Partial Solutions

for the problems of the Textbook

PHYSICS XI

A Supplement to the Book

"Solution Hints"

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Chapter 3

Prob. 3.1 **A helicopter is ascending vertically at the rate of 19.6 ms^{-1}. When it is at a height of 156.8 m above the ground, a stone is dropped. How long does the stone take to reach the ground?**

Soln:

We have [Data]

For upward direction:

Initial velocity = v_i = 19.6 ms^{-1}

Vertical distance, h = S = 156.8 m

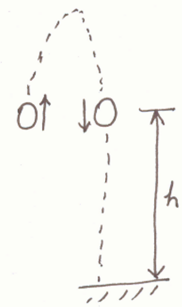
For downward direction:

For vertical distance, h = S = 156.8 m

Initial velocity = v_i = -19.6 ms^{-1}

Acceleration due to gravity = g = 9.8 ms^{-2}

To find time = t = ?



Using the formula

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

putting the values, we have

$156.8 = -19.6 \times t + \frac{1}{2} \times 9.8 \times t^2$

or $\frac{1}{2} \times 9.8 \times t^2 - 19.6 \times t - 156.8 = 0$

or $t^2 - \frac{19.6 \times 2}{9.8} t - \frac{156.8 \times 2}{9.8} = 0$

or $t^2 - 4t - 32 = 0$

solving the above equation for t,

or $t^2 - 8t + 4t - 32 = 0$

or $t(t - 8) + 4(t - 8) = 0$

or $(t - 8)(t + 4) = 0$

either t = 8

or t = -4 [but time cannot be -ve]

so $t = 8$ sec

alternate soln:

using the formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

putting the values

$$t = \frac{-4 \pm \sqrt{4^2 - 4 \times 1 \times 32}}{2 \times 1}$$

or $t = \frac{4 \pm 12}{2} = \frac{16}{2}$

or t = 8 sec. [ignoring t = -4]

Hence **Time taken by the stone to reach the ground = 8 sec.**

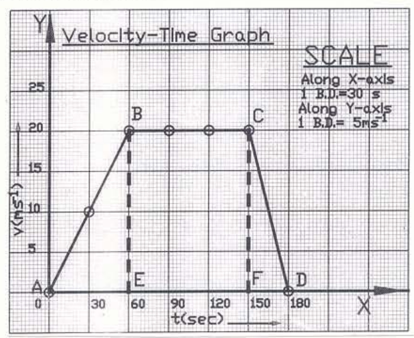
Prob. 3.2 **Using the following data, draw a velocity-time graph for a short journey on a straight road of a motorbike.**

Velocity(ms^{-1})	0	10	20	20	20	20	0
Time (s)	0	30	60	90	120	150	180

Use the graph to calculate
(a) the initial acceleration
(b) the final acceleration and
(c) the total distance traveled by the motorcylist.

Soln:

[For plotting the graph see my "Physics Practical Notebook" for class XI]



Initial acceleration = a_i = slope AB = $\frac{BE}{AE}$

$= \frac{20}{60} =$ 0.33 ms^{-2}

$\left[a = \frac{v}{t} \right.$ = slope

final acceleration = a_f = slope CD = $\frac{CF}{FD}$

$= \frac{-20}{30} =$ -0.67 ms^{-2}

total distance traveled = S = Area ABCDA

$= \frac{1}{2} A_{ABE} + A_{BCFE} + \frac{1}{2} A_{FCD}$

$= \frac{60 \times 20}{2} + 90 \times 20 + \frac{30 \times 20}{2}$

= 600 + 1800 + 300 = 2700 m

$\left[S = v \times t \right.$ = area

or S = 2.7 km

so

Initial acceleration = a_i = 0.33 ms^{-2}
Final acceleration = a_f = -0.67 ms^{-2}
Total distance traveled by the motorcyclist = S = 2.7 km

Prob. 3.5 **An amoeba of mass 1.0×10^{-12} kg propels itself through water by blowing a jet of water through a tiny orifice. The amoeba ejects water with a speed of 1.0×10^{-4} ms^{-1} and at a rate of 1.0×10^{-13} kgs^{-1}. Assume that the water is being continuously replenished so that the mass of the amoeba remains the same.**

a) If there were no force on amoeba other than the reaction force caused by the emerging jet, what would be the acceleration of the amoeba?

b) If amoeba moves with constant velocity through water, what is force of surrounding water (exclusively of jet) on the amoeba?

Soln:

We have [Data]

Mass of amoeba = M = 1.0×10^{-12} kg

[relative] speed of ejected water = v = 1.0×10^{-4} ms^{-1}

Rate of mass ejected per sec. = m = 1.0×10^{-13} kgs^{-1}

[mass per time = $\frac{m}{t}$ or mass per one sec = m]

To find

Acceleration of the amoeba = a = ?

Force of water on amoeba = F = ?

Using the formula,

$$a = \frac{mv}{M}$$

putting the values

$$a = \frac{1.0\times10^{-13}\times1.0\times10^{-4}}{1.0\times10^{-12}}$$

or $\boxed{a = 1.0 \times 10^{-5}\ ms^{-2}}$

Now using the formula,

$$F = \frac{mv}{t}$$

for velocity of mass m per sec. we have

$$F = mv$$

Putting the values, we get

$F = 1.0 \times 10^{-13} \times 1.0 \times 10^{-4}$ or $\boxed{F = 1.0 \times 10^{-17}\ N}$

[We have

$$F = \frac{mv_f - mv_i}{t} \quad \text{(relative vel.)}$$

or $$F = \frac{m(v_f - v_i)}{t} = \frac{mv}{t} \quad .....(1)$$

also $F = Ma$ ..... (2)

from eqs. (1) & (2) we get

$$Ma = \frac{mv}{t}$$

or velocity of mass m per sec.

$Ma = mv$

or $\boxed{a = \frac{mv}{M}}$]

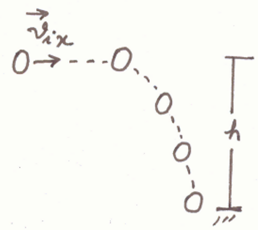
So **Acceleration of the amoeba = a = 1.0×10^{-5} ms^{-2}**
& Force of water on amoeba = F = 1.0×10^{-17} N

Definition:

Amoeba : A single-celled, microscopic animal found in pounds; one of the simplest form of life; in *Medical*, infection with amoebas, esp. as causing dysentery.

Prob. 3.11 **A ball is thrown horizontally from a height of 10 m with velocity of 21 ms^{-1}. How far off it hit the ground and with what velocity?**

Soln:



We have [Data]

Height = h = y = 10 m

Initial horizontal velocity = v_{ix} = 21 ms^{-1}

To find

Distance = R = S = ?

Final velocity = v = ?

Taking the equation

$$S = v_i t + \tfrac{1}{2} a t^2$$

$$y = v_{iy} t + \tfrac{1}{2} g t^2$$

[first we will find For vertical case time t, to be used for finding distance]

putting the values, we get

$$10 = 0 + \tfrac{1}{2} \times 9.8\, t^2$$

$$\text{or} \quad t^2 = \frac{10\times 2}{9.8} \quad \text{or} \quad t = \sqrt{\frac{10\times 2}{9.8}}$$

or t = 1.43 sec.

Now to find horizontal distance, we have

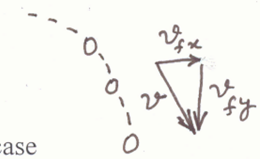
$$S = v\,t$$

[S = R = ?
$v = v_{ix}$ = 21 ms^{-1}
t = 1.41 sec]

Putting the values

R = 21 x 1.43 = 30

or **R = 30 m**



To find velocity, we have

$$v_f = v_i + a\,t$$

for vertical component of velocity, taking vertical case

$$v_{fy} = v_{iy} + g\,t$$

[$v_{iy} = 0$
& horizontal component of velocity remains constant]

putting the values

v_{fy} = 0 + 9.8 x 1.43

or v_{fy} = 13.8 ms^{-1}

& $v_{ix} = v_{fx}$ = 21 ms^{-1}

so $v = \sqrt{v_{fx}^2 + v_{fy}^2}$ or $\vec{v}$ = 25 ms^{-1}

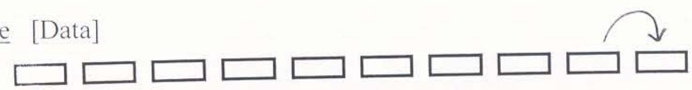
Hence **Horizontal distance of the ball thrown = R = 30 m & Final velocity when hit the ground = v = 25 ms^{-1}**

Chapter 4

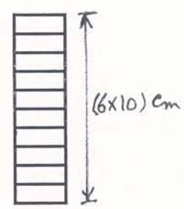
Prob. 4.3 **Ten bricks, each 6.0 cm thick and mass 1.5 kg, lie flat on a table. How much work is required to stack them one on the top of another?**

Soln:

We have [Data]



Number of bricks = 10
Mass of each brick = 1.5 kg
Height of each brick = 6.0 cm = 6/100 m



To find work required to stack them,

No work is done by first brick.

For work done by 9 bricks, we have

Total mass = (9 x 1.5) kg

Mean height $= \frac{6\times10}{2}\text{cm} = \frac{6\times10}{2\times100}\text{m}$

So Work done = W = $Fd\cos\theta$ F = mg

or W = $mgh\cos 0^o$ d = h

putting the values, we get

$$W = 9\times1.5\times9.8\times\frac{6\times10}{2\times100}$$

or W = 39.69 $\cong$ 40 J

Hence

Work required to stack the bricks one on the top of another is

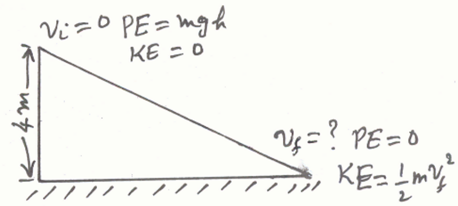
W = 40 J

Prob. 4.10 **A child starts from rest at the top of a slide of height 4.0 m.**
(a) What is his speed at the bottom if the slide is frictionless?
(b) if he reaches the bottom, with a speed of 6 ms^{-1}, what percentage of his total energy at the top of the slide is lost as a result of friction?

Soln:

We have [Data]

Height of the slide = 4.0 m



a) To find speed at bottom,
using the formula,
Loss of PE = Gain in KE

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

or $9.8 \times 4 = \frac{1}{2} v^2$

or $v = \sqrt{(9.8 \times 4)2}$ = **8.8 m s^{-1}**

b) To find percentage of energy lost, we have

Loss of PE = Gain in KE + W. done against friction
or mgh = ½ mv^2 + Energy lost due to friction

or energy lost = mgh – ½ mv^2
= m (gh – ½ v^2)

$$\% \text{age} = \frac{\text{difference of two values}}{\text{actual value}} \times 100 = \frac{\text{Energy lost}}{\text{Energy at top}} \times 100$$

so Percentage lost = $\frac{m(gh - \frac{1}{2}v^2)}{mgh} \times 100$

putting the values, we get

Percentage lost = $\frac{9.8 \times 4 - \frac{1}{2} \times (6)^2}{9.8 \times 4} \times 100$ = **54 %**

Hence

Speed of the child at the bottom = 8.8 m s^{-1}
&
Percentage of total energy lost = 54 %

Chapter 5

Prob. 5.1 **A tiny laser beam is directed from the Earth to the moon. If the beam is to have a diameter of 2.50 m at the Moon, how small must divergence angle be for the beam? The distance of Moon from the Earth is 3.8×10^8 m.**

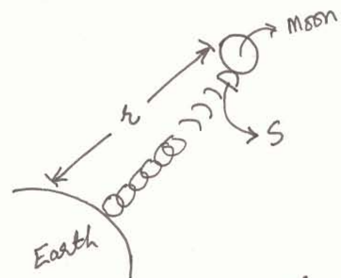
Soln:

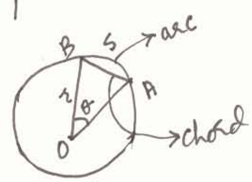
We have,

Diameter of the beam or length of the arc = $S = 2.50$ m

Distance of Moon from Earth = $r = 3.8 \times 10^8$ m.

To find divergence angle = $\theta = ?$





Using the formula,

$$S = r\theta$$

Putting the values

For small angle chord AB = arc S

$$2.5 = 3.8 \times 10^8 \times \theta$$

$$\text{or} \quad \theta = \frac{2.5}{3.8 \times 10^8} = 6.578 \times 10^{-9}\,\text{rad}$$

$$\text{or} \quad \theta = 6.58 \times 10^{-9}\,\text{rad} = 6.6 \times 10^{-9}\ \text{rad}$$

so

Divergence angle for the laser beam, must be equal to 6.6×10^{-9} rad

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Laser: (*L*ight *A*mplification by *S*timulated *E*mission of *R*adiation) A device which is able to produce a beam of radiation with unusual properties, generally the beam is coherent, (the waves are in phase) monochromatic (the waves are of effectively the same wavelength), parallel with high intensity(carrying a great deal of energy). The beam produced is narrow and emerges almost perfectly collimated (made accurately parallel).

Chapter 5

5.2) $\alpha = \frac{\omega_f - \omega_i}{t} = ...$

5.3) $L = I\omega; \quad \tau = I\alpha \quad [\omega$ is constant, so $\alpha = \frac{\Delta\omega}{t} = \frac{0}{t} = 0$

5.4) $\tau = rF\sin 90^0 = rF = ...$ & $\tau = I\alpha$ or $\alpha = \frac{\tau}{I}$ $\quad [I = \frac{1}{2}mr^2$

5.5) $L = I\omega = \frac{2}{5}mr^2\omega = ...$ $\quad \omega = \frac{\theta}{t} = \frac{2\pi}{20 \text{ days}} = \frac{2\pi}{20\times24\times60\times60}$

$KE = \frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{2}{5}mr^2\right)\times\omega^2 = ...$ $\quad I = \frac{2}{5}mr^2$

5.6) $F_C = \frac{mv^2}{r} = ...$

5.7) $a_C = g = \frac{v^2}{r} \Rightarrow v = ...$

5.8) $L_o = (MR^2)\,\omega; \quad L_S = \left(\frac{2}{5}M\,r_m^2\right)\omega$

$\frac{L_s}{L_o} = \frac{\left(\frac{2}{5}M\,r_m^2\right)\not{\omega}}{MR^2\not{\omega}} = \frac{2r_m^2}{5R^2} = ...$ $\quad \left[r_m = 1.74\times10^6 m \;\; \& \;\; R = 3.85\times10^8 m\right]$

5.9) $I_1\omega_1 = I_2\omega_2$ or $\left(\frac{2}{5}MR^2\right)\omega_1 = \left\{\frac{2}{5}M\left(\frac{R}{2}\right)^2\right\}\omega_2$

or $\frac{2}{5}MR^2\frac{2\pi}{T_1} = \frac{2}{5}\frac{MR^2}{4}\frac{2\pi}{T_2}$ $\quad [T_1 = 24$ hours

5.10) $v = \sqrt{\frac{GM}{r}} = ...$ $\quad [G = 6.67\times10^{-11}Nm^2Kg^{-2}$

Typical Format:

We have

[D A T A]

Using the equation

[F O R M U L A]

or [its modified form]

Putting the values,

[just substitute values without using calculator]

Hence

[use calculator in final equation]

Chapter 6

6.1) $v_t = \frac{2gr^2\rho}{9\eta} \Rightarrow r = ………$

6.2) $A_1v_1 = A_2v_2$ or $\pi r_1^2 v_1 = \pi r_2^2 v_2$

or $\left(\frac{D_1}{2}\right)^2 v_1 = \left(\frac{D_2}{2}\right)^2 v_2 \Rightarrow D_2 = ………$

6.3) $v_2 = \sqrt{2g(h_1 - h_2)}$ $A = 0.06\ cm^2$

$\rho = \frac{m}{V}$ or $m = \rho V = \rho Avt$ $t = 1$ sec & $\rho = 1000\ kg\ m^{-3}$

or $m = \rho Avt = ………$

6.4) $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$ $[h_1 - h_2 = 3\ m]$

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

6.5) $P_A + \frac{1}{2}\rho v_A^2 = P_B + \frac{1}{2}\rho v_B^2$ or $P_A - P_B = \frac{1}{2}\rho(v_B^2 - v_A^2) = ………$

6.6) $A_1v_1 = A_2v_2$

or $\pi r_1^2 v_1 = A_2 v_2 \Rightarrow v_2 = ………$

6.8) $P_1 - P_2 + \frac{1}{2}\rho(v_1^2 - v_2^2) + \rho g(h_1 - h_2) = 0$ $P_1 - P_2 = 1000\ Nm^{-2}$

$\Rightarrow v_1 = ……..$ $h_1 - h_2 = 1\ m$ & $v_2 = 160\ m/s$

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

$P_2 - P_1 = \rho g(h_1 - h_2) = ……….$ $h_1 - h_2 = 15\ m$

Important Formulas:

$F = 6\pi\eta rv$; $v_t = \frac{2gr^2\rho}{9\eta}$; $\rho = \frac{m}{V}$ or $m = \rho V = \rho Avt$

$A_1v_1 = A_2v_2$; $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

$v_2 = \sqrt{2g(h_1 - h_2)}$; $P_A + \frac{1}{2}\rho v_A^2 = P_B + \frac{1}{2}\rho v_B^2$

Chapter 7

7.1) $F = mg$ & $F = kx$

$\Rightarrow mg = kx$ or $k = \frac{mg}{x} = 24.5$

& $T = 2\pi\sqrt{m/k}$ $\Rightarrow m = \frac{T^2}{4\pi^2} \times k = 0.2002$

$m = 100$ g 100×10^{-3} kg
$x = 4$ cm $= 4 \times 10^{-2}$ m
$T = 0.568$ s

7.2) $F = mg$ & $F = kx$

$\Rightarrow mg = kx$ or $k = \frac{mg}{x} = 7.35$

& $T = 2\pi\sqrt{m/k} = 1.2566$

$v_o = x_o\sqrt{k/m} = 0.4877$ m s^{-1} =50 cm s^{-1}

$m = 15$ g $= 15 \times 10^{-3}$ kg
$x = 2$ cm $= 2 \times 10^{-2}$ m
$m = 294$ g $= 294 \times 10^{-3}$ kg
$x_o = 10$ cm $= 10 \times 10^{-2}$ m
$m = (15 \times 10^{-3} + 294 \times 10^{-3})$ kg

7.3) $F = kx \Rightarrow k = F/x = 200$

& $T = 2\pi\sqrt{m/k} = 1.2566$

$a + k/m\, x = 0 \Rightarrow a = 3.00$

$v = x_o\sqrt{k/m\,(1 - x^2/x_o^2)} = 1.3748$

$K.E. = \frac{1}{2}kx_o^2\left(1 - x^2/x_o^2\right) = 7.50$

$P.E. = \frac{1}{2}kx^2 = 1.44$

$F = 60$ N
$x = 30$ cm $= 30 \times 10^{-2}$ m
$m = 8$ kg

$x = 12$ cm $= 12 \times 10^{-2}$ m
$x_o = 30$ cm $= 30 \times 10^{-2}$ m

7.4) $PE_g = PE_e$

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

$\Rightarrow x_o = \sqrt{\frac{2mgh}{k}} = 0.1789$

$m = 4$ kg
$h = 0.8$ m
$k = 1960$ Nm^{-1}

7.5) $f = 1/T = \frac{1}{2\pi}\sqrt{g/\ell} = 0.7047$

$\ell = 50 \times 10^{-2}$ m & $g = 9.8$ ms^{-2}

7.6) $v_o = x_o\sqrt{k/m} = 0.50$

$m = 1.6$ kg & $k = 1960$ Nm^{-1}
$x_o = 2$ cm $= 2 \times 10^{-2}$ m

7.7) $f = \frac{1}{2\pi}\sqrt{k/m} = 1.1781$

$k = 4k' = 4 \times 20{,}000$ Nm^{-1}
$m = (1300 + 160)$ kg

7.8) $x = 0.25\cos\left(\pi/8\right)t$

comparing with $x = x_o\cos\omega t$

$\Rightarrow x_o = 0.25,\ \omega = 2\pi f = \pi/8$ or $f = 1/16$ Hz & $T = 1/f = 16$

& $x = 0.25\cos\left(\pi/8 \times 2\right) = 0.25\cos\left(\frac{180 \times 2}{8}\right)^0 = 0.1768$

[*Two things wrong!---No units in the Ans. & should be up to two decimal points*]

Chapter 8

Prob. 8.2 **Two speakers are arranged as shown in the fig. The distance between them is 3 m and they emit a constant tone of 344 Hz. A microphone P is moved along a line parallel to and 4.00 m from the line connecting the two speakers. It is found that tone of maximum loudness is heard and displayed on the CRO when microphone is on the center of the line and directly opposite each speakers. Calculate the speed of sound.**

Soln:

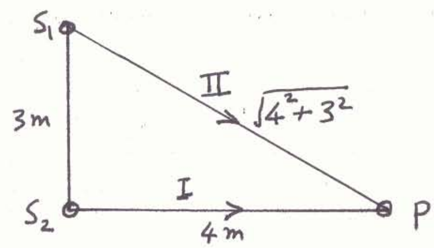
We have,

Distance between the two speakers = 3 m

Frequency of constant tone = f = 344 Hz

Place of the microphone, P = 4.00 m

From the given conditions, drawing the figure.



The path difference ΔS is,

$$\Delta S = S_1P - S_2P = \left(\sqrt{4^2+3^2}\right) - 4 = 1 \text{ m}$$

For constructive interference (when maximum loudness is heard),

$$\Delta S = n\,\lambda$$

or $\lambda = \dfrac{\Delta S}{n} = 1 \text{ m}$ [n = 1]

So speed of sound v will be

$$v = f\,\lambda$$

putting the values,

$$v = 344 \times 1 = 344 \text{ m s}^{-1}$$

Hence **Speed of sound = 344 m s^{-1}**

Prob. 8.4 **The frequency of the note emitted by a stretched string is 300 Hz. What will be the frequency of this note when;**

(a) length of the wave is reduced by one-third without changing the tension.

(b) tension is increased by one-third without changing the length of the wire.

Soln:

We have, the frequency of the stretched string = $f_1 = 300$ Hz

a) From the given conditions,

reduced length , $\ell' = \ell - \frac{\ell}{3} = \left(1 - \frac{1}{3}\right)\ell = \frac{2}{3}\ell$

Using the equation $f_1 = \frac{1}{2\ell}\sqrt{\frac{F}{m}}$ or $f_1' = \frac{1}{2\ell'}\sqrt{\frac{F}{m}}$

putting the values,

$$f_1' = \frac{1}{2\times\frac{2}{3}\ell}\sqrt{\frac{F}{m}} = \frac{3}{2}\times\frac{1}{2\ell}\sqrt{\frac{F}{m}} = \frac{3}{2}\times f_1 = \frac{3}{2}(300) = \boxed{\textbf{450 Hz}}$$

b) From the given conditions,

Increased tension, $F' = F + \frac{F}{3} = \left(1 + \frac{1}{3}\right)\times F = \frac{4}{3}F$

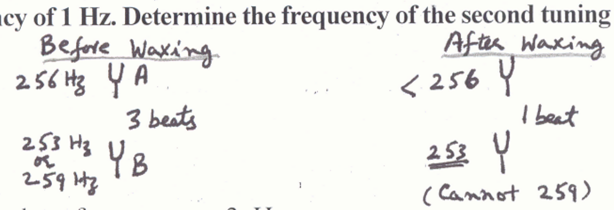
using the equation, $f_1 = \frac{1}{2\ell}\sqrt{\frac{F}{m}}$ or $f_1' = \frac{1}{2\ell}\sqrt{\frac{F'}{m}}$

putting the values,

$$f_1' = \frac{1}{2\ell}\sqrt{\frac{\frac{4}{3}F}{m}} = \sqrt{\frac{4}{3}}\times\frac{1}{2\ell}\sqrt{\frac{F}{m}} = \sqrt{\frac{4}{3}}\times f_1 = \sqrt{\frac{4}{3}}(300) = 346.41 \text{ Hz} = \boxed{\textbf{346 Hz}}$$

Prob. 8.7 **Two tuning forks exhibit beats at a beat frequency of 3 Hz. The frequency of one fork is 256 Hz. Its frequency is then lowered slightly by adding a bit of wax to one of its prong. The two forks then exhibit a beat frequency of 1 Hz. Determine the frequency of the second tuning fork.**

Soln:



We have, beat frequency = 3 Hz

Frequency of first tuning fork = $f_1 = 256$ Hz

From the given conditions,

Frequency of the second tuning fork = $f_2 = 256 \pm 3$ i.e. 259 or 253 Hz

Taking 1st option i.e. $f_2 = 259$ Hz

In this case, number of beats should increase, but beats are decreasing in the given conditions, so f_2 cannot be equal to 259 Hz

Thus $\boxed{\mathbf{f_2 = 253 \text{ Hz}}}$

Chapter 8

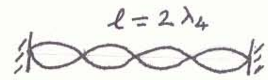
8.1) a) $v = f\lambda$

or $v = (200 \times 10^3 \times 1500) = 3 \times 10^8 \ \text{m s}^{-1}$

b) $v = f_2\lambda_2$

or $\lambda_2 = \dfrac{v}{f_2} = \dfrac{200\times10^3\times1500}{1000\times10^3} = 300 \text{ m}$

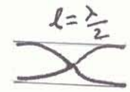
8.3) $\ell = 2\lambda_4$



or $\lambda_4 = \dfrac{\ell}{2} = \dfrac{120\times10^{-2}}{2} = 0.6 \text{ m}$

& $f_n = n f_1$ or $f_4 = 4f_1 \Rightarrow f_1 = \dfrac{f_4}{4} = \dfrac{120}{4} = 30 \text{ Hz}$

8.5) a) $\ell = \dfrac{\lambda}{2}$

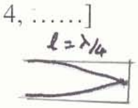


or $\lambda = 2\ell = 2\times50\times10^{-2}$ m

$f_1 = \dfrac{v}{2\ell} = \dfrac{350}{2\times50\times10^{-2}} = 350 \text{ Hz}$

& $f_2 = 2f_1 = 2\times350 = 700 \text{ Hz}$ [n = 1, 2, 3, 4, ……]

b) $\ell = \dfrac{\lambda}{4}$ or $\lambda = 4\ell$



$f_1 = \dfrac{v}{4\ell} = \dfrac{350}{4\times50\times10^{-2}} = 175 \text{ Hz}$

& $f_2 = nf_1 = 3f_1 = 3\times175 = 525 \text{ Hz}$ [n = 1, 3, 5, 7, ……]

8.6) We have $f_n = \dfrac{nv}{4\ell}$ [n = 1,3,5,7,.....]

for minimum length,

$f_1 = \dfrac{v}{4\ell} = \dfrac{340}{4\times30\times10^{-3}} = 2833.333 = 2833 \text{ Hz}^*$

for longest length,

$f_1 = \dfrac{v}{4\ell} = \dfrac{340}{4\times4} = 21.25 = 21 \text{ Hz}^*$

8.8)

It is the case: Source is moving towards stationary observer.

We have $f_C = \left(\dfrac{v}{v-u_s}\right)f$ or $f = f_C \Big/ \left(\dfrac{v}{v-u_s}\right) = \dfrac{f_C\times(v-u_s)}{v}$

$v = 340 \text{ m s}^{-1}$
$u_s = (20 - 12) = 8 \text{ m s}^{-1}$
$f_C = 830 \text{ Hz}$

Putting the values, $f = \dfrac{830\times(340-[20-12])}{340} = 810.47 = 810 \text{ Hz}$

8.9)

It is the case: Source is moving away from the stationary observer.

We have $f_D = \left(\dfrac{v}{v+u_s}\right)f$

or $\dfrac{f_D}{f} = \dfrac{v}{(v+u_s)}$ or $v + u_s = \dfrac{v \times f}{f_D}$

or $u_s = \dfrac{v \times f}{f_D} - v = \dfrac{340 \times 1200}{1140} - 340 = 17.89 = 17.9 \text{ m s}^{-1}$

Now $S = (u_s)_{av} \times t = \dfrac{0 + 17.9}{2} \times 50 = 447.5 = 448 \text{ m}$

$f = 1200$ Hz
$f_D = 1140$ Hz
$v = 340 \text{ m s}^{-1}$
$t = 50$ s

$S = v_{av}t$

8.10) Since $f' = \dfrac{c}{478}$ Hz is less than $f = \dfrac{c}{397}$ Hz

It is the case :
Source is moving away from the stationary observer.
So the galaxy is moving away from the Earth.

$v = f\lambda$
or $f = \dfrac{v}{\lambda} = \dfrac{c}{\lambda}$

b) We have $f_D = \left(\dfrac{v}{v+u_s}\right)f$

or $\dfrac{f_D}{f} = \dfrac{v}{(v+u_s)}$ or $v + u_s = \dfrac{v \times f}{f_D}$

or $u_s = \dfrac{v \times f}{f_D} - v$

or $u_s = \dfrac{c \times \cancel{c}/\lambda}{\cancel{c}/\lambda'} - c = \dfrac{c \times 1/\lambda}{1/\lambda'} - c$

or $u_s = \left(\dfrac{\lambda'}{\lambda} - 1\right) \times c$

$v = c$
&
$f = \dfrac{c}{\lambda}$

putting the values, we get

$$u_s = \left(\frac{478 \times 10^{-9}}{397 \times 10^{-9}} - 1\right) \times 3 \times 10^8 = 6.1 \times 10^7 \text{ m s}^{-1}$$

*[*Please note that the Answer should be in the units / format of the data. If figures are in decimal then use that otherwise should be without decimals.*]

Chapter 9

9.1) $d\sin\theta = \left(m+\frac{1}{2}\right)\lambda$ or $\sin\theta = \frac{\left(m+\frac{1}{2}\right)\lambda}{d}$

$\lambda = 546\times10^{-9}\,m$
$d = 0.1\times10^{-3}\,m$
$L = 20\times10^{-2}\,m$
$m = 0$

or $\theta = \sin^{-1}\frac{\left(m+\frac{1}{2}\right)\lambda}{d} = \sin^{-1}\frac{\left(0+\frac{1}{2}\right)546\times10^{-9}}{0.1\times10^{-3}} = 0.16^0$

$\Delta y = \frac{\lambda L}{d} = \frac{546\times10^{-9}\times20\times10^{-2}}{0.1\times10^{-3}} = 0.0011\text{ m} = 0.0011\times10^3\text{ mm} = 1.1\text{ mm}$

9.2) $y = \frac{m\lambda L}{d}$ or $\lambda = \frac{y\,d}{m\,L}$

$d = 0.5\times10^{-3}\,m$
$L = 200\times10^{-2}\,m$
$y = 2.4\times10^{-3}\,m$
$m = 1$

or $\lambda = \frac{2.4\times10^{-3}\times0.5\times10^{-3}}{1\times200\times10^{-2}} = 6.00\times10^{-7}\text{ m} = 600\text{ nm}$

9.3) $d\sin\theta = m\lambda$

$m = 2$
$\theta = 0.25^0$
$\lambda = 650\times10^{-9}\,m$

or $d = \frac{m\lambda}{\sin\theta} = \frac{2\times650\times10^{-9}}{\sin(0.25)^0} = 0.0003\text{ m}$

or $d = 0.0003\text{ m} = 0.0003\times10^3\text{ mm} = 0.3\text{ mm}$

9.4) $L = m\frac{\lambda}{2}$

$\lambda = 588\times10^{-9}\,m$
$L = 0.233\times10^{-3}\,m$

or

$m = \frac{2L}{\lambda} = \frac{2\times0.233\times10^{-3}}{588\times10^{-9}} = 792.517 \Rightarrow = 792$

9.5) $d\sin\theta = m\lambda$ or $\lambda = \frac{d\sin\theta}{m}$

$m = 2$
$\theta = 38.0^0$
$d = \frac{1}{N} = \frac{1}{5400}\times10^{-2}\text{ lines/m}$

or $\lambda = \frac{\frac{1}{5400}\times10^{-2}\times\sin38^0}{2} = 5.7\times10^{-7}\text{ m} = 570\text{ nm}$

9.6) $d\sin\theta = m\lambda$

$d = \frac{1}{N} = \frac{1}{2500}\times10^{-2}\text{ lines/m}$
$m = 2$ & $\theta = 15.0^0$

or $\lambda = \frac{d\sin\theta}{m}$

or $\lambda = \frac{\frac{1}{2500}\times10^{-2}\sin15^0}{2} = 5.176\times10^{-7}\text{ m} = 518\text{ nm}$

9.7 $d\sin\theta = m\lambda$

$\lambda = 589\times10^{-9}\,m$
$d = \frac{1}{N} = \frac{1}{3000}\times10^{-2}\text{ lines/m}$
for highest order, $\theta = 90^0$

or $m = \frac{d\sin\theta}{\lambda}$

or $m = \frac{\frac{1}{3000}\times10^{-2}\sin90^0}{589\times10^{-9}} = 5.6593 \Rightarrow 5^{th}$ order

9.8) $d \sin\theta = m\,\lambda$

or $\dfrac{1}{N}\sin\theta = m\,\lambda$

or $N = \dfrac{\sin\theta}{m\,\lambda}$

| $\lambda = 480\times10^{-9}\,m$
| $m = 2$
| $\theta = 30^0$ & $d = \dfrac{1}{N}$

or $N = \dfrac{\sin 30^0}{2\times 480\times10^{-9}} = 520{,}833.333 = 5.2\times10^5\,\text{lines/m} = 5.2\times10^3\,\text{lines/cm}$

9.9) $2d\sin\theta = n\,\lambda$

or $d = \dfrac{n\,\lambda}{2\sin\theta}$

| $\lambda = 0.150\times10^{-9}\,m$
| $n = 1$
| $\theta = 13.3^0$

or $d = \dfrac{1\times 0.150\times10^{-9}}{2\sin 13.3^0} = 3.26\times10^{-10}\,m = 0.326\times10^{-9}\,m = 0.326\ nm$

9.10) For 2nd beam;

$2d\sin\theta = n\,\lambda$

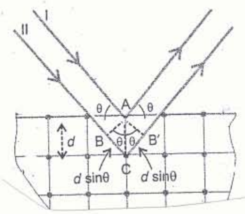
or $d = \dfrac{n\,\lambda}{2\sin\theta}$

| $n = 3$
| $\theta = 60.0^0$
| $\lambda = 0.097\times10^{-9}\,m$

or $d = \dfrac{3\times 0.097\times10^{-9}}{2\sin 60.0^0}$

or $d = 1.68\times10^{-10}\,m$

or $d = 0.168\ nm$



For 1st beam;

$2d\sin\theta = n\,\lambda$

or $\lambda = \dfrac{2d\sin\theta}{n}$

| $n = 1$
| $\theta = 26.5^0$

or $\lambda = \dfrac{2\times 0.168\times10^{-9}\times\sin 26.5^0}{1} = 1.499\times10^{-10}\,m = 0.150\ nm$

<u>Please Note:</u>

I use hp (Hewlett Packard), 42 S , RPN Scientific calculator.
That makes the calculations in a single step.
How about your calculator and calculations?

Chapter 10

10.1) i) Using the formula

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{(-q)}=\frac{1}{p}-\frac{1}{q}$$

| f = 5.0 cm
| q = -25 cm

or $\frac{1}{p}=\frac{f(-q)}{-q-f}=\frac{-fq}{-(q+f)}=\frac{5\times 25}{25+5}=$ **4.2 cm**

ii) $M=1+\frac{d}{f}=1+\frac{25}{5}=$ **6.0** [d = 25 cm]

iii) $\frac{1}{f}=\frac{1}{p}+\frac{1}{q(=\infty)}$ or $\frac{1}{f}=\frac{1}{p}+0$

| $q=\infty$
| or $\frac{1}{\infty}=0$

or $\frac{q}{f}=\frac{q}{p}$ so $M=\frac{q}{p}=\frac{q}{f}=\frac{25}{5}=$ **5.0**

10.2) $M=\frac{f_o}{f_e}$

| f_o = 96 cm
| D = 12 cm
| M = 24

or $f_e=\frac{f_o}{M}=\frac{96}{24}=$ **4.0 cm**

since $D \propto f$

so $\frac{D_e}{D_o}=\frac{f_e}{f_o}$ $\Rightarrow D_e=D_o\frac{f_e}{f_o}=12\times\frac{4}{96}=$ **0.50 cm**

10.3) $M=\frac{f_o}{f_e}=\frac{20}{5}=$ **4.0**

| f_o = 20 cm
| f_e = 5.0 cm

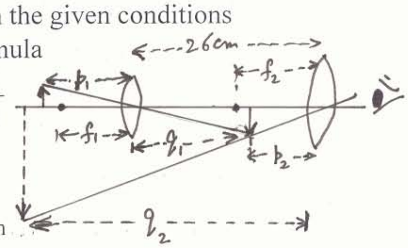
10.4) i) For normal adjustment the final image is formed at **infinity**

| f_o = 100 cm
| f_e = 5.0 cm

ii) $M=\frac{f_o}{f_e}=\frac{100}{5}=$ **20**

10.5) The ray diagram is made from the given conditions

i) For first lens, from the formula



$$\frac{1}{f_1}=\frac{1}{p_1}+\frac{1}{q_1} \text{ or } \frac{1}{f_1}-\frac{1}{p_1}=\frac{1}{q_1}$$

or $\frac{1}{q_1}=\frac{p_1-f_1}{f_1p_1}$

or $q_1=\frac{f_1p_1}{p_1-f_1}=\frac{3\times 3.6}{3.6-3}=18$ cm

so $p_2=26-q_1=26-18=8$ cm

Now for second lens, $\frac{1}{f_2}=\frac{1}{p_2}+\frac{1}{q_2}$

| p_1 = 3.6 cm
| f_1 = 3.0 cm
| f_2 = 16.0 cm
| L = 26.0 cm
| q_2 = ?

or $\frac{1}{q_2}=\frac{1}{f_2}-\frac{1}{p_2}$

or $q_2=\frac{f_2p_2}{p_2-f_2}=\frac{16\times 8}{8-16}=-16$ cm

i.e. 16 cm from second lens.

10.6) For compound microscope,

$$M = \frac{q}{p}\left(1 + \frac{d}{f_e}\right), \quad f_o < f_e$$

f_o = 1.0 cm
f_e = 3.0 cm
p = 1.2 cm
q_e = 25 cm
L = ?
M = ?

Using the formula

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

for object lens, we have

$$\frac{1}{f_o} = \frac{1}{p} + \frac{1}{q}$$

or $\frac{1}{q} = \frac{1}{f_o} - \frac{1}{p} = \frac{p - f_o}{f_o p}$

or $q = \frac{f_o p}{p - f_o} = \frac{1 \times 1.2}{1.2 - 1} = 6 \text{ cm}$

& for eyepiece, we have

$$\frac{1}{f_e} = \frac{1}{p_e} + \frac{1}{-q_e}$$

or $\frac{1}{p_e} = \frac{1}{f_e} + \frac{1}{q_e} = \frac{q_e + f_e}{f_e q_e}$

or $p_e = \frac{f_e q_e}{q_e + f_e} = \frac{3 \times 25}{25 + 3} = 2.68 \text{ cm}$

so $L = p_e + q = 2.68 + 6 = 8.68 =$ **8.7 cm**

& $M = \frac{q}{p}\left(1 + \frac{d}{f_e}\right) = \frac{6}{1.2}\left(1 + \frac{25}{3}\right) \doteq 46.67 =$ **47**

10.7 We have

λ = 589 x 10^{-9} m
D = 0.9 x 10^{-2} m
α_{min} = ?

$$\alpha_{min} = 1.22 \frac{\lambda}{D}$$

$\alpha_{min} = 1.22 \times \frac{589 \times 10^{-9}}{0.9 \times 10^{-2}} = 7.98 \times 10^{-5} =$ **8.0 x 10^{-5} rad**

Now for maximum α_{min}, we shall use, $\lambda_{violet} = 400 \times 10^{-9}$ m

So $\alpha_{min} = 1.22 \frac{\lambda_{violet}}{D} = 1.22 \times \frac{400 \times 10^{-9}}{0.9 \times 10^{-2}} =$ **5.4 x 10^{-5} rad**

10.8) $M = \frac{f_o}{f_e}$

M = 5
$L = f_o + f_e = 24$ cm

or $5 = \frac{f_o}{f_e}$ or $f_o = 5f_e$ ….. (1)

& $L = f_o + f_e = 24$ ….. (2)

from equations (1) & (2) we get

$5f_e + f_e = 24$ or $6f_e = 24$ or $f_e = \frac{24}{6} =$ **4 cm**

& $f_o = 5 \times 4 =$ **20 cm**

10.9) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

or $n_1 \sin 39^0 = 1 \sin 90^0$

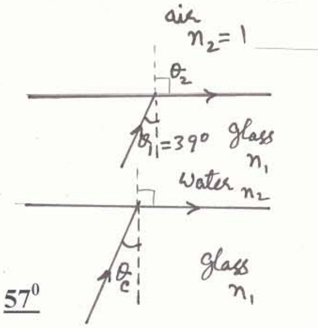
$$\Rightarrow \quad n_1 = \frac{\sin 90^0}{\sin 39^0} = 1.59$$

Now for water & glass interface

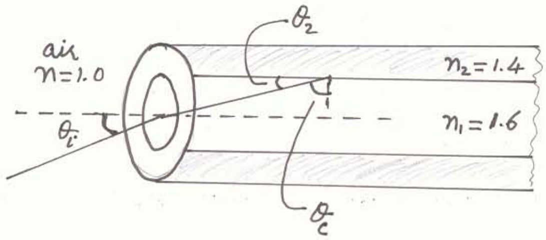
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\sin\theta_1 = \frac{n_2}{n_1}\sin\theta_2$$

or $\sin\theta_c = \frac{n_2}{n_1}\sin\theta_2 = \frac{1.33}{1.59}\sin 90^0 = 56.77 = \underline{\mathbf{57^0}}$



10.10) Putting given conditions in the figure



i) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$\Rightarrow \quad \theta_c = \frac{n_2 \sin\theta_2}{n_1} = \frac{1.4 \sin 90^0}{1.6} = \underline{\mathbf{61^0}}$$

ii) for air and optical fibre interface
angle of refraction $= \theta_2 = 90 - \theta_c = 29^0$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\Rightarrow \quad \theta_i = \sin^{-1}\frac{1.6 \times \sin 29^0}{1} = 50.76 = \underline{\mathbf{51^0}}$$

Chapter 11

11.1) $T = \frac{2}{3k} < \frac{1}{2} mv^2 >$

or $T = \frac{2}{3k} \times \frac{1}{2} m < v^2 >$

or $< v^2 > = \frac{3kT}{m} = \frac{3 \times 1.38 \times 10^{-23} \times 273}{28 \times 10^{-3} / 6.022 \times 10^{23}}$

or $< v^2 > = \frac{3 \times 1.38 \times 10^{-23} \times 6.022 \times 10^{23} \times 273}{28 \times 10^{-3}} = 243078.03$

or $\sqrt{< v^2 >} = 493.03$ or $< v > = 493 \text{ ms}^{-1}$

$T = 273$ K
$k = 1.38 \times 10^{-23} \text{ JK}^{-1}$
$m = \frac{\text{molecular mass}}{N_A}$
or $m = \frac{28 \times 10^{-3}}{6.022 \times 10^{23}}$ kg mole^{-1}

11.2) $T = \frac{2}{3k} < \frac{1}{2} mv^2 >$

$\Rightarrow T_1 = \frac{2}{3k} < \frac{1}{2} m_1 v_1^2 >$ & $T_2 = \frac{2}{3k} < \frac{1}{2} m_2 v_2^2 >$

As $T_1 = T_2$ so $\frac{2}{3k} < \frac{1}{2} m_1 v_1^2 > = \frac{2}{3k} < \frac{1}{2} m_2 v_2^2 >$

or $< m_1 v_1^2 > = < m_2 v_2^2 >$

or $\frac{< v_1^2 >}{< v_2^2 >} = \frac{m_2}{m_1}$ or $\frac{\sqrt{< v_1^2 >}}{\sqrt{< v_2^2 >}} = \frac{\sqrt{m_2}}{\sqrt{m_1}}$

11.3) W = P V

or $V = \frac{W}{P} = \frac{100}{1.25 \times 10^5} = 8 \times 10^{-4} \text{ m}^3$

$P = 1.25 \times 10^5 \text{ Nm}^{-2}$
W = 100 J
V = ?

11.4) $Q = \Delta U + W$

or Q = (-300) + (-120) = – 420 J

ΔU = 300 J
W = 120 J
Q = ?

11.5) i) $\eta = 1 - \frac{T_2}{T_1}$

or $\eta = 1 - \frac{127 + 273}{227 + 273} = 0.2 = 0.2 \times 100 = 20\ \%$

ii) $\eta = \frac{\text{Output}}{\text{Input}} = \frac{W}{Q_1}$

or $Q_1 = \frac{W}{\eta} = \frac{10,000}{0.2} = 5 \times 10^4 \text{ J}$

iii) $\eta = 1 - \frac{Q_2}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

or $Q_1 - Q_2 = \eta Q_1$

or $Q_2 = Q_1 - \eta Q_1 = Q_1(1 - \eta) = 5 \times 10^4 (1 - 0.2) = 4 \times 10^4 \text{ J}$

T_1 = (127 +273) K
T_2 = (227 +273) K
η = ?
W = 10,000 J
Q_1 = ?
Q_2 = ?

11.6) $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

or $1 - \frac{Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}$

$T_1 - T_2 = 100$
$Q_1 = 746$ J
$Q_2 = 546$ J
$T_1 = ?$
$T_1 = ?$

or $T_1 = \frac{T_1 - T_2}{\left(1 - Q_2/Q_1\right)} = \frac{100}{1 - 546/746} = 373$ K $= 373 - 273 = 100$ °C

& $T_1 - T_2 = 100$ or $T_2 = T_1 - 100 = 100 - 100 = 0$ °C

11.7 $\eta = 1 - \frac{T_2}{T_1}$

or $\eta = 1 - \frac{27 + 273}{327 + 273} = 0.5 = 0.5 \times 100 = 50$ %

$T_2 = (27 + 273)$ K
$T_1 = (327 + 273)$ K
$\eta = 52$ %

His claim of 52 % is not correct.

11.8) $\eta = \frac{\text{Output}}{\text{Input}} = \frac{W}{Q_1}$

or $\eta = \frac{100}{500} = 0.2 = 0.2 \times 100 = 20$ %

$W = 100$ J
$Q_2 = 400$ J
$W = Q_1 - Q_2$
or $Q_1 = W + Q_2$
or $Q_1 = 100 + 400$

11.9) For 1st condition,

$\eta = 1 - \frac{T_2}{T_1}$ or $\frac{T_2}{T_1} = 1 - \eta$ or $\frac{T_2}{1 - \eta} = T_1$

or $T_1 = \frac{T_2}{1 - \eta} = \frac{7 + 273}{1 - 50/100} = 560$ K

For desired condition,

$\eta = 1 - \frac{T_2}{T_1'}$ or $T_1' = \frac{T_2}{1 - \eta} = \frac{7 + 273}{1 - 70/100} = 933.33$ K

To be increased: $T_1' - T_1 = 933.33 - 560 = 373.33 = 373$ K $\equiv 373$ °C

[Since magnitude of the degree of Celsius Scale & Kelvin Scale is equal , so for the difference we can write °C for K]

11.10) $\eta = 1 - \frac{T_2}{T_1}$

or $\eta = 1 - \frac{300}{450} = 0.33 \times 100 = 33$ %

$T_1 = 450$ K
$T_2 = 300$ K
$\eta = ?$

11.11) Heat (ΔQ) required for 1 gm = 336 J
Heat (ΔQ) // // 30 gm = 336 x 30 J
Temperature = T = 0 + 273 = 273 K

So $\Delta S = \frac{\Delta Q}{T} = \frac{336 \times 30}{0 + 273} = 36.92$ JK^{-1}

Water changed to ice means, heat is removed from the system,
& Change in entropy (ΔS) will be **-ve**

So $\Delta S = -36.92$ JK^{-1}