of 3m in 2 second.

(a) How much work does he do against gravitational field?

(b) What is the average power output?

Data:

Mass = m = 70 kg

Height =h = 3m

Time =t = 2 sec

Work Done =W =?

Power = P =?

Solution:-

For Work done

W=mgh

W= 70 ×9.8× 3

W = 2058 Joules

For Power

$P = \frac{W}{t}$

$P = \frac{mgh}{t}$

$P = \frac{70 \times 9.8 \times 3}{2}$

P =1029 watt

Q.5 A neutron travels a distance of 12m in a time interval of 3.6×10^{-4} sec. Assuming its speed was constant, find its kinetic energy. Take the mass of neutron as $1.7 \times 10^{-27} kg$.

Data.

Mass = m = $1.7 \times 10^{-27} kg$

Time = t = 3.6×10^{-4}sec

Distance= d =12 m

K.E. =?

Solution:-

For Velocity

$$V = \frac{d}{t}$$

$$V = \frac{12}{3.6 \times 10^{-4}}$$

$$\boxed{V = 33333.33 \text{ m/s}}$$

For K.E.

$$K.E. = \frac{1}{2}mv^2$$

$$K.E. = \frac{1}{2} \times 1.7 \times 10^{-27} \times (33333.33)^2$$

$$K.E. = 9.44 \times 10^{-19} \text{ Joules}$$

$$K.E. = \frac{9.44 \times 10^{-19}}{1.6 \times 10^{-19}}$$

[1e.v. = 1.6×10^{-19} J]

$$\boxed{K.E. = 5.9 \text{ e.V.}}$$

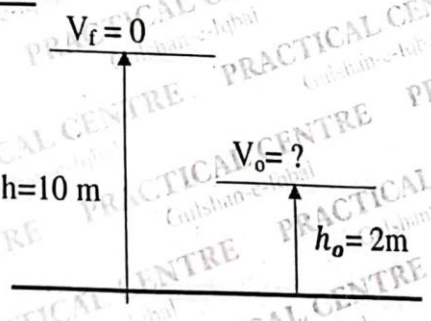
Q.6 A stone is thrown vertically upwards and can reach a height of 10m. Find the speed of stone, when it is just 2m above the ground?

Data:

Height = h = 10 m

Velocity at height (h_o) 2m above the ground =V_o=?

Solution:-



For initial velocity

At height h,

K.E. = P.E.

$$\frac{1}{2}mv^2 = mgh$$

$v_i = \sqrt{2gh}$

$v_i = \sqrt{980}$

$v_i = 14$ m/sec

For V_o

$2gs = v_f^2 - v_i^2$

$2 \times -9.8 \times 2 = (V_o)^2 - (14)^2$

$-39.2 + 196 = v_o^2$

$v_o = \sqrt{156.8}$

$v_o = 12.52$m/sec

Q.7 The potential energy of a body at the top of a building is 200 joules. When it is dropped, its kinetic energy, just before striking the ground, is 160 J. Find the work done against the air resistance.

Data:-

P.E. = 200 joules

K.E. = 160 joules

Work done=?

Solution:-

Loss of P.E. = Work done against friction + Gain in K.E.

$200 = W + 160$

$W = 200 - 160$

$W = 40$ joules

Q.8 Find the energy equivalent of 1 gram.

Data.

E=?

Mass = m= 1 gram= 0.001 kg

Solution:-

$E = mC^2$

$E = 0.001 \times (3 \times 10^8)^2$

$E = 9 \times 10^{13}$ Joules

$E = \frac{9 \times 10^{13}}{1.6 \times 10^{-19}} = 5.78$ev [1e.v. = 1.6×10^{-19} J]

Q.9 A 1KW motor pump pumps the water from the ground to a height of 10m. Find how much liter of water it can pump in one hour.

Data:

Power = P= 1KW = 1000 watt

Height= h = 10m

Time = t = 1hr = 3600 sec

Mass = m =?

Solution:-

$$P = \frac{W}{t}$$

$$P = \frac{mgh}{t}$$

$$1000 = \frac{m \times 9.8 \times 10}{3600}$$

$$m = \frac{1000 \times 3600}{9.8 \times 10}$$

$$\boxed{m = 3.6 \times 10^4 \text{ kg}}$$

1 kg of pure water is equal to 1 liter at 4°C,

$V = 3.6 \times 10^4$ liter

Q.10 A rocket of mass 2 kg is launched in air. When it attains the height of 15m, the 400 joules of its chemical fuel is burnt. Find the speed of the rocket at maximum height.

Data:

Mass =m = 2kg

Height= h = 15

Work done= 400 joules

Speed = v =?

Solution:-

Work done = Gain in K.E. + Gain in P.E.

$$W = \frac{1}{2}mv^2 + m\,g\,h$$

$$400 = \frac{1}{2} \times 2 \times v^2 + 2 \times 9.8 \times 15$$

$$400 - 294 = v^2$$

$$v = \sqrt{106}$$

$$\boxed{v = 10.29 \text{ m/s}}$$

Q.11 A motor pumps water at the rate of 500 gram/minute to a height of 120m. If the motor is 50% efficient, then how much input of electric power is needed?

Data.

$$\frac{mass}{time} = \frac{m}{t} = \frac{500gm}{1\,minute} = \frac{0.5\,kg}{60\,sec} = 8.33\times10^{-3}\,\frac{kg}{sec}$$

Height = h= 120 m

Efficiency = η = 50 %

Power = P =?

Solution:-

$$P = \frac{W}{t}$$

$$P = \frac{mgh}{t}$$

$$P = 8.33\times10^{-3}\times9.8\times120$$

P=9.8 watt

Pump efficiency is 50% therefore the actual power of pump will be

P=19.6 watt

PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No. 6
FLUID STATICS

2023-24

info@practicalcentre.edu.pk
021-34976530
021-34812547
021-34984762
B-14, Block-1,
Gulshan-e-Iqbal, Karachi.
www.practicalcentre.edu.pk

PROBLEMS

1. In a hydraulic press a force of 20 N is applied to a piston of area 0.20 m². The area of the other piston is 2.0 m². What is (a) the pressure transmitted through the fluid; (b) the force on the piston?

Data:

$F_1 = 20$ N
$A_1 = 0.20\ m^2$
$A_2 = 2.0\ m^2$
$P_1 = ?$
$F_2 = ?$

Solution:

For P_1.
By the definition of pressure.

$$P = \frac{F}{A}$$

Or

$$P_1 = \frac{F_1}{A_1}$$

$$P_1 = \frac{20}{0.2}$$

$$P_1 = 100 \text{ Pa}$$

For F_2.
By the mechanical advantage of hydraulic press.

$$M.A = \frac{A_2}{A_1} = \frac{F_2}{F_1}$$

$$\frac{2.0}{0.20} = \frac{F_2}{20}$$

$$10 = \frac{F_2}{20}$$

$$F_2 = 10 \times 20$$

$$F_2 = 200 \text{ N}$$

2. The pressure in a water pipe in the ground floor of a building is 4×10^5 Pa but three floors up it is only 2×10^5 Pa. What is the height between the ground floor and the third floor? The water in the pipe may be assumed to be stationary; density of water $= 1 \times 10^3$ Kg/m^3.

Data:

$P_1 = 4 \times 10^5$ Pa
$P_2 = 2 \times 10^5$ Pa
$h = ?$
$\rho = 1 \times 10^3$ Kg/m^3

Solution:

Change in pressure.

$$\Delta P = P_1 - P_2$$

$$\Delta P = 4 \times 10^5 - 2 \times 10^5$$

$$\Delta P = 2 \times 10^5$$

Now by pressure of fluid.

$$\Delta P = \rho g h$$

$$2 \times 10^5 = (1 \times 10^3)(9.8)\, h$$

$$h = \frac{2 \times 10^5}{(1 \times 10^3)(9.8)}$$

$$h = \frac{2 \times 10^5}{9800}$$

$$h = 20.4 \text{ m}$$

3. The small piston of hydraulic press has an area of 10.0 cm^2. If the applied force is 50.0 N, what must the area of the large piston to exert a pressing force of 4800N?

Data:

$A_1 = 10.0\ cm^2$
$F_1 = 50.0\ N$
$A_2 = ?$
$F_2 = 4800N$

Solution:

By the mechanical advantage of hydraulic press.

$$M.A = \frac{A_2}{A_1} = \frac{F_2}{F_1}$$

$$\frac{A_2}{10.0} = \frac{4800}{50.0}$$

$$\frac{A_2}{10.0} = 96$$

$$A_2 = 96 \times 10.0$$

$$A_2 = 960\ cm^2$$

4. Mechanical advantage of a hydraulic jack is 420. Find the weight of the heaviest automobile that can be lifted by an applied force of 55 N.

Data:

$M.A = 420$
$W = F_2 = ?$
$F_1 = 55\ N$

Solution:

By the mechanical advantage of hydraulic press.

$$M.A = \frac{A_2}{A_1} = \frac{F_2}{F_1}$$

$$420 = \frac{F_2}{55}$$

$$F_2 = 420 \times 55$$

$$F_2 = 23100\ N$$

5. A flat-bottom river barge is 30 ft wide, 85 ft long and 15 ft. deep, (a) how many m^3 of water will displace while the top stays 1 m above the water? (b) What load in tons will the barge contain under these conditions if the empty barge weighs 160 tons in dry dock?

Data:

$w = 30\ ft$
$\ell = 85\ ft$
$d = 15\ ft$
$V = ?\ (m^3)$

Top of barge above water = 1 m = 1 x 3 ft = 3 ft
Height of barge in water = h = d – top of barge above water = 15 – 3 = 12 ft
Load of barge carry = m_{carry} = ? (Tons)
Mass of empty barge = m_b = 160 tons
Weight density of water = ρ_w = 62.4 Lb / ft^3

Solution:

For "V".
By the definition of volume.

$$V = w \times \ell \times h$$
$$V = 30 \times 85 \times 12$$
$$V = 30600\ ft^3 = 3.06 \times 10^4\ ft^3 = 3.1 \times 10^4\ ft^3$$

In m^3.
We know that.
1 ft^3 = 0.0283 m^3

$$V = (3.1 \times 10^4) \times 0.0283 = 877.3\ m^3$$

For "m_{carry}".
Upthrust on barge.

$$F_{up} = \rho\, g\, V$$

Where $\rho\, g$ = weight density = ρ_w

$$F_{up} = \rho_w\, V$$
$$F_{up} = 62.4 \times 3.1 \times 10^4$$
$$F_{up} = 1934400\ Lb = 1.93 \times 10^6\ Lb$$

Weight of empty barge.
1ton = 2000 Lb

$$W_b = 160 \times 2000 = 3.2 \times 10^5\ Lb$$

Weight carried by barge in water.

$$F_{carry} = F_{up} - W_b$$
$$F_{carry} = 1.93 \times 10^6 - 3.2 \times 10^5$$
$$F_{carry} = 1610000\ Lb = 1.61 \times 10^6\ Lb$$

Now

$$m_{carry} = 1.61 \times 10^6 / 2000$$
$$m_{carry} = 805\ tons$$

6. A canal lock gate is 20 m wide and 10 m deep. Calculate the thrust acting on it assuming that the water in the canal is in level with the top of the gate. Density of water is 1000 kg/m³

Data:

w = 20 m
d = h = 10 m
F = ?
Density of water = ρ = 1000 kg / m^3

Solution:
By the definition of pressure.

$$P = \frac{F}{A}$$

Therefore,

Or $F = P A$

For "P", $F = P (w \times h)$ --------(1)

As the water in canal is in level with the top of gate, therefore.

$$P = \frac{(P_{top} + P_{bot})}{2}$$

Where,

$P_{top} = \rho g$ (height of water at top of gate)

$P_{top} = 1000 \times 9.8 \times 0 = 0$ Pa

$P_{bot} = \rho g$ (height of water at bottom of gate)

Hence, $P_{bot} = 1000 \times 9.8 \times 10 = 9.8 \times 10^4$ Pa

$$P = \frac{(0 + 9.8 \times 10^4)}{2}$$

$P = 9.8 \times 10^4 / 2 = 4.9 \times 10^4$ Pa

Now equation (1) becomes.

$F = (4.9 \times 10^4)(20 \times 10)$

$F = (4.9 \times 10^4)(200)$

$F = 9.8 \times 10^6$ N

7. A tank 4 m long, 3 m wide and 2 m deep is filled to the brim with paraffin (density 800 kg/m³). Calculate the pressure on the base? What is the thrust on the base?

Data:

$\ell = 4$ m

$w = 3$ m

$d = h = 2$ m

$P = ?$

$F = ?$

Solution:

For "P".

By the pressure of fluid.

$P = \rho g h$

$P = 800 \times 9.8 \times 2$

$P = 15680$ Pa

For "F".

By the definition of pressure.

$$P = \frac{F}{A}$$

$F = P A = P (\ell \times w)$

$F = 15680 (4 \times 3)$

$F = 188160$ N

Solution:

W_{lift} = upthrust of cold air – thrust of hot air

$W_{lift} = F_{up} - F$

$W_{lift} = \rho_1 g V - \rho_2 g V$

$W_{lift} = (\rho_1 - \rho_2) g V$

$W_{lift} = (1.205 - 0.946) \times 9.8 \times 2200$

$W_{lift} = 0.259 \times 21560$

$W_{lift} = 5584$ N

10. A spherical balloon has a radius of 7.35 m and is filled with helium. How large a cargo can it lift, assuming that the skin and structure of the balloon have a mass of 930 kg? Neglect the buoyant force on the cargo volume itself.

Data:

$r = 7.35$ m

$m_{cargo} = ?$

$m_{ballon} = 930$ kg

$\rho_{He} = 0.179$ kg / m^3

$\rho_{air} = 1.29$ kg / m^3

Solution:

$$F_{up} = W_{cargo} + W_{ballon} + W_{He}$$

$$\rho_{air}\, g\, V = m_{cargo}\, g + m_{ballon}\, g + \rho_{He}\, g\, V$$

$$\rho_{air}\, V = m_{cargo} + m_{ballon} + \rho_{He}\, V$$

Where

$$V = \frac{4}{3}\pi r^3$$

Therefore

$$\rho_{air}\left(\frac{4}{3}\pi r^3\right) = m_{cargo} + m_{ballon} + \rho_{He}\left(\frac{4}{3}\pi r^3\right)$$

$$m_{cargo} = \rho_{air}\left(\frac{4}{3}\pi r^3\right) - \rho_{He}\left(\frac{4}{3}\pi r^3\right) - m_{ballon}$$

$$m_{cargo} = (\rho_{air} - \rho_{He})\left(\frac{4}{3}\pi r^3\right) - m_{ballon}$$

$$m_{cargo} = [(1.29 - 0.179) \times 4/3 \times (3.142)\,(7.35)^3] - 930$$

$$m_{cargo} = [(1.111) \times 4/3 \times (3.142)\,(397.1)] - 930$$

$$m_{cargo} = (5540 / 3) - 930$$

$$m_{cargo} = 1846 - 930$$

$$m_{cargo} = 916 \text{ kg} = 920 \text{ kg}$$

PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No. 7

FLUID DYNAMICS

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

NUMERICALS

Numerical 1:

Two spherical raindrops of equal size are falling through air at a velocity of 0.08 m/s. If the drops join together, forming a large spherical drop, what will be the new terminal velocity?

Data:

$v_t = 0.08$ m/s

$v_T = ?$

Solution:

We know that

$$v_t = \frac{2r^2\rho g}{9\eta}$$

Also

$$v_T = \frac{2R^2\rho g}{9\eta}$$

By dividing

$$\frac{v_T}{v_t} = \frac{R^2}{r^2}$$

$$\frac{v_T}{v_t} = \left(\frac{R}{r}\right)^2 ----(1)$$

When two similar spheres combine together to form a single large sphere, then,

$$V_1 + V_2 = V$$

$$\frac{4}{3}\pi r^3 + \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$2\left(\frac{4}{3}\pi r^3\right) = \frac{4}{3}\pi R^3$$

$$2r^3 = R^3$$

$$\frac{R^3}{r^3} = 2$$

$$\frac{R}{r} = (2)^{1/3}$$

Now equation (1),

$$\frac{v_T}{v_t} = \left(\frac{R}{r}\right)^2$$

$$\frac{v_T}{0.08} = \left[(2)^{1/3}\right]^2$$

$$v_T = 0.08\,(2)^{2/3}$$

$$v_T = 0.08\,(1.587)$$

$$v_T = 0.126 = 0.13 \text{ m/s}$$

Numerical 2:

Calculate the viscous drag on a drop of oil, of 0.1 mm radius, falling through air at this terminal velocity. (Viscosity of air = 1.8x10 Pa. s; density of oil = 850 kg/m³)

Data:

$r = 0.1\ mm = 0.1 \times 10^{-3}\ m$

$\eta = 1.8 \times 10^{-5}\ Pa.s$

$\rho = 850\ kg/m^3$

$F_d = ?$

$v_t = ?$

Solution:

For "v_t".

We know that

$$v_t = \frac{2r^2\rho g}{9\eta}$$

$$v_t = \frac{2(0.1 \times 10^{-3})^2(850)(9.8)}{9(1.8 \times 10^{-5})}$$

$$v_t = \frac{2(1 \times 10^{-8})(850)(9.8)}{1.62 \times 10^{-4}}$$

$$v_t = \frac{1.66 \times 10^{-4}}{1.62 \times 10^{-4}}$$

$$v_t = 1.024\ m/s$$

For "F_d".

By Stoke`s law

$$F_d = 6\pi\eta r v_t$$

$$F_d = 6(3.142)(1.8 \times 10^{-5})(0.1 \times 10^{-3})(1.024)$$

$$F_d = 3.48 \times 10^{-8}\ N$$

Numerical 3:

What area must a heating duct have if air moving 3.0 m/s along it can replenish the air every 15 minutes in a room of volume 300 m³? Assume air density remains constant.

Data:

$A = ?$

$v = 3.0\ m/sec$

$t = 15\ minutes = 15 \times 60 = 900\ sec$

$V = 300\ m^3$

Solution:

By the rate of volume of fluid,

$$\frac{V}{t} = Av$$

$$A = \frac{V}{vt}$$

$$A = \frac{300}{3 \times 900}$$

$$A = \frac{300}{2700}$$

$$A = 0.11\ m^2$$

Numerical 4:

Water circulates throughout a house in a hot-water heating system. If the water is pumped at a speed of 0.50 m/s through a 4.0 cm diameter pipe in the basement under a pressure of 3.0 atm, what will be the flow speed and pressure in a 2.6 cm diameter pipe on the second floor 5.0 m above? Assume the pipes do not divide into branches.

Data:

$v_1 = 0.50$ m/s

$d_1 = 4.0$ cm $= 0.04$ m

$r_1 = d_1 / 2 = 0.04 / 2 = 0.02$ m

$P_1 = 3.0$ atm $= 3.0\,(1.01 \times 10^5) = 3.03 \times 10^5$ Pa

$v_2 = ?$

$d_2 = 2.6$ cm $= 0.026$ m

$r_2 = d_2 / 2 = 0.026 / 2 = 0.013$ m

$h = 5.0$ m

Solution:

For "v_2".

By the equation of continuity.

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1 v_1}{A_2}$$

$$v_2 = \frac{\pi r_1^2 v_1}{\pi r_2^2}$$

$$v_2 = \frac{r_1^2 v_1}{r_2^2}$$

$$v_2 = \frac{(0.02)^2 (0.5)}{(0.013)^2}$$

$$v_2 = \frac{(4 \times 10^{-4})(0.5)}{1.69 \times 10^{-4}}$$

$$v_2 = \frac{2 \times 10^{-4}}{1.69 \times 10^{-4}}$$

$$v_2 = 1.18 = 1.2 \frac{m}{s}$$

For "P_2".

From Bernoulli`s equation.

$$(P_1 - P_2) = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho g h_2 - \rho g h_1$$

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho g h$$

$$P_1 - P_2 = \rho\left(\frac{1}{2} v_2^2 - \frac{1}{2} v_1^2 + g h\right)$$

$$3.03 \times 10^5 - P_2 = 1000\left[\frac{1}{2}(0.12)^2 - \frac{1}{2}(0.5)^2 + 9.8(5)\right]$$

$$3.03 \times 10^5 - P_2 = 1000\left[\frac{1}{2}(0.0144) - \frac{1}{2}(0.25) + 49\right]$$

$$3.03 \times 10^5 - P_2 = 1000\,[7.2 \times 10^{-3} - 0.125 + 49]$$

$$3.03 \times 10^5 - P_2 = 1000\,(48.9)$$

$$3.03 \times 10^5 - P_2 = 4.89 \times 10^4$$

$$P_2 = 3.03 \times 10^5 - 4.89 \times 10^4$$

$$P_2 = 2.541 \times 10^5 \text{ Pa}$$

In atm,

$$P_2 = \frac{2.541 \times 10^5}{1.01 \times 10^5}$$

$$P_2 = 2.51 \text{ atm}$$

Numerical 5:

What is the volume rate of flow of water from a 1.85 cm diameter faucet if the pressure head is 12 m?

Data:

$V/t = ?$

$d = 1.85 \text{ cm} = 0.0185 \text{ m}$

$r = d/2 = 0.0185/2 = 9.25 \times 10^{-3} \text{ m}$

$h = 12 \text{ m}$

Solution:

By the volume rate of flow of fluid.

$$\frac{V}{t} = A\,v \text{ ----(1)}$$

For "A".

$$A = \pi r^2$$

$$A = 3.142\,(9.25 \times 10^{-3})^2$$

$$A = 2.69 \times 10^{-4} \text{ m}^2$$

For "v".

By the energy transformation.

$$K.E = P.E$$

$$\frac{1}{2} m v^2 = mgh$$

$$v = \sqrt{2gh}$$

$$v = \sqrt{2\,(9.8)\,(12)}$$

$$v = 15.33 \frac{m}{s}$$

Now equation (1).

$$\frac{V}{t} = (2.69 \times 10^{-4})(15.33)$$

$$\frac{V}{t} = 4.13 \times 10^{-3} \frac{m^3}{s}$$

Numerical 6:

The stream of water emerging from a faucet 'neck down' as it falls. The cross-sectional area is 1.2 cm² and 0.35 cm². The two levels are separated by a vertical distance of 45 mm as shown in figure. At what rate does water flow from the tap?

Data:

$A_1 = 1.2\ cm^2$

$A_2 = 0.35\ cm^2$

$h = 45\ mm = 4.5\ cm$

$V / t = ?$

Solution:

By the volume rate of flow of fluid.

$$\frac{V}{t} = A\,v$$

$$\frac{V}{t} = A_2\,v \quad \text{----(1)}$$

For "v".

By using the formula.

$$v = \sqrt{\frac{2\,g\,h\,A_2^2}{A_1^2 - A_2^2}}$$

$$v = \sqrt{\frac{2\,(980)\,(4.5)\,(0.35)^2}{(1.2)^2 - (0.35)^2}}$$

$$v = \sqrt{\frac{2\,(980)\,(4.5)\,(0.1225)}{(1.44) - (0.1225)}}$$

$$v = \sqrt{\frac{1080.45}{1.3175}}$$

$$v = \sqrt{820.07}$$

$$v = 28.63\ \frac{cm}{s}$$

Now equation (1).

$$\frac{V}{t} = A_2\,v$$

$$\frac{V}{t} = (1.2)(28.63)$$

$$\frac{V}{t} = 34.4\ \frac{cm^3}{s}$$

Numerical 7:

Water leaves the jet of a horizontal hose at 10 m/s.. If the velocity of water within the hose is 0.40 m/s, calculate the pressure within the hose. Density of water is 1000 kg/m² and atmospheric pressure is 100000 Pa.

Data:

$v_1 = 10\ m/s$

$v_2 = 0.40\ m/s$

$P_2 = ?$

$\rho = 1000\ kg/m^3$

$P_1 = 100000\ Pa$

Solution:

From Bernoulli`s equation.

$$(P_1 - P_2) = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho g h_2 - \rho g h_1$$

Also

$$(P_1 - P_2) = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$$

$$(P_1 - P_2) = \frac{1}{2}\rho (v_2^2 - v_1^2)$$

$$(100000 - P_2) = \frac{1}{2} 1000 [(0.4)^2 - (10)^2]$$

$$(100000 - P_2) = 500 [0.16 - 100]$$

$$(100000 - P_2) = 500 [-99.84]$$

$$(100000 - P_2) = -49920$$

$$P_2 = 100000 + 49920$$

$$P_2 = 1.49 \times 10^5\ Pa = 1.5 \times 10^5\ Pa$$

Numerical 8:

What is the maximum weight of an aircraft with a wing area of 50 m² flying horizontally, if the velocity of the air over the upper surface of the wing is 150 m/s and that of the lower surface is 140 m/s? Density of air is 1.29 kg/m³.

Data:

$W = ?$

$A = 50\ m^2$

$v_1 = 140\ m/s$

$v_2 = 150\ m/s$

$\rho = 1.29\ kg/m^3$

Solution.

From Bernoulli's equation.

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$$

$$\Delta P = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

$$\frac{F}{A} = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

$$F = \frac{1}{2}\rho A(v_2^2 - v_1^2)$$

But $F = w$

$$w = \frac{1}{2}\rho A(v_2^2 - v_1^2)$$

$$w = \frac{1}{2}(1.29)(50)[(150)^2 - (140)^2]$$

$$w = \frac{1}{2}(64.5)[(22500) - (19600)]$$

$$w = \frac{1}{2}(64.5)(2900)$$

$$w = \frac{1}{2}(187050)$$

$$w = 93525N$$

Numerical 9:

A liquid flows through a pipe with a diameter of 0.50 m at a speed of 4.20 m/s. What is the rate of flow in L/min?

Data:

$d = 0.50$ m

$r = d/2 = 0.50 / 2 = 0.25$ m

$v = 4.20$ m/s

$V / t = ?$

Solution:

From the rate of volume of fluid.

$$\frac{V}{t} = Av$$

Where $A = \pi r^2$

$$\frac{V}{t} = \pi r^2 v$$

$$\frac{V}{t} = (3.142)(0.25)^2 (4.20)$$

$$\frac{V}{t} = (3.142)(0.0625)(4.20)$$

$$\frac{V}{t} = 0.8247 \ \frac{m^3}{s}$$

But $1m^3 = 1000$ litre

And $1s = 1/60$ minutes

$$\frac{V}{t} = 0.8247 \times 1000 \times 60$$

$$\frac{V}{t} = 49486.5 = 49500 \ \frac{\text{litre}}{\text{minute}}$$

Numerical 10:

Calculate the average speed of blood flow in the major arteries of the body, which have a total cross-sectional area of about 2.1 cm². Use the data of example.

Data:

$A_{areries} = A_2 = 2.1cm^2$

$r_{aorta} = r_1 = 1.2$ cm

$v_{aorta} = v_1 = 40$ cm / s

$v_{arteries} = v_2 = ?$

Solution:

By equation of continuity.

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1 v_1}{A_2}$$

$$v_2 = \frac{\pi r_1^2 v_1}{A_2}$$

$$v_2 = \frac{(3.142)(1.2)^2 (40)}{2.1}$$

$$v_2 = \frac{(3.142)(1.44)(40)}{2.1}$$

$$v_2 = \frac{181}{2.1}$$

$$v_2 = 86.2 \ \frac{cm}{s}$$

PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No. 8

ELECTRIC FIELDS

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

NUMERCICALS

1. (a) Calculate the value of two equal charges if they repel one another with a force of 0.1 N when situated 50 cm apart in a vacuum.
(b) What would be the size of the charges if they were situated in an insulating liquid whose permittivity was ten times that of a vacuum?

(a)

$q_1 = q$
$q_2 = q$
$F = 0.1N$
$\sum = 50cm$
$= \frac{50}{100} = 0.5m$

(b) q
$\varepsilon_r = 10\varepsilon_o$

Sol:

$$F = \frac{Kq_1q_2}{r^2}$$
$$F = \frac{Kqq}{r^2}$$
$$\frac{F}{1} = \frac{Kq^2}{r^2}$$
$$Kq^2 = F \times r^2$$
$$9\times10^9\times q^2 = 0.1\times(0.5)^2$$
$$9\times10^9\times q^2 = 0.025$$
$$q^2 = \frac{0.025}{9\times10^9}$$
$$q^2 = 2.77\times10^{-12}$$
$$q = \sqrt{2.77\times10^{-12}}$$
$$q = 1.666\times10^{-6}C$$

or

$$q = 1.7\times10^{-6}C$$
$$q = 1.7\,\mu c$$

(b) Now

$$Kq^2 = F'\times r^2$$
$$Kq^2 = \frac{F}{10}\times r^2$$
$$9\times10^9\times q^2 = \frac{0.1}{10}\times(0.5)^2$$
$$q^2 = \frac{0.01\times(0.5)^2}{9\times10^9}$$
$$q^2 = 2.77\times10^{-13}$$
$$q = \sqrt{2.77\times10^{-13}}$$
$$q = 5.27\times10^{-7}\,c$$

2. How far apart must two protons be, if the magnitude of the electrostatic force, acting on either one due to the other, is equal to the magnitude of the gravitational force on a proton at Earth's surface?(mass of proton = 1.67×10^{-27} kg, charge of proton = 1.6×10^{-19} coulomb)

Data:

$q_1 = 1.6\times10^{-19}c$
$q_2 = 1.6\times10^{-19}c$
$m = 1.67\times10^{-27}kg$
$r = ?$

coulomb's force = gravition force on proton

$$\frac{Kq_1q_2}{r^2} = mg$$
$$\frac{Kq_1q_2}{mg} = r^2$$
$$\frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{1.67\times10^{-27}\times9.8} = r^2$$
$$\frac{2.304\times10^{-28}}{1.6366\times10^{-26}} = r^2$$
$$0.01407 = r^2$$
$$\sqrt{0.01407} = r^2$$

Or $0.1186 = r$
$0.119m = r$

The two protons must be 0.119 meter apart.

An electron of charge 1.6×10^{-19} C is situated in a uniform electric field of intensity 1200-volt cm^{-1}. Find the force on it, its acceleration, and the time it takes to travel 2 cm from rest (electronic mass, m, = 9.1×10^{-31} kg).

Data:-

$q = 1.6 \times 10^{-19} c$

$E = 1200\ Vcm^{-1}$

$= \frac{1200V}{cm}$

$= \frac{1200V}{0.01m}$

$= 120000\ Vm^{-1}$

$S = 0.02m$

$F = ?$

$a = ?$

$t = ?$

Sol:- Force:

$E = \frac{F}{q}$

$F = qE$

$F = 1.6 \times 10^{-19} \times 120000$

$F = 1.92 \times 10^{-14}$ N

Acceleration:

$a = \frac{F}{m}$

$a = \frac{1.92 \times 10^{-14}}{9.1 \times 10^{-31}}$

$= 2.109 \times 10^{16}\ m/s^2$

Time it takes to travel:

$S = Vit + \frac{1}{2} a t^2$

$0.02 = (0 \times t) + \frac{1}{2} \times 2.109 \times 10^{16} \times t^2$

$0.02 = \frac{1}{2} \times 2.109 \times 10^{16} \times t^2$

$\frac{2 \times 0.02}{2.109 \times 10^{16}} = t^2$

$1.8958 \times 10^{-18} = t^2$

$\sqrt{1.8958 \times 10^{-18}} = t$

$1.37 \times 10^{-9} s = t$

4. An alpha particle (the nucleus of a helium atom) has a mass of 6.64×10^{-27} kg and a charge of 2e. What are the (a) magnitude and (b) direction of the electric field that will balance the gravitational force on the particle?

Data:-

$m = 6.64 \times 10^{-27}$ kg

$q = 2e = 2 \times 1.6 \times 10^{-19} c$

(a) $E = ?$

Solution:-

Electric force = gravitational force

$qE = W$

$qE = mg$

$E = \frac{mg}{q}$

$= \frac{6.64 \times 10^{-27} \times 9.8}{2 \times 1.6 \times 10^{-19}}$

$E = \frac{6.5072 \times 10^{-26}}{3.2 \times 10^{-19}}$

$E = 2.03 \times 10^{-7}$ N/C

Electric fied is directed upward.

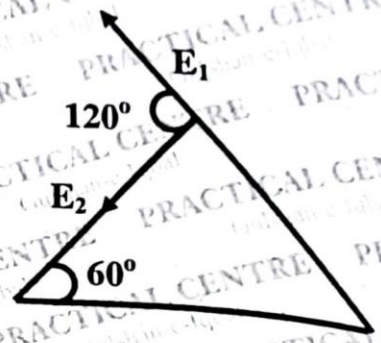
5. A proton and an electron form two corners of an equilateral triangle of side length 2.0×10^{-6} m. What is the magnitude of the net electric field which these two particles produce at the third corner?

Data

$r = 2.0 \times 10^{-6}$m

$q_p = 1.6 \times$ [illegible]

$q_e = 1.6 \times 10^{-9}$c



Solution:

Electric field due to electron

$$E_1 = \frac{Kq}{r^2}$$

$$E_1 = \frac{9\times10^9 \times 1.6\times10^{-19}}{(2\times10^{-6})^2}$$

$$E_1 = \frac{1.44\times10^{9}}{(4\times10^{-12})}$$

$E_1 = 360N$

E due to proton

$$E_2 = \frac{Kq}{r^2}$$

$$E_1 = \frac{Kq}{r^2}$$

$$E_1 = \frac{9\times10^9 \times 1.6\times10^{-19}}{(2\times10^{-6})^2}$$

$E_1 = 360N$

Net electric field.

$$E = \sqrt{E_1^2 + E_2^2 2E_1E_2 \cos\theta}$$

$$E = \sqrt{(360)^2 + (360)^2 2(360)(360)\cos 120^\circ}$$

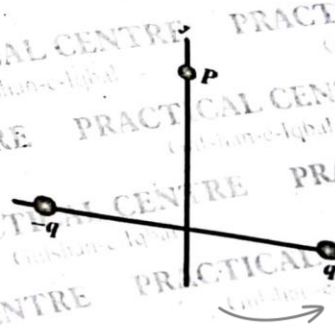
$$E = \sqrt{129600 + 129600 + 259200\times(-0.5)}$$

$$E = \sqrt{129600 + 129600 - 129600}$$

$$E = \sqrt{129600}$$

$E = 360.N/c$

6. Figure shows two charged particles on an x axis: $-q = -3.20 \times 10^{-19}$ C at x = -3.00 m and $q = 3.20 \times 10^{-19}$ C at x = 3.00 m. What are the (a) magnitude and (b) direction (relative to the positive direction of the x axis) of the net electric field produced at point P at y = 4.00 m?



Data:

Net electric field due to dipole.

$E_{net} = E_{(+)}\cos\theta + E_{(-)}\cos\theta$

$E_{(+)} = E_{(-)}$

$E_{net} = E\cos\theta + E\cos\theta$

$= 2E\cos\theta$

$$E = 2\left(\frac{Kq}{r^2}\right) \times \cos\theta$$

$$E = \frac{2Kqd}{r^3} \quad [r = (d^2 + y^2)^{1/2}]$$

$$E = \frac{2\times9\times10^9\times3.20\times10^{-19}\times3}{[(2)^2+(4)^2]^{3/2}}$$

$$E = \frac{1.728\times10^{-8}}{125}$$

$$E = 1.38\times10^{-10}\ N/c$$

7. A proton and an electron form two corners of an equilateral triangle of side length 5 μm. What is the magnitude of the net electric field these two particles produce at the third corner?

Solution:

$$E_{net} = E_{(+)}\cos\theta + E_{(-)}\cos\theta$$

$$E_{(+)} = E_{(-)}$$

$$E_{net} = E\cos\theta + E\cos\theta$$

$$= 2E\cos\theta$$

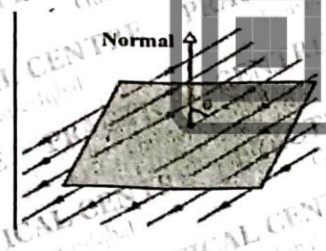
$$= 2\left(\frac{Kq}{r^2}\right)\times\cos\theta$$

$$= \frac{2\times9\times10^9\times1.6\times10^{-19}\times\cos60^\circ}{(5\times10^{-6})^2}$$

$$= \frac{2\times9\times10^9\times1.6\times10^{-19}\times0.5}{2.5\times10^{-11}}$$

$$E_{net} = 57.6\ N/c$$

8. The square surface shown in the figure measures 3.2 mm on each side. It is immersed in a unifrom electric field with magnitude E = 1800 N/C and with field lines at an angle of θ = 35° with a normal to the surface, as shown. Take that normal to be directed " outward," as though the surface were one face of a box, calculate the electric flux throudh the surface.



Data:

$r = 3.2\ mm$
$= 3.2\times10^{-3} m$
$E = 1800\ N/c$
$\theta = 35^\circ$
$A = L\times b$
$= 3.2\times10^{-3}\times3.2\times10^{-3}$
$A = 1.024\times10^{-5} m^2$

Solution:

$\Phi = EA\cos\theta$
$\Phi = 1800\times1.024\ 10^{-5}\cos35^\circ$
$= 1800\times1.024\times10\text{-}5\times0.8191$
$= 0.01509$
$\Phi = 1.509\times10^{-2} N.m^2/c$

9. An electron is liberated from the lower of two large parallel metal plates separated by a distance h = 2 cm. The upper plate has a potential of 2400 volts rlavtive to the lower. How long does the electron take to reach it?

Data:

$V = 2400V$

$d = 2cm = 0.02m$

$E = ?$

$t = ?$

Solution:

$V = Ed$

$E = \frac{V}{d}$

$E = \frac{2400}{0.02}$

$E = 120000$

$F = qE$

$F = 1.6 \times 10^{-19} \times 1.2 \times 10^{5}$

$F = 1.92 \times 10^{-14} N$

$F = ma$

$a = \frac{F}{m}$

$a = \frac{1.92 \times 10^{-14}}{9.1 \times 10^{-31}}$

$a = 2.109 \times 10^{16} m/s^2$

$s = V_i t + \frac{1}{2} at^2$

$0.02 = (0 \times t) \frac{1}{2} \times 2.109 \times 10^{16} t^2$

$0.02 = 0.5 \times 2.109 \times 10^{16} t^2$

$\frac{0.02}{0.5 \times 2.109 \times 10^{16}} = t^2$

$1.8966 \times 10^{-16} = t^2$

$\sqrt{1.8966 \times 10^{-16}} = t^2$

$1.37 \times 10^{-9} sec = t$

10. Two large parallel metal plates are 1.5cm apart and have charges of equal magnitude but opposite sign on their facing surfaces. Take the potential of the negative plate to be zero. If the potential halfway between the plates is then 5.0V, what is the electric field in the region between the plates?

Data:

$d = 1.5cm$

$= \frac{1.5}{100} = 0.015m$

$V_1 = 0$

$V_2 = 5V$

Solution:

$E = \frac{\Delta V}{\frac{d}{2}}$

$E = \Delta V \times \frac{2}{d}$

$= 2 \frac{\Delta V}{d}$

$= \frac{2 \times (V_2 - V_1)}{d}$

$= \frac{2 \times (5 - 0)}{0.015}$

$= \frac{2 \times (5)}{0.015}$

$E = 6.666 \times 10^{-2} v/m$

$E = 6.7 \times 10^{2} v/m$

PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No. 9

CAPACITORS

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

NUMERICAL

Q.1 The capacitance of an air-filled parallel-plate capacitor is 1.3pF. If the separation of the plates is doubled and wax is inserted between them, the new capacitance is 2.6 pF. Find the dieletric constant of the wax.

$$C_o = \frac{\varepsilon_o A}{d} \text{ ---------- } (1)$$

The capacitance of parallel plates when dielectric slab is the medium between the plates.

$$C = \frac{\varepsilon_o \varepsilon_r A}{2d} \text{ ---------- } (2)$$

Dividing equation (2) by equation (1)

$$\frac{C}{\varepsilon_o} = \frac{\frac{\varepsilon_o \varepsilon_r A}{2d}}{\frac{\varepsilon_o A}{d}}$$

$$\frac{2.6}{1.3} = \frac{\varepsilon_o \varepsilon_r A}{2d} \times \frac{d}{\varepsilon_o A}$$

$$2 = \frac{\varepsilon_r}{2}$$

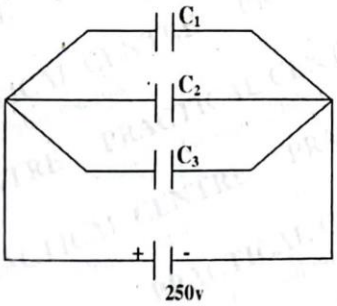
$$4 = \varepsilon_r$$

Q.2 Three capacitors have capacitances 10, 50 and 25 μF respectively as shown in the figure. Calculate (i) charge on each when connected in parallel to a 250 V supply (ii) total capacitance and (iii) potential difference across each when connected in series.

Data:

$C_1 = 10\mu F$
$C_2 = 50\mu F$
$C_3 = 25\mu F$
$V = 250V$

(a) Three capacitors are connected in parallel.



(i) Total capacitance

$Ce = C_1 + C_2 + C_3$

$Ce = 10 + 50 + 25$

$Ce = 85\mu F$

Charge on capacitor C_1

$$Q_1 = C_1V$$

$$Q_1 = 10 \times 10^{-6} \times 250$$

$$Q_1 = 2.5 \times 10^{-3}C$$

Charge on capacitance C_2

$$Q_2 = C_2V$$

$$Q_2 = 50 \times 10^{-6} \times 250$$

$$Q_2 = 5 \times 10^{-3}c$$

Charge on capacitance C_3

$$Q_3 = C_3V$$

$$Q_3 = 25 \times 10^{-6} \times 250$$

$$Q_3 = 6.25 \times 10^{-3}C$$

Or $Q_3 = 6.25mC$

P.d. across each capacitance is same

P.d. across C_1

$V_1 = 250V$

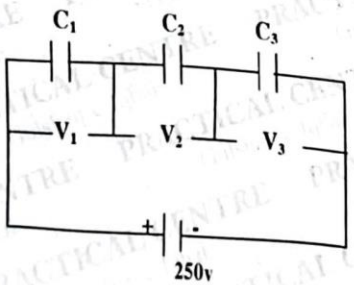
P.d. across C_2

$V_2 = 250V$

P.d. across C_3

$V_3 = 250V$

(b) Total capacitance



$$\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_e} = \frac{1}{10} + \frac{1}{50} + \frac{1}{25}$$

$$\frac{1}{C_e} = \frac{5+1+2}{50}$$

$$\frac{1}{C_e} = \frac{8}{50}$$

$$C_e = \frac{50}{8} = 6.25\,\mu F$$

$$Q_e = Ce\,V$$

$$Q_e = 6.25 \times 10^{-6} \times 250$$

$$Q_e = 1562.5 \times 10^{-6} c$$

P.d across C_1

$$Q_e = C_1 V_1$$

$$V_1 = \frac{Q_e}{C_1}$$

$$V_1 = \frac{1562.5 \times 10^{-6}}{10 \times 10^{-6}}$$

$$V_1 = 156.25 \text{ Volt}$$

P.d across C_2

$$V_2 = \frac{Q_e}{C_2}$$

$$V_2 = \frac{1562.5 \times 10^{-6}}{50 \times 10^{-6}}$$

$$V_2 = 31.25 \text{ Volt}$$

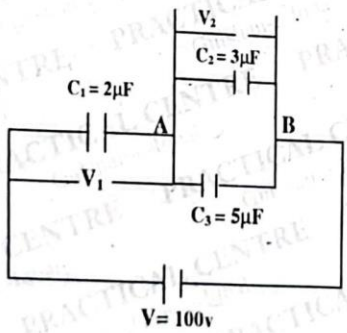
P.d across C_3

$$V_3 = \frac{Q_e}{C_3}$$

$$V_3 = \frac{1562.5 \times 10^{-6}}{25 \times 10^{-6}}$$

$$V_3 = 62.5 \text{ Volt}$$

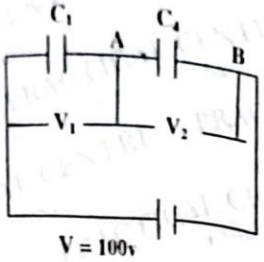
Q.3 **Three capacitors are connected through a potential difference of 100 volts as shown in the figure. Find the charges and potential difference across each capacitor.**



C_2 & C_3 are in parallel

$$C_4 = C_2 + C_3$$

$$C_4 = 3 + 5 = 8\mu F$$



C_1 & C_4 are in series

$$C_e = \frac{C_1 \times C_2}{C_1 + C_4} = \frac{2 \times 8}{2 + 8}$$

$$C_e = \frac{16}{10} = 1.6\,\mu F$$

Total charge

$$Q_e = C_e V$$

$$Q_e = 1.6 \times 10^{-6} \times 100$$

$$Q_e = 160 \times 10^{-6} C$$

P.d. across C_1

$$V_1 = \frac{Q_e}{C_1} = \frac{160 \times 10^{-6}}{2 \times 10^{-6}}$$

$$V_1 = 80 \text{ Volt}$$

P.d. across A & B

$$V_2 = \frac{Q_e}{C_4}$$

$$V_2 = \frac{160 \times 10^{-6}}{8 \times 10^{-6}} = 20V$$

P.d. across C_2

$$V_2 = 20V$$

P.d. across C_3

$$V_3 = V_2$$

$$V_3 = 20V$$

Charge on C_1

$$C_1 = Q_e = 160 \times 10^{-6} C$$

Charge on C_2

$$Q_2 = C_2V_2 = 3 \times 10^{-6} \times 20$$

$$Q_2 = C_2V_2 = 60 \times 10^{-6}\ C$$

Charge on C_3

$$Q_3 = C_3V_3 = 5 \times 10^{-6} \times 20 = 100 \times 10^{-6} C$$

4. Capacitor is charged through a large non-reactive resistance by a battery of a constant voltage V. For this arrangement, if the capacitor has a capacitance of 10 μ F and the resistance is 1 M Ω, calculate the time taken for the capacitor to receive 90% of its final charge.

Data:

$$C = 10\mu F = 10 \times 10^{-6}\ F$$

$$R = 1M\ \Omega = 1 \times 10^{6}\ \Omega$$

$$Q = 90\%\ Q_o$$

$$Q = 0.9\ Q_o$$

Solution:

$$Q = Q_o(1 - (1 - e^{\frac{-t}{c}})$$

$$0.9\ Q_o = Q_o(1 - e^{\frac{-t}{c}})$$

$$0.9 = 1 - e^{\frac{-t}{Rc}}$$

$$Rc = 1 \times 10^{6} \times 10 \times 10^{-6}$$

$$Rc = 10$$

$$0.9 = 1 - e^{\frac{-t}{10}}$$

$$e^{\frac{-t}{10}} = 1 - 0.9$$

$$e^{\frac{-t}{10}} = 0.1$$

Taking *ln* on both the sides,

$$ln\,(e^{\frac{-t}{10}}) = ln\,(0.1)$$

$$ln\,(e^{-1t}) = ln\,(0.1)$$

$$-0.1t\ ln\,(e) = ln\,(0.1)$$

$$-0.1\,t = -2.3$$

$$t = 23\ sec.$$

5. What capacitance is required to store energy of 10 kWh at a potential difference of 1000 V?

Data:

$U = 10k\ wh$

$U = 10x100\ x3600$

$U = 3600\ 000\ J = 3.6 \times 10^6\ J$

$V = 1000\ V$

Solution:

$$U = \frac{1}{2}CV^2$$

$$36 \times 10^6 = \frac{1}{2} \times C \times (1000)^2$$

$$2 \times 36 \times 10^6 = C \times 1000000$$

$$72 \times 10^6 = C \times 10^6$$

$$\boxed{72\ F = C}$$

6. A 2.0 μF capacitor and 4.0 μF capacitor are connected in parallel across a 300 V potential difference. Calculate the total energy stored in the capacitors.

Data:

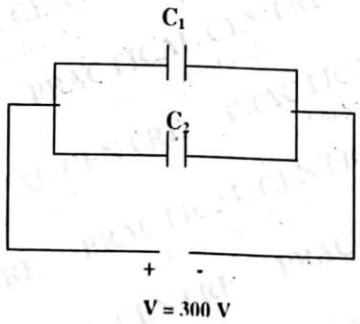
$C_1 = 2.0\mu F = 2.0x10^{-6}\ F$

$C_2 = 4.0\mu F = 4.0x10^{-6}\ F$

$V = 300V$

$U = ?$

Solution:



$C = C_1 + C_2$

$C = 2.0 + 4.0 = 6.0\mu F$

7. A 12.0-V battery is connected to a capacitor, resulting in 54.0 μC of charge stored in the capacitor. How much energy is stored in the capacitor?

Data:

$V = 12.0V$

$Q = 54.0\mu C$

$Q = 54.0 \times 10^{-6} C$

Solution:

$$U = \frac{1}{2} Q V$$

$$U = \frac{1}{2} \times 54.0 \times 10^{-6} \times 12.0$$

$$U = 324 \times 10^{-6} J$$

or $$U = 3.24 \times 10^{-4} J$$

PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No. 10

DC CIRCUIT

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

NUMERICALS

Q.1 The storage battery of a car has an emf of 12 V. If the internal resistance of the battery is 0.5Ω, what is the maximum current that can be drawn from the battery?

Data:

$E = 12V$

$r = 0.5\Omega$

$I = ?$

Formula:

$E = Ir$

$I = \frac{E}{r}$

$I = \frac{12}{0.5} = \frac{120}{5} = 24$ volt Ans.

Q.2 A negligible small current is passed through a wire of length 12m and uniform cross section $4.0 \times 10^{-7} m^2$, and its resistance is measured to be 6.0 Ω. What is the resistivity of the material at the temperature of the experiment?

Data:

$L = 12m$

$A = 4 \times 10^{-7} m^2$

$R = 6.0\Omega$

$\rho = ?$

Formula:

$R = \frac{\rho L}{A}$

$\rho = \frac{AR}{L}$

$= \frac{4 \times 10^{-7} \times 6.0}{12}$

$= 2 \times 10^{-7}\ \Omega.m$ Ans.

Q.3 In a potentiometer arrangement, a cell of emf 1.20 V gives a balance point at 40.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 74.0 cm, what is the emf of the second cell?

Data:

$E_1 = 1.20$ volt

$L_1 = 40.0cm$

$L_2 = 74.0cm$

$E_2 = ?$

Formula:

$\frac{E_1}{E_2} = \frac{L_1}{L_2}$

$\frac{E_2}{E_1} = \frac{L_2}{L_1}$

$E_2 = \frac{L_2}{L_1} \times E_1$

$= \frac{74 \times 1.2}{40}$

$E_2 = 2.22$ volt Ans.

Q.4 (a) Three resistors 1 Ω, 2 Ω, 3 Ω are combined in series. What is the equivalent resistance?

(b) If the combination is connected to a battery of emf 24 V and negligible internal resistance, obtain the potential drop across each resistor.

Data:

$R_1 = 1\Omega$

$R_2 = 2\ \Omega$

$R_3 = 3\Omega$

$R = ?$

Formula:

(a) $R = R_1 + R_2 + R_3$

$= 1+2+3 = 6\Omega$ **Ans**

(b) $V = 24$ volt

$V_1 = ?$

$V_2 = ?$

$V_3 = ?$

By Ohm's law

$V = I.R$

$I = \frac{V}{R} = \frac{24}{6}$

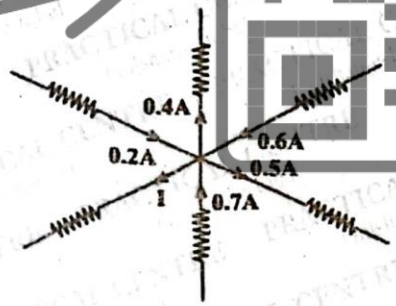
$I = 4A$

$V_1 = IR_1 = 4x1 = 4$volt Ans.

$V_2 = IR_2 = 4x2 = 8$ volt Ans.

$V_3 = IR_3 = 4x3 = 12$ volt Ans.

Q.5 From the given circuit finds the value of I.



Data:

$I_1 = 0.4A$

$I_2 = 0.6A$

$I_3 = 0.5A$

$I_4 = 0.7A$

$I_5 = I = ?$

$I_6 = 0.2A$

From Kirchhoff's current law

Current flowing towards the node = current flowing away from the node

$I_6 + I_2 + I_4 = I_1 + I_3 + I$

$0.2 + 0.6 + 0.7 = 0.4 + 0.5 + I$

$1.5 = 0.9 + I$

$1.5 - 0.9 = I$

$I = 0.6$ A Ans.

Q.6 In a meter bridge with a standard resistance of 15 Ω in the right gap, the ratio of balancing length is 5:3. Find the value of the other resistance.

$\ell_1 : \ell_2 = 5 : 3$

Resistance in the right gap

$= R_2 = 15\,\Omega$

Resistance in the left gap = R_1 = ?

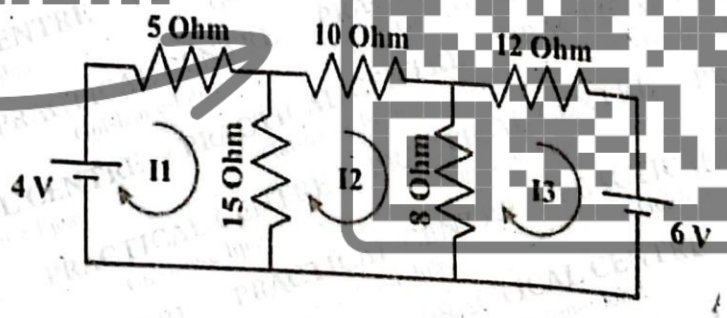
$$\frac{R_1}{R_2} = \frac{\ell_1}{\ell_2}$$

$$R_1 = \frac{\ell_1}{\ell_2} x R_2$$

$$R_1 = \frac{5}{3} x 25$$

$$R_1 = \frac{75}{3} = 25\,\Omega \quad \textbf{Ans.}$$

Q.7 By using KVL find current flowing through 10 Ω resistances.



First loop:

$E_1 = V_5 + V_{15}$

$4 = 5xI_1 + 15x(-I, + I_2)$

$4 = 5I_1 - 15I, + 15I_2$

$4 = -70I, + 15I_2$

First loop:

$2\ V = 0$

$V_{15} + V_{10} + V_8 = 0$

$15\ (I_1 - I_2) + 10 \times I_2 + 8\ (I_2 - I_3) = 0$

$15I_1 - 15I_2 + 10I_2 + 8I_2 - 8I_3 = 0$

$15I_1 + 3I_2 - 8I_3 = 0$.....(2)

Third loop:

$+6 = V_8 + V_{12}$

$+6 = 8(I_2 - I_3) + 12(I_3) = 0$

$+6 = 8I_2 - 8I_3 + 12I_3 = 0$

$+6 = 8I_2 + 4I_3$ ------(3)

Solving (2) and (3)

Multiplying eq (3) by 2 and adding in eq (2)

$+12 = 16I_2 + \cancel{8I_3}$

$0 = 15I_1 + 3I_2 - \cancel{8I_3}$

$+12 = 31I_1 + 3I_2$ ------ (4)

$I_1 = \frac{56}{175} = -0.32$

$4 = 20 \times 0.32 - 15I_2$

$-2.4 = -15I_2$

$\frac{-2.4}{-15} = I_2$

$-4 + 5I_1 + 15(I_1 - I_2) = 0$

$-4 + 5I_1 + 15I_1 - 15I_2$

$-4 + 20I_1 - 15I_2 = 0$ ----- (1)

$\boxed{20I_1 - 15I_2 = 4}$

$10I_2 + 8(I_2 - I_3) + 15(I_2 - I_1) = 0$

$10I_2 + 8I_2 - 8I_3 + 15I_2 - 15I_1 = 0$

$33I_2 - 8I_3 - 15I_1 = 0$ ------(2)

$6 + 12I_3 + 8(I_3 - I_2) = 0$

$6 + 12I_3 + 8I_3 - 8I_2 = 0$

$6 + 20I_3 - 8I_2 = 0$

$\boxed{8I_2 - 20I_3 = 6}$ --------(3)

Solving eq. (1) eq. (2) and eq. (3) by Cramer's Rule.

$$\frac{20\begin{vmatrix}0 & -8\\ 6 & -20\end{vmatrix}-4\begin{vmatrix}-15 & -8\\ 0 & -20\end{vmatrix}+0}{20\begin{vmatrix}33 & -8\\ 8 & -20\end{vmatrix}+15\begin{vmatrix}-15 & -8\\ 0 & -20\end{vmatrix}+0}$$

$$\frac{20(0+48)-4(300)}{20(-660+64)+15(300+0)}$$

$$\frac{960-1200}{20(-596)+4500}=\frac{-240}{11920+4500}$$

$$=\frac{240}{7420}$$

$$I_2 = 0.0323\ A$$

PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No. 11

OSCILLATIONS

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

Q1: The period of oscillation of an object in an ideal spring and mass system is 0.50 s and the amplitude is 5.0 cm, what is the speed at the equilibrium point and the acceleration at the point of maximum extension of the spring?

Data:

$T = 0.5$ Sec

$x_o = 5cm = 0.05m$

$a_{max} = ?$

$V_{max} = ?$

Sol:

$$a_o = \frac{K}{m} \cdot x_o \qquad \therefore T = 2\pi\sqrt{\frac{m}{K}}$$

$$a_o = \frac{4\pi^2 x_o}{T^2} \qquad \sqrt{\frac{m}{K}} = \frac{T}{2\pi}$$

$$\boxed{a_o = 6.9\ m/s^2} \qquad \frac{m}{K} = \frac{T^2}{4\pi^2}$$

$$V_o = \sqrt{\frac{K}{m} \cdot x_o} \qquad \frac{K}{m} = \frac{4\pi^2}{T^2}$$

$$V_o = \frac{2\pi x_o}{T} \qquad \therefore \sqrt{\frac{K}{m}} = \frac{2\pi}{T}$$

$$V_o = \frac{2 \times 3.14 \times 0.05}{0.5}$$

$$\boxed{V_o = 0.628\ m/s}$$

Q2: A sewing machine needle moves with a rapid vibratory motion, like SHM, as it sews a seam. Suppose the needle moves 8.4 mm from its highest to its lowest position and it makes 24 stitches in 9.0s, what is the maximum speed of the needle?

Data:

$$x_o = \frac{8.4}{2} = 4.2\,mm = 4.2 \times 10^{-3} m$$

Time = 9sec

No. of vibration = 24 vibration.

$V_o = ?$

Sol:

$$\text{Time period} = \frac{\text{time}}{\text{No. of Vibrations}}$$

$$T = \frac{9}{24} = 0.375\ sec$$

$$T = \frac{2\pi}{\omega}$$

Or

$$\omega = \frac{2\pi}{T}$$

$$\omega = \frac{2 \times 3.14}{0.375} = 16.75\,Rad/Sec$$

$$V_o = x_o\,\omega$$

$$V_o = 4.2 \times 10^{-3} \times 16.75$$

$$\boxed{V_o = 0.07\ m/sec}$$

Q3: An ideal spring, with a spring constant of 15 N/m, is suspended vertically. A body of mass 0.60 kg is attached to the upstretched spring and released. (a) What is the extension of the spring when the speed is a maximum? (b) What is the maximum speed?

Data:

$K = 15\ N/m$
$M = 0.6\ kg$
$F = mg$
$\chi_o = ?$
$V_o = ?$

Sol:

$F = k\chi_o$

$$\chi_o = \frac{F}{K} = \frac{mg}{K}$$

$$\chi_o = \frac{0.6 \times 9.8}{15}$$

$$\boxed{\chi_o = 0.392m}$$

$$V_o = \chi_o \sqrt{\frac{K}{m}}$$

$$V_o = 0.392 \sqrt{\frac{15}{0.6}}$$

$$V_o = 1.96\ m/Sec$$

Q.4 A body is suspended vertically, from an ideal spring of spring constant 2.5 N/m, the spring is initially in its relaxed position. The body is then released and oscillates about its equilibrium position. The motion is described by y= (4.0cm) sin[(0.70rad/s) t]. What is the maximum kinetic energy of the body?

Data:

$K = 2.5\ N/m$
$y = 4 \sin (0.7t)$

Solution:

$y = A_o \sin wt$

where A_o is the amplitude.

$y = x_o \sin 0.7t$

By comparing we get.

$x_o = 4cm = 0.04m$
$w = 0.7\ Rad/sec$

As

$$(K.E.)_{max} = \frac{1}{2} Ku_0^2$$

$$(K.E.)_{max} = \frac{1}{2} \times 2.5\ (0.04)^2$$

$$\boxed{(K.E.)_{max} = 2 \times 10^{-3}\ J} \text{ or } \boxed{2\ m\ J}$$

Q.5 The period of oscillation of a simple pendulum does not depend on the mass of the bob. By contrast, the period of a mass-spring system does depends on mass. Explain the apparent condition.

As we know that the time period of simple pendulum is given as

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

The above equation shows that the time period of simple pendulum is independent of the mass of the bob and depends upon the length of the pendulum and it is also clear that the time period is directly proportional to square root of length.
And the time period of spring mass system is given as,

$$T = 2\pi\sqrt{\frac{m}{K}}$$

The above equation shows that the time period of spring mass system depends upon the mass and time period is directly proportional to square root of mass in spring – mass system.

Q6: What is the period, of a simple pendulum of a 6.0 kg mass, oscillating on a 4.0 m long string?

Data:

$\ell = 4m$
$T = ?$

Solution:

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$T = 2x3.14\sqrt{\frac{4}{9.8}}$$

$$T = 4.01sec$$

Q.7 A pendulum of length 75 cm, and mass 2.5 kg, swings with a mechanical energy of 0.015 J. What is its amplitude?

Data:

$\ell = 75cm = 0.75m$
$E = 0.015\ J$
$m = 2.5\ kg$
$x_o = ?$

Solution:

$$w = \sqrt{\frac{g}{\ell}}$$

$$w = \sqrt{\frac{9.8}{0.75}}$$

$$\boxed{w = 3.61\ Rad/sec}$$

or

$$w = \sqrt{\frac{K}{m}}$$

$$w^2 = \frac{K}{m}$$

$$K = w^2 m$$

$$K = (3.61)^2 \times 2.5$$

$$\boxed{K = 32.58\ N/m}$$

$$E = \frac{1}{2} K x_o^2$$

$$x_o = \sqrt{\frac{2E}{K}}$$

$$x_o = \sqrt{\frac{2 \times 0.015}{32.58}}$$

$$x_o = 0.03m$$

Q.8 A pendulum of length L_1 has a period of $T_1 = 0.950$ s. The length of the pendulum is adjusted to a new value L_2, such that $T_2 = 1.00$ s. What is the ratio L_2/L_1?

Data:

$L = L_1$

$T_1 = 0.95sec$

$L = L_2$

$T_2 = 1sec$

$\frac{L_2}{L_1} = ?$

Solution:

$$T_1 = 2\pi\sqrt{\frac{L_1}{g}} \quad \text{——(1)}$$

$$T_2 = 2\pi\sqrt{\frac{L_2}{g}} \quad \text{——(2)}$$

Dividing equation (2) by (1)

$$\frac{T_2}{T_1} = \frac{2\pi\sqrt{\frac{L_2}{g}}}{2\pi\sqrt{\frac{L_1}{g}}}$$

$$\frac{T_2}{T} = \sqrt{\frac{L_2}{L_1}}$$

Or

$$\frac{L_2}{L_1} = \frac{T_2^2}{T_1^2}$$

$$\frac{L_2}{L_1} = \frac{(1)^2}{(0.95)^2}$$

$$\frac{L_2}{L_1} = 1.108$$

Q.9 A wire is hanging from the top of a tower such that the top is not visible due to darkness. How do you calculate the height of the tower?

In order to calculate the height of tower which is not visible due to darkness but a wire is attached at the top of the tower, we will attach a hob with the wire. Then it becomes a simple pendulum.

Now, we will find the time period of pendulum experimentally and then, by using the formula of time period $(T = 2\pi\sqrt{\frac{\ell}{g}})$, we will find the length of the pendulum which will be equal to the height of the tower.

Q.10 The amplitude of oscillation of a pendulum decays by a factor of 20.0 in 120 s. By what factor has its energy decayed in that time? (The energy has decreased by a factor of 400)

Data:

x_o = Maximum amplitude

$x_o = \frac{1}{20} x_o$ (Reduced amplitude)

Time = 120 sec.

Solution:

As

$$E = \frac{1}{2} K x_o^2$$

Reduced energy

$$E' = \frac{1}{2} K x_o'^2$$

$$E' = \frac{1}{2} K \left(\frac{1}{20} x_o\right)^2$$

$$\boxed{E' = \frac{1}{400} E}$$

So the energy reduced by 400 times.

NUMERICALS

Q.1 The equation of a wave is $y(x, t) = 3.5 \sin\{(\frac{\pi}{3.0})x - 66t\}$ cm where t is in seconds x and y both are in cm. Find (a) the amplitude and (b) the wavelength of this wave.

Data:

(i) $y(x, t) = 3.5 \sin\{(\frac{\pi}{3.0})x - 66t\}$

Now

(ii) $y(x, t) = A \sin(kx - wt)$

Comparing equation (i) and (ii)

(a) **Amplitude**

(amplitude) A = 3.5 cm

(b) **Wavelength**

$$K x = \frac{\pi}{3.0} x$$

$$K = \frac{\pi}{3.0} \quad \left\{k = \frac{2\pi}{\lambda}\right\}$$

$$\frac{2\pi}{\lambda} \quad \frac{\pi}{3.0}$$

$$\lambda \times \pi = 2\lambda \times 3.0$$

$$\pi = 2 \times 3.0$$

$$\pi = 6.0 \text{ cm}$$

Q.2 Why is it that your own voice sounds strange to you if you hear it played on a tape recorder, but your friends all agree that it is just what your voice sounds like?

Ans: We normaly hear our own voice while talking, we receive both, the sound transferred to our ears externally by air conduction and the sound transferred internally through our bones. This bone conduction of sound delivers rich low frequencies which are not included in air-conducted vocal sound. So, when you hear your recored voice without these frequencies, it sounds higher and different. Basically, the reasoning is that because our recorded voice does not sound how we expect it to, we do not like it.

Q.3 Why is the speed of sound in solids much faster than the speed of sound in air?

Ans: Sound travels faster in solids than in air because particles in a solid are closer together, allowing quicker energy transfer.

In solids, the particles are tightly packed together. They are much closer to each other than the particles in a gas like air. This close proximity allows the energy of the sound wave to be transferred more quickly from particle to particle, resulting in a faster speed of sound.

The particles in air are much farther apart. When sound wave travels through air, it has to transfer its energy from one particle to the next over these greater distances. This take more time, so the speed of sound is slower in air than in solid.

Q.4 An increase in pressure of 100 k Pa causes a certain volume of water to decrease by 5×10^{-3} percent of its original volume. Find the (a) Bulk modulus of water. (b) the speed of sound in water.

Data:

$\Delta P = 100$ K Pa

$\Delta P = 100 \times 10^3$ Pa

$\frac{\Delta V}{V}\% = 5\times10^{-3}$

$\frac{\Delta V}{V} \times 100 = 5\times10^{-3}$

$\frac{\Delta V}{V} = \frac{5\times10^{-3}}{100} = 5\times10^{-5}$

$\rho = 1000$ kg/m^3

To Determine

Bulk modulus $B = ?$

$V = ?$

Solutions.

$$B = \frac{\Delta P}{\frac{\Delta V}{V}}$$

$$= \frac{100\times10^3}{5\times10^{-5}}$$

$$= 2\times10^9 \text{ Pa}$$

$$= 2\times1000\times10^6 \text{ Pa}$$

$$= 2000 \text{ MPa}$$

(b)

$$V = \sqrt{\frac{B}{\rho}}$$

$$= \sqrt{\frac{2\times10^9}{1000}}$$

$$\boxed{V = 1414.2 \text{ m/s}}$$

Q.5 A uniform string of length 10.0m and weight 0.25 N is attached to the ceiling. A weight of 1.00 kN hangs from its lower end. The lower end of the string is suddenly displaced horizontally. How long does it take the resulting wave pulse to travel to upper end? Neglect the weight of the string in comparison to the hanging mass.

Data:-

$L = 10.0m$

$W_{string} = 0.25N$

$m = \frac{0.25}{9.8}$

$m = 0.02551$ kg

$W = 1.00$ kN

$W = 1000$ N

To determine

$V = \sqrt{\frac{T}{\mu}}$

$T = \text{weight}$

$T = 1000N$

$\mu = \frac{m}{L}$

$\mu = \frac{0.002551}{10}$

$\mu = 0.002551$ kg/m

$V = \sqrt{\frac{T}{\mu}}$

$= \sqrt{\frac{1000}{0.002551}}$

$V = \sqrt{392003.13}$

$V = 626.1$ m/s

$V = \frac{s}{t}$

$t = \frac{S}{V}$

$t = \frac{L}{V}$

$$t = \frac{10}{626.1}$$

$$t = 0.01597 \text{ sec}$$

$$t = 15.97 \times 10^{-3} \text{sec}$$

$$t = 15.97 \text{ m/s}$$

Q.6 A travelling sine wave is the result of the superposition of two other sine waves with equal amplitudes, wavelengths, and frequencies. The two component waves each have amplitudes 5.00 cm. If the resultant wave has amplitude 6.69, what is the phase difference φ between the component waves?

Data:-

$A_o = 5.0$ cm

$A_o = \frac{5.0}{100}$ m

$A_o = 0.05$m

$Y = 6.69$cm

$Y = \frac{6.69}{100} = 0.0669$m

$\varphi = ?$

Solution:

Resultant amplitude of two waves is given by:

$$Y = 2 A_o \cos \frac{\Phi}{2}$$

$$0.0669 = 2 \times 0.05 \cos \frac{\Phi}{2}$$

$$0.0669 = 0.1 \times \cos \frac{\Phi}{2}$$

$$0.669 = \cos \frac{\Phi}{2}$$

$$\cos^{-1}(0.669) = \frac{\Phi}{2}$$

$$48 = \frac{\Phi}{2}$$

$$2 \times 48 = \Phi$$

$$\boxed{96^\circ = \Phi}$$

Q.7 In order to decrease the fundamental frequency of a guitar string by 4.0%, by what percentage should you reduce the tension?

Data:

$f'_1 = 4\%$ decreased by f_1

$f'_1 = (100 - 4)\% \, f_1$

$f'_1 = 96\% \, f_1$

$f'_1 = \frac{96}{100} f_1$

$f'_1 = 0.96 \, f_1$

To determine:

$\frac{\Delta T}{T}\% = ?$

Solution:

Fundamental frequency is given by

$$f_1 = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

$$f_1 = \frac{1}{2L\sqrt{\mu}} \times \sqrt{T}$$

Suppose L & μ are constant,

$$2L\sqrt{\mu} = k$$

$$f_1 = k\sqrt{T} \text{ ---------(1)}$$

After reducing frequency,

$$f'_1 = k\sqrt{T'} \text{ ---------(2)}$$

Dividing equation (2) by (1),

$$\frac{f'_1}{f_1} = \frac{k\sqrt{T'}}{k\sqrt{T}}$$

Now $f'_1 = 0.96 \, f_1$,

$$\frac{0.96 f_1}{f_1} = \sqrt{\frac{T'}{T}}$$

$$0.96 = \sqrt{\frac{T'}{T}}$$

Squaring both the sides,

$$(0.96)^2 = \left(\sqrt{\frac{T'}{T}}\right)^2$$

$$0.9216 = \frac{T'}{T}$$

Now

$$T' = 0.9216\,T$$

$$\Delta T = T - T'$$

Putting the value of $T' = 0.9216\,T$ in above equation, we get

$$\Delta T = T - 0.9216\,T$$

$$\Delta T = (1 - 0.9216)\,T$$

$$\frac{\Delta T}{T} = 0.0784$$

$$\boxed{\frac{\Delta T}{T}\% = 7.84\%}$$

Q.8 A string 2.0 m long is held fixed at both ends. If a sharp blow is applied to the string at its centre, it take 0.050 s for the pulse to travel to both ends of the string and return to the middle. What is the fundamental frequency of oscillation for this string?

Data:

$L = 2$ m

$t = 0.05$ sec

$f_1 = ?$

Solution:

$$f_1 = \frac{v}{2L}$$

$$f_1 = \frac{1}{2L} \times V \qquad \left\{ V = \frac{s}{t} = \frac{L}{t} \right\}$$

$$f_1 = \frac{1}{2L} \times \frac{L}{t}$$

$$f_1 = \frac{1}{2 \times 2} \times \frac{2}{0.05}$$

$$f_1 = \frac{2}{0.2}$$

$$f_1 = 10 \text{ Hz}$$

Q.9 A sound source of frequency f_o and an observer are located at a fixed distance apart. Both the source and observer are at rest. However, the propagation medium (through which the sound waves travel at speed v) is moving at a uniform velocity v_m in an arbitrary direction. Find the frequency detected by the observer, giving physical explanation.

Solutions: The velocity of mechanical waves is affected by the motion of the medium. If the medium is moving with a velocity Vm in the direction of propagation of sound, the effective velocity of sound is increased from V to (V + Vm).

In this case, V is replaced by (V + Vm)

$$f' = \frac{V}{\lambda}$$

$$= \frac{V + Vm}{\lambda}$$

$$= \frac{(V + Vm)}{\frac{V}{f_o}}$$

$$f' = \left(\frac{V + Vm}{V}\right) f_o \Rightarrow f' > f_o$$

If the medium is moving with a velocity Vm opposite to the direction of wave propagation, V is replaced by (V-Vm).
The frequency detected by the observer is:

$$f' = \frac{V}{\lambda}$$

$$= \frac{V - Vm}{\frac{V}{f_o}}$$

$$f' = \left(\frac{V - Vm}{V}\right) f_o \Rightarrow f' < f_o$$

Q.10 A train sounds its whistle, while passing by a railroad crossing. An observer at the crossing, measures a frequency of 219 Hz as the train approaches the crossing and a frequency of 184 Hz as the train leaves. The speed of the sound is $340ms^{-1}$. Find the speed of the train and the frequency of its whistle.

Data:

The observed frequency when the train approaches = $f_1' = 219Hz$. The observed frequency when the train leaves = $f_2' = 184Hz$.

Solution:

$$f_1' = \frac{V}{V - Vs} f \text{.....(1)}$$

$$f_2' = \frac{V}{V + Vs} f \text{.....(2).}$$

dividing eq (1) by (2)

$$\frac{f_1'}{f_2'} = \frac{\left(\frac{V}{V - Vs}\right)f}{\left(\frac{V}{V + Vs}\right)f}$$

$$\frac{219}{184} = \frac{V}{(V \quad Vs)} \times \frac{V + Vs}{V}$$

$$\frac{1.1902}{1} = \frac{V + Vs}{V - Vs}$$

$$1.1902\ V - 1.1902Vs = V + Vs$$

$$1.1902\ V - V = Vs + 1.1902\ Vs$$

$$0.1902 \times V = 2.1902\ Vs$$

$$\frac{0.1902 \times 340}{2.1902} = Vs$$

$$\frac{64.668}{2.1902} = Vs$$

$$\boxed{29.5\ m/s = Vs}$$

Now

$$f_1' = \left(\frac{V}{V - Vs}\right)f$$

$$219 = \left(\frac{340}{340 - 29.5}\right)f$$

$$219 = \left(\frac{340}{310.5}\right)f$$

$$219 = 1.095\ f$$

$$\frac{219}{1.095} = f$$

$$\boxed{200\ Hz = f}$$

PRACTICAL CENTRE

CLASS-XI

PHYSICS

CHAPTER No.13

PHYSICAL OPTICS

2023-24

info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

NUMERICAL

1. A monochromatic light of wavelength 6900 A° is used to illuminate two parallel slits. On a screen that is 3.30 m away from the slits, interference fringes are observed. The distance between the adjacent bright fringes in the centre of the pattern is 1.80 cm. What is the distance between the slits?

Data:

Wavelength of light = $\lambda = 6900A^0$

$\lambda = 6900 \times 10^{-10}m = 6.9 \times 10^{-7}m$

Distance between the slits and screen = L = 3.30m

Fringe spacing = Δx = 1.80 cm = 0.018 m

Separationof the slits = d =?

Solution:

The fringe spacing is given as,

$$\Delta x = \frac{L\lambda}{d}$$

$$d = \frac{L\lambda}{\Delta x}$$

$$d = \frac{3.30 \times 6.9 \times 10^{-7}}{0.018}$$

$$\boxed{d = 1.265 \times 10^{-4}m}$$

2. A Michelson interferometer is adjusted so that a bright fringe appears on the screen. As one of the mirrors is moved 25.8 micrometers, 92 bright fringes are counted on the screen. What is the wavelength of light used in the interferometer?

Data:

Displacement of the movable mirror = d = 25.8μm

$d = 25.8 \times 10^{-6}m$

The number of fringes = m = 92

λ =?

Solution:

The displacement of the movable mirror is given by the equation;

$$d = m\frac{\lambda}{2}$$

$$\lambda = \frac{2d}{m}$$

$$\lambda = \frac{2 \times 25.8 \times 10^{-6}}{92}$$

$$\boxed{\lambda = 5.60 \times 10^{-7} = 510nm}$$

3. In section 13.4 we studied interference due to thin films. Why must the film be thin? Why do we not see the interference effect when looking through a window or at a poster covered by a plate of glass, even if the glass is optically flat?

Ans: When white light enters on thin film, wavelengths interfere and produce colourful fringes. In the case of thick films such as glass windows or glass top on a poster, the optical path difference of **2t** is much greater than the wavelengths of visible light. There is no superposition of two coherent waves and thus, no interference pattern (formation of fringes) and hence, all light appears as white light. This limits thin film effects to films a micrometer or less in thickness.

4. Newton's rings are formed by a light of 400nm wavelength. Determine the change in air film thickness between the third and sixth bright fringe. If the radius of curvature of the curved surface is 5.0m, what is the radius of the third bright fringe?

Data:

The wavelength of light = λ = 400 nm

$\lambda = 400 \times 10^{-9} = 4 \times 10^{-7}$m

Radius of curvature of lens = R = 5.0m

Change in thickness of the thin film = t =?

Radius of third bright ring = r =?

Solution:

For bright fringes in the thin film of air,

$$2t = \left(m + \frac{1}{2}\right)\lambda$$

For third bright fringe, m = 2

$$2t_3 = \left(2 + \frac{1}{2}\right)\lambda = \frac{5}{2}\lambda$$

$$t_3 = \frac{5}{4}\lambda = \frac{5}{4}(400)$$

$$t_3 = 500 \text{ nm}$$

For the sixth bright fringe, m = 5

$$2t_6 = \left(5 + \frac{1}{2}\right)\lambda = \frac{11}{2}\lambda$$

$$t_6 = \frac{11}{4}\lambda = \frac{11}{4}(400)$$

$$t_6 = 1100 \text{ nm}$$

$$t = t_6 - t_3$$

$$t = 1100 - 500 = 600 \text{ n}$$

The radius of third bright ring,

$$r = \sqrt{\left(N - \frac{1}{2}\right)R\lambda}$$

$$r = \sqrt{\left(3 - \frac{1}{2}\right) \times 5.0 \times 4 \times 10^{-7}}$$

$$r = 2.236 \times 10^{-3}\text{m} = 2.236 \text{ mm}$$

5. A soap bubble has an index of refraction n = 1.50. The film is viewed in reflected light.

a) At a spot where the film thickness is 910.0 nm, which wavelengths are missing in reflected light?

b) Which wavelengths are the strongest in the visible light?

Data:

Refractive index = n = 1.50

Thickness of the thin film = t = 910.0 nm

(a) Missing wavelengths = λ = ?

(a) Visible wavelengths = λ = ?

Solution:

(a) For missing wavelengths of visible light due to destructive interference,

$$2nt = m\lambda$$

$$\lambda = \frac{2nt}{m}$$

for visible region, we take only m =4,5,6

If m = 4,

$$\lambda = \frac{2(1.50)(910.0)}{4}$$

$$\lambda = 682.3 \text{ nm}$$

If m = 5,

$$\lambda = \frac{2(1.50)(910.0)}{5}$$

$$\lambda = 546 \text{ nm}$$

If m = 6,

$$\lambda = \frac{2(1.50)(910.0)}{6}$$

$$\lambda = 455 \text{ nm}$$

(b) For the strongest wavelengths of visible light due to constructive interference,

$$2nt = \left(m + \frac{1}{2}\right)\lambda$$

$$\lambda = \frac{2nt}{\left(m + \frac{1}{2}\right)}$$

If m = 4,

$$\lambda = \frac{2(1.50)(910.0)}{\left(4 + \frac{1}{2}\right)}$$

$$\boxed{\lambda = 607 \text{ nm}}$$

If m = 5,

$$\lambda = \frac{2(1.50)(910.0)}{\left(5 + \frac{1}{2}\right)}$$

$$\lambda = 496 \text{ nm}$$

If m = 6,

$$\lambda = \frac{2(1.50)(910.0)}{\left(6 + \frac{1}{2}\right)}$$

$$\boxed{\lambda = 420 \text{ nm}}$$

6. What is the difference between deviation and diffraction? What do diffraction and interference have in common?

Diffraction and deviation are both wave properties. They sound similar, as both represent some sort of bending of waves. Diffraction is the bending or spreading of waves around an obstacle. For example, the bending of light around the corners of the door. The diffraction of light produces a fringe pattern.

Refraction or deviation is the bending of waves passing through one medium into another. For example, a straw appears to be broken in a glass of water due to the bending of light. The refraction of light creates visual illusions but not fringe patterns.

7. Is it possible to increase the order of maxima for a given energy spectrum from a diffraction grating?

The order of maxima in a diffraction grating is inversely proportional to the number of lines per unit length.

$$m = \frac{\sin\theta}{N\lambda}$$

To get maximum number of orders, we put $\sin\theta = 1$

$$m = \frac{1}{N\lambda}$$

It is clear from the above equation, if we decrease the number of lines, the order of maxima increases.

8. Describe what happens to a single slit diffraction pattern as the width of the slit is slowly increased.

There is an inverse relation between the width of the slit and the size of the diffraction pattern on the screen. The width of the central maxima is

$$\beta = 2\theta = \frac{\lambda}{a}$$

According to the above relation, as the width of slit 'a' decreases slowly, the width of central maxima increases. The diffraction pattern would go wider with lower intensity.

9. **The diffraction pattern from a single slit of width 0.020mm is viewed on a screen. If the screen is 1.20m from the slit and light of wavelength 430nm is used, what is the width of the central maxima?**

Data:

Width of the slit = a = 0.020mm

$a = 2 \times 10^{-5}m$

Distance between the slits and screen – L – 1.20m

Width of the central maxima = Δx = ?

Solution:

For the central maxima,

$$\frac{a}{2}\sin\theta = \lambda \qquad \left(\sin\theta \approx \tan\theta = \frac{\Delta x}{L}\right)$$

$$\frac{a}{2}\left(\frac{\Delta x}{L}\right) = \lambda$$

$$\Delta x = \frac{2L\lambda}{a}$$

$$\Delta x = \frac{2(1.20)(4.3 \times 10^{-7})}{2 \times 10^{-5}}$$

$$\Delta x = 0.0516m = 5.16cm$$

10. **A grating has exactly 8000 lines, uniformly spaced over 2.54 cm, and is illuminated by light from a mercury vapour discharge lamp. What is the expected angle for the third-order maximum of the light of wavelength 546 nm?**

Data:

The number of lines = 8000

Lenght of the grating = L = 2.54cm

L = 0.0254m

The wavelength of light = λ = 546 nm

$\lambda = 5.46 \times 10^{-7}m$

Angular deviation for the third order=θ=?

Solution:

The grating element is,

$$d = \frac{L}{N}$$

$$d = \frac{0.0254}{8000} = 3.175 \times 10^{-6}m$$

We know that,

$$d\sin\theta = m\lambda$$

$$\sin\theta = \frac{m\lambda}{d}$$

$$\sin\theta = \frac{(3)(5.46 \times 10^{-7})}{3.175 \times 10^{-6}}$$

$$\sin\theta = 0.5159$$

$$\theta = \sin^{-1}(0.5159) = 31^0\ 3'\ 29''$$

11. How many lines per centimetre are there in a grating which gives 1st order spectra at an angle of 30^0 when the wavelength of light is 6×10^{-5}cm?

Data:

Number of lines per cm = N = ?

Wavelength of light = $\lambda = 6 \times 10^{-5}$cm

Angular deviatio for the first order = $\theta = 30^0$

Solution:

We know that,

$$d \sin\theta = m\lambda$$

$$d = \frac{m\lambda}{\sin\theta}$$

$$d = \frac{(1)(6 \times 10^{-5})}{\sin 30^0}$$

$$d = 1.2 \times 10^{-4}\text{cm}$$

The number of lines per cm is,

$$N = \frac{1}{d}$$

$$N = \frac{1}{1.2 \times 10^{-4}} = 8333 \text{ lines /cm}$$

12. Light of wavelength 450nm is incident on a diffraction grating on which 5000 lines /cm have been ruled. Determine:

(i) The orders of spectra that can be observed on either side of the spectra.

(ii) The angle corresponding to each order.

Data:

Number of lines = 5000

Lenght of the grating = L = 1cm

L = 0.01m

Wavelength of light = $\lambda = 450$ nm

$\lambda = 4.50 \times 10^{-7}$m

For maximum order = $\theta = 90^0$

(i) m = ?

(ii) θ = ?, for each possible order of diffraction

Solution:

The grating element is,

$$d = \frac{L}{N}$$

$$d = \frac{0.01}{5000} = 2 \times 10^{-6}\text{m}$$

We know that,

$$d \sin\theta = m\lambda$$

$$m = \frac{d \sin\theta}{\lambda}$$

$$m = \frac{(2 \times 10^{-6}) \sin 90^0}{4.50 \times 10^{-7}}$$

$$m = 4$$

For m = 1

$$\sin\theta = \frac{m\lambda}{d}$$

$$\sin\theta = \frac{(1)(4.5 \times 10^{-7})}{2 \times 10^{-6}}$$

$$\sin\theta = 0.225$$

$$\theta = \sin^{-1}(0.225) = 13^0$$

For m = 2

$$\sin\theta = \frac{m\lambda}{d}$$

$$\sin\theta = \frac{(2)(4.5 \times 10^{-7})}{2 \times 10^{-6}}$$

$$\sin\theta = 0.45$$

$$\theta = \sin^{-1}(0.45) = 26.7^0$$

For m = 3

$$\sin\theta = \frac{m\lambda}{d}$$

$$\sin\theta = \frac{(3)(4.5 \times 10^{-7})}{2 \times 10^{-6}}$$

$$\sin\theta = 0.675$$

$$\theta = \sin^{-1}(0.675) = 42.5^0$$

For m = 4

$$\sin\theta = \frac{m\lambda}{d}$$

$$\sin\theta = \frac{(4)(4.5 \times 10^{-7})}{2 \times 10^{-6}}$$

$$\sin\theta = 0.9$$

$$\theta = \sin^{-1}(0.9) = 64.2^0$$

13. Why does a crystal act as a three-dimensional grating for X-rays but not for visible light?

X-rays (of 0.01 to 10 nanometers) have a much shorter wavelength than that of visible light (400 to 700 nanometers). And since the inter atomic distances in a crystal are of the order of the X-rays, the regular arrangement of atoms in a crystal makes a perfect three-dimensional grating for X-rays but not for visible light. Interference patterns will be significant, based on the fact that the path lengths of the reflected rays between the adjacent planes in the crystal will be greater than those that could be obtained from visible light.

14. A beam of X-rays, of wavelength 0.071 nm, is diffracted by a diffracting plane of rock salt while the distance between the atomic planes is 1.98A° Find the glancing angle for the second-order diffraction.

Data:

$\lambda = 0.071\text{nm} = 0.071 \times 10^{-9}$

Or

$\lambda = 7.1 \times 10^{-11}\text{m}$

$d = 1.98A^0 = 1.98 \times 10^{-10}\text{m}$

$n = 2$

Glancing angle $= \theta = ?$

Solution:

According to Bragg's law,

$$2d\sin\theta = n\lambda$$

$$\sin\theta = \frac{n\lambda}{2d}$$

$$\sin\theta = \frac{(2)(7.1 \times 10^{-11})}{2 \times 1.98 \times 10^{-10}}$$

$$\sin\theta = 0.358$$

$$\theta = \sin^{-1} 0.358 = 21^0$$

15. Unpolarized light passes through two polarizers in turn with polarization axes at 45° to each other. What is the fraction of the incident light intensity that is transmitted?

Data:

Intensity of the incident light $= I_0$

Intensity of the transmitted light $= ?$

Angle of rotation $= \theta = 45^0$

Solution:

The intensity of the transmitted light is,

$$I = \frac{I_0}{2}\cos^2\theta$$

$$I = \frac{I_0}{2}(\cos 45^0)^2$$

$$I = \frac{I_0}{2}\left(\frac{1}{\sqrt{2}}\right)^2$$

$$I = \frac{I_0}{4} = 0.25\, I_0$$

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PHYSICS

CHAPTER No. 14

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info@practicalcentre.edu.pk

021-34976530
021-34812547
021-34984762

B-14, Block-1,
Gulshan-e-Iqbal, Karachi.

www.practicalcentre.edu.pk

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