PROSPERITY ACADEMY

AS PHYSCIS 9702
Crash Course

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WAVES

COMPLETE NOTES

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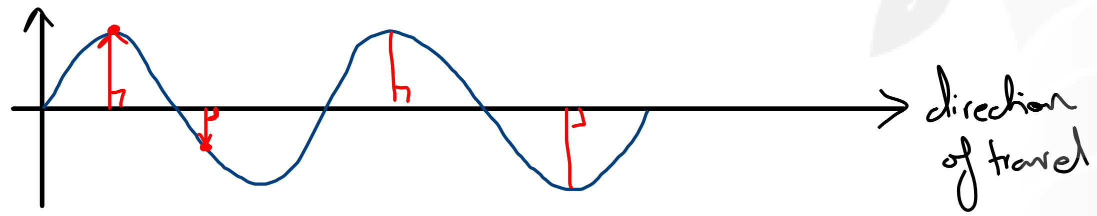
Waves:-

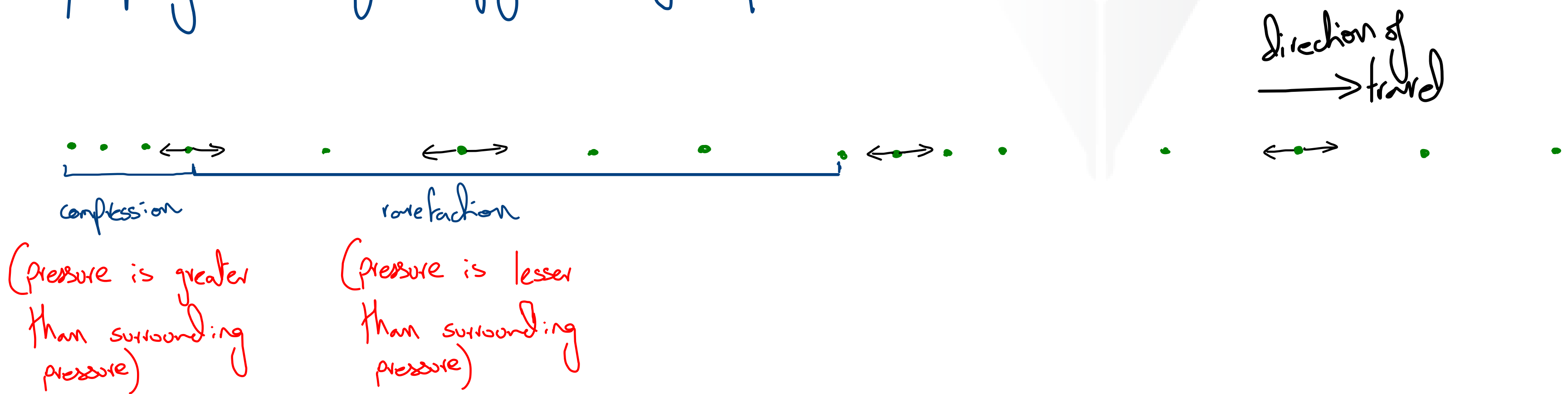
Progressive Waves:- Transfer energy from one place to another

Stationary Waves:- They don't transfer energy.

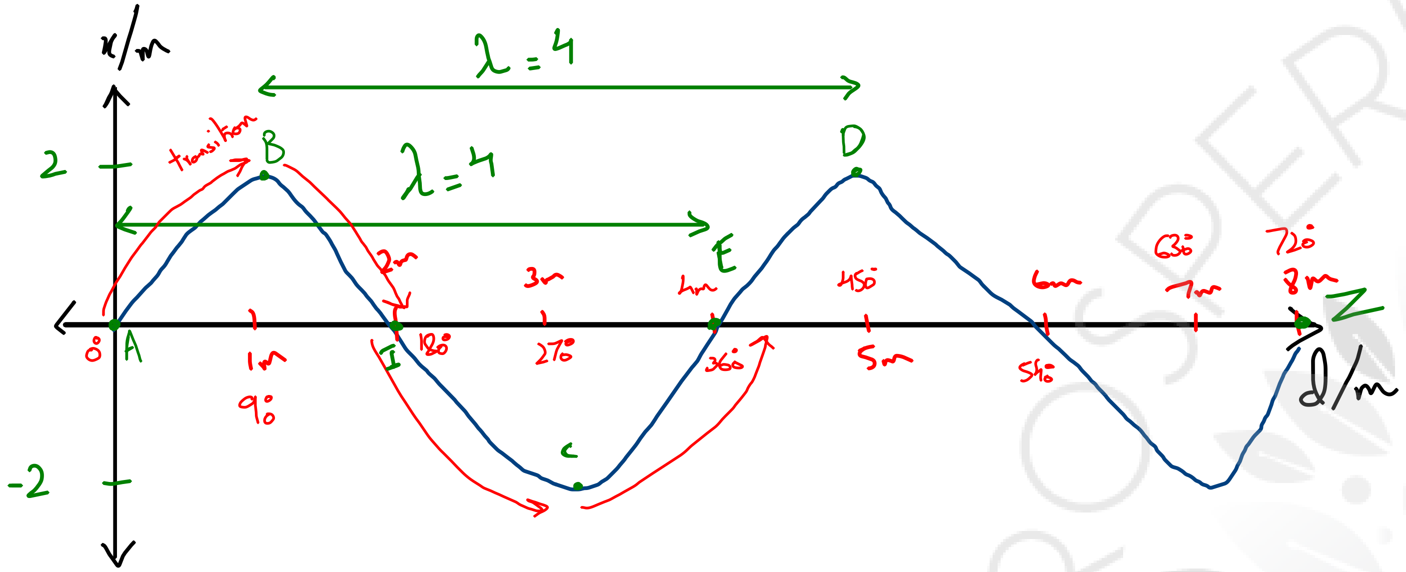
→ **Transverse Waves:-** Vibration/Motion of particles is perpendicular to direction of travel of waves / to direction of propagation of energy. They can travel in vaccum. (Electromagnetic spectrum, Water waves)

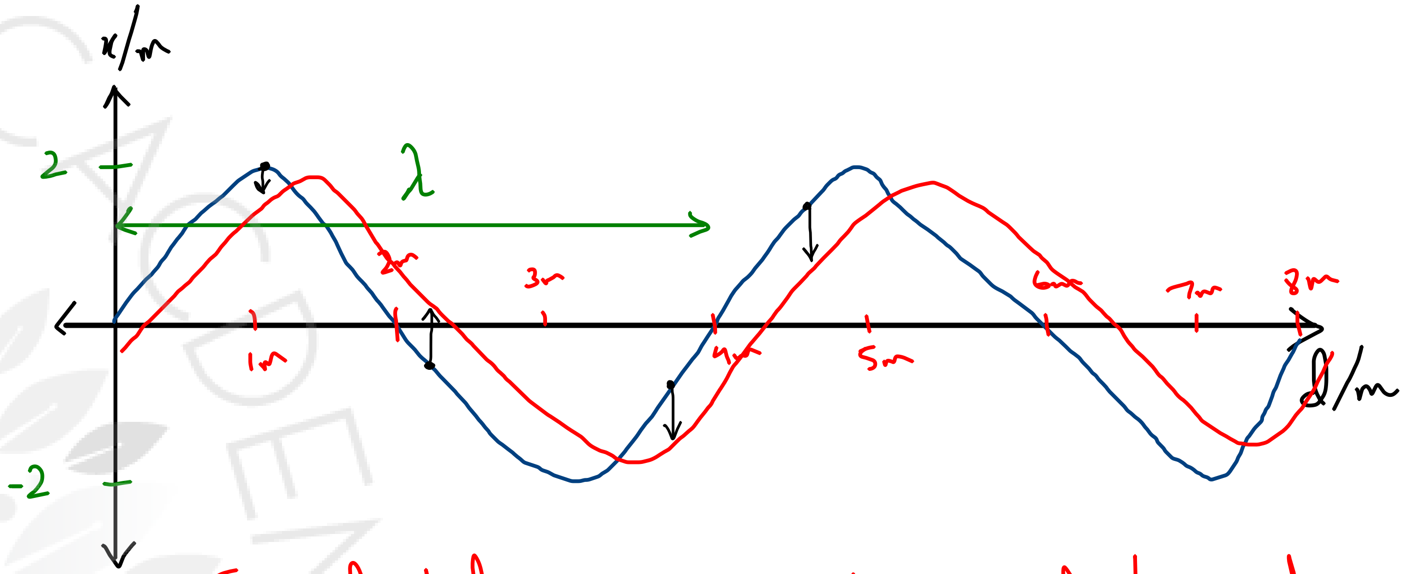


→ **Longitudinal Waves:-** Vibration/Motion of particles is parallel to direction of travel of waves / to direction of propagation of energy. They require a medium to travel. (Sound waves)



Displacement - distance :- (At a particular time)





To tell which particle moves where in displacement distance, Draw the next wave

Displacement :- Distance moved by particle from its mean position

Distance :- Distance moved along the wave

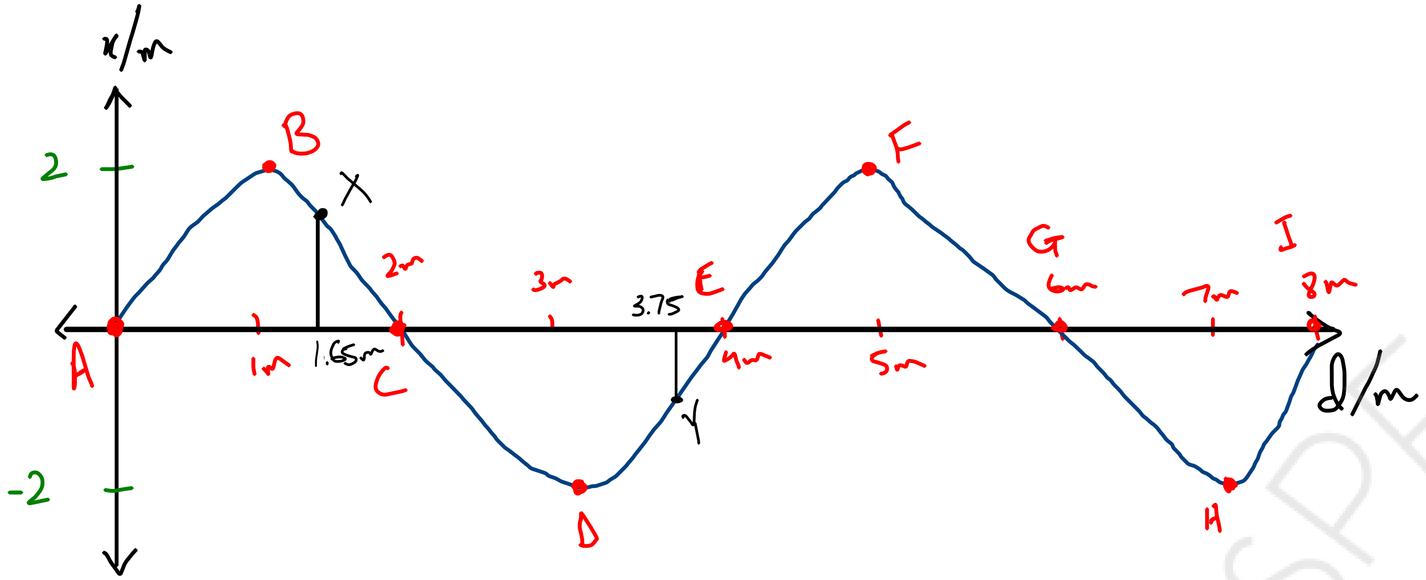
Amplitude :- Maximum displacement of a particle from its mean position in a wave. Scalar

Wavelength (λ) :- Distance between 2 consecutive points in phase.

Phase difference :- Basically, it tells how much of a wave is completed.

0° → 0% wave 360° → 100% wave

1 transition ($\frac{1}{4}$ wave) ⇒ $\frac{1}{4} \times 360° = 90°$



Phase difference b/w

A & C :- 180°

A & E :- 360° or 0°

D & F :- 180°

C & H :- 450° or 90°

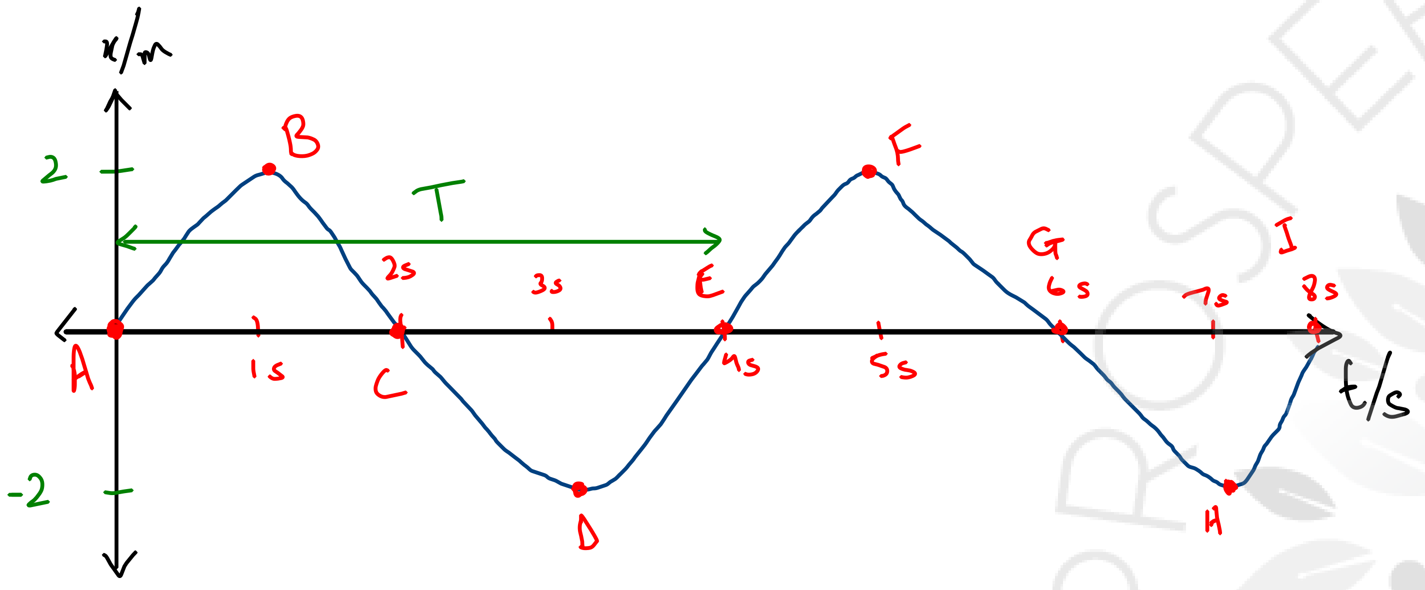
D & G :- 270°

$$\text{Phase difference} = \frac{\Delta x}{\lambda} \times 360°$$

$$\text{Phase difference b/w X \& Y} = \frac{3.75 - 1.65}{4} \times 360°$$

$$= 189°$$

Displacement - time :- (At a particular distance, for one particle)



Phase difference :- Basically, it tells how much of a wave is completed.

$0° \rightarrow 0\%$ wave $\quad 360° \rightarrow 100\%$ wave

1 transition ($\frac{1}{4}$ wave) $\Rightarrow \frac{1}{4} \times 360° = 90°$

$$\text{Phase difference} = \frac{\Delta t}{T} \times 360°$$

Displacement :- Distance moved by particle from its mean position

Amplitude :- Maximum displacement of a particle from its mean position in a wave. Scalar

Time period (T) :- The time taken for one complete wave to form. (Seconds)

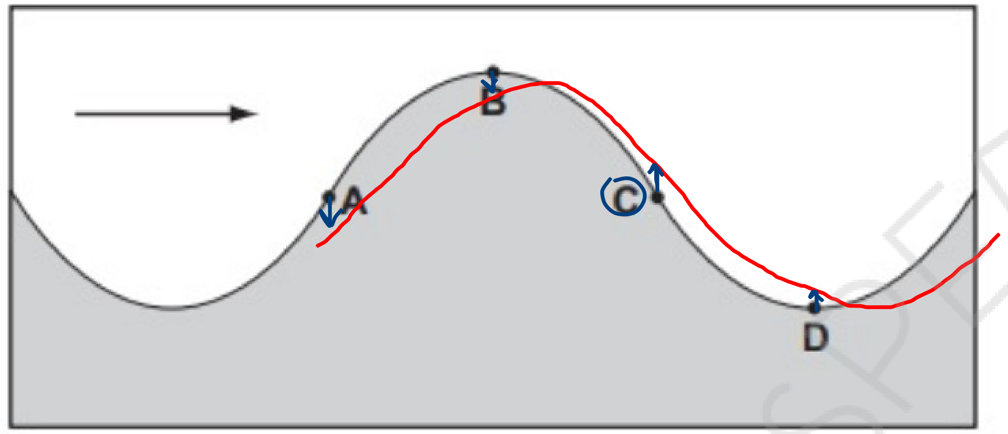
frequency :- The number of complete waves formed in 1 sec.

$$f = \frac{n}{t} = \frac{1}{T}$$

n → no. of complete waves
t → time for n waves to form
1 → 1 wave
T → time period

24 The diagram shows a vertical cross-section through a water wave moving from left to right.

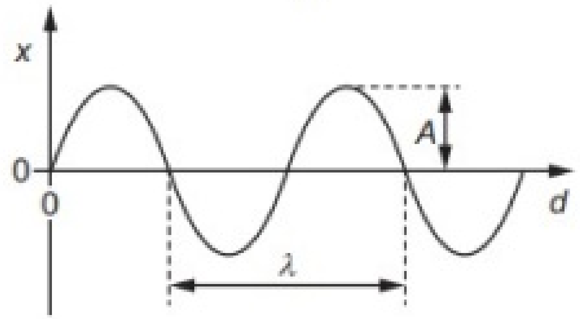
At which point is the water moving upwards with maximum speed?



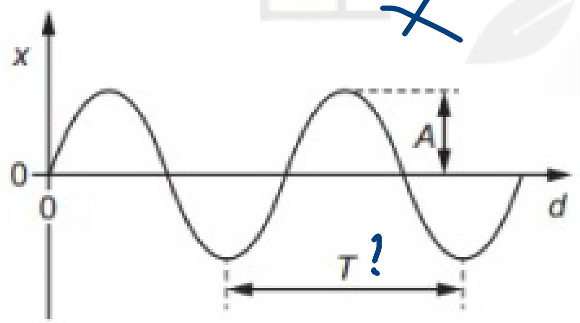
22 A wave has period T, wavelength λ and amplitude A. The wave is shown on a graph of displacement x against distance d.

Which graph is correctly labelled?

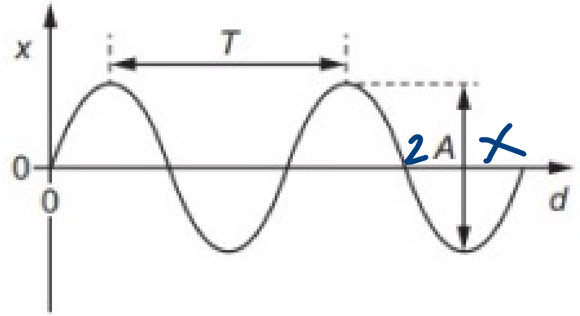
A



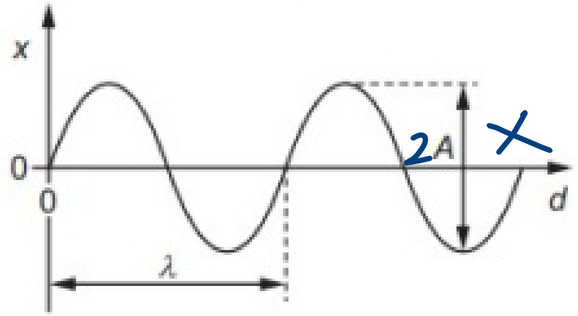
B



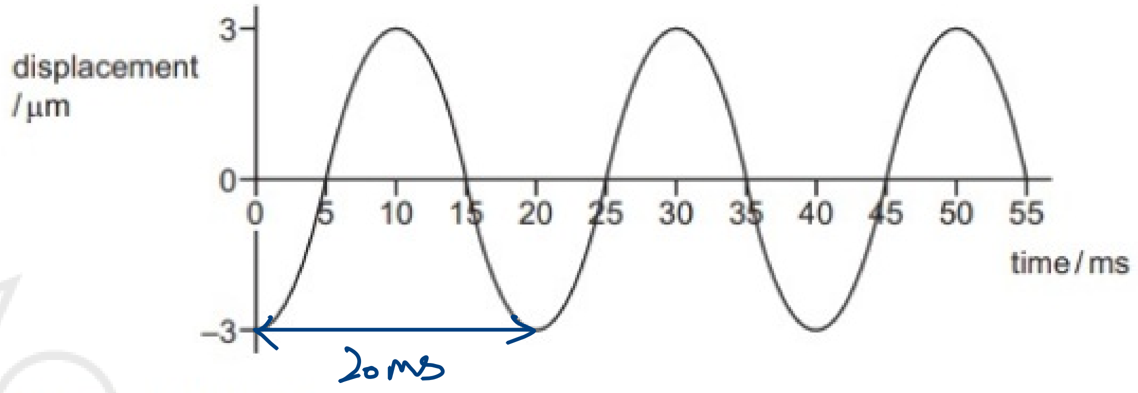
C



D



22 The graph represents a sound wave.



Which statement is correct?

A The wave is longitudinal and has a period of 25 ms.

B The wave is longitudinal and has a frequency of 50 Hz.

C The wave is transverse and has an amplitude of 3 µm.

D The wave is transverse and has a wavelength of 20 ms.

$f = \frac{1}{20\times10^{-3}} = 50\,Hz$

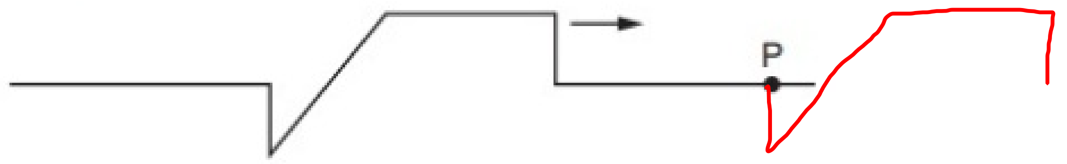
$f = \frac{n}{t} = \frac{2}{40\times10^{-3}} = 50\,Hz$

28 X and Y are two points on the surface of water in a ripple tank. A source of waves of constant frequency begins to generate waves which then travel past X and Y, causing them to oscillate.

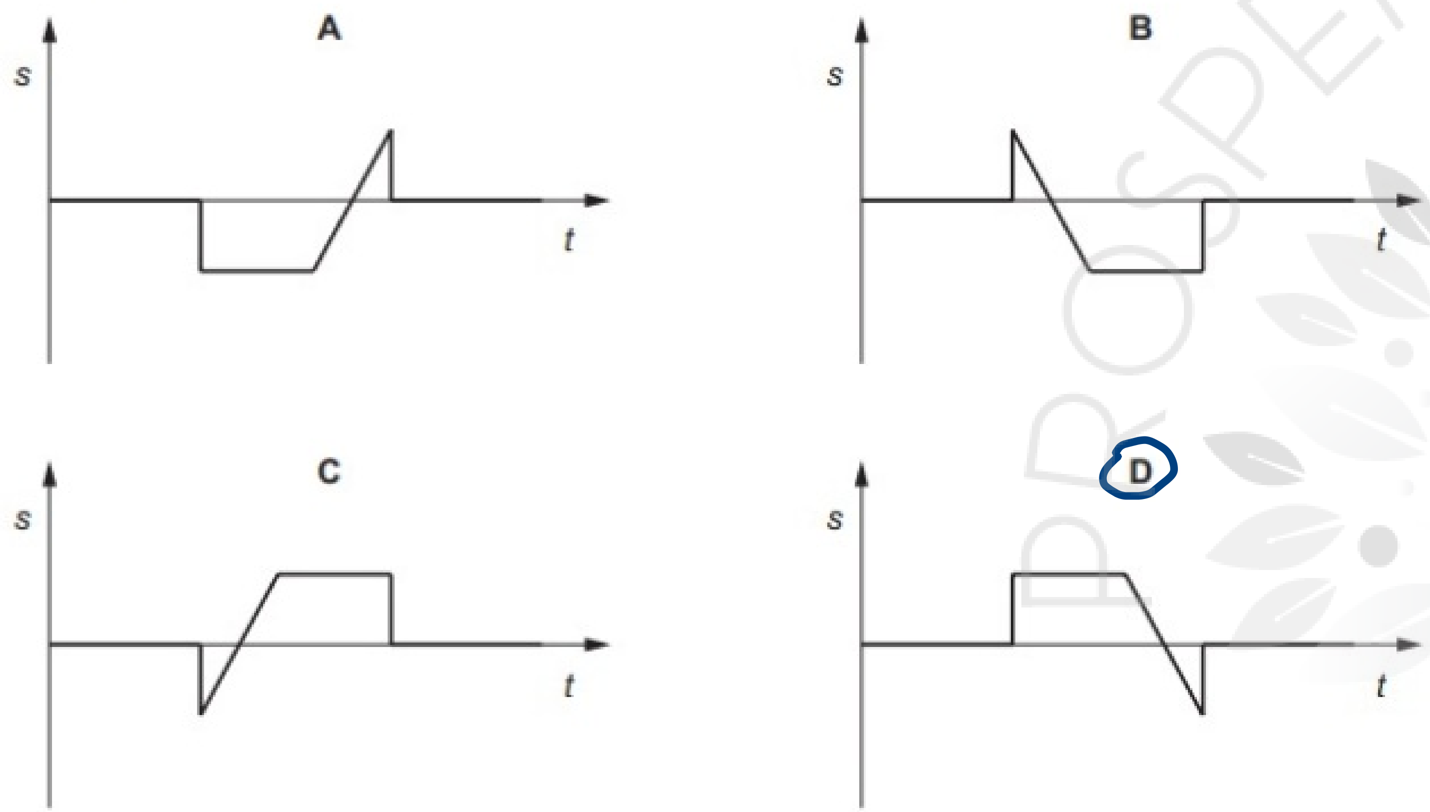
What is the phase difference between X and Y?

A 45° **B** 135° **C** 180° **D** 270°

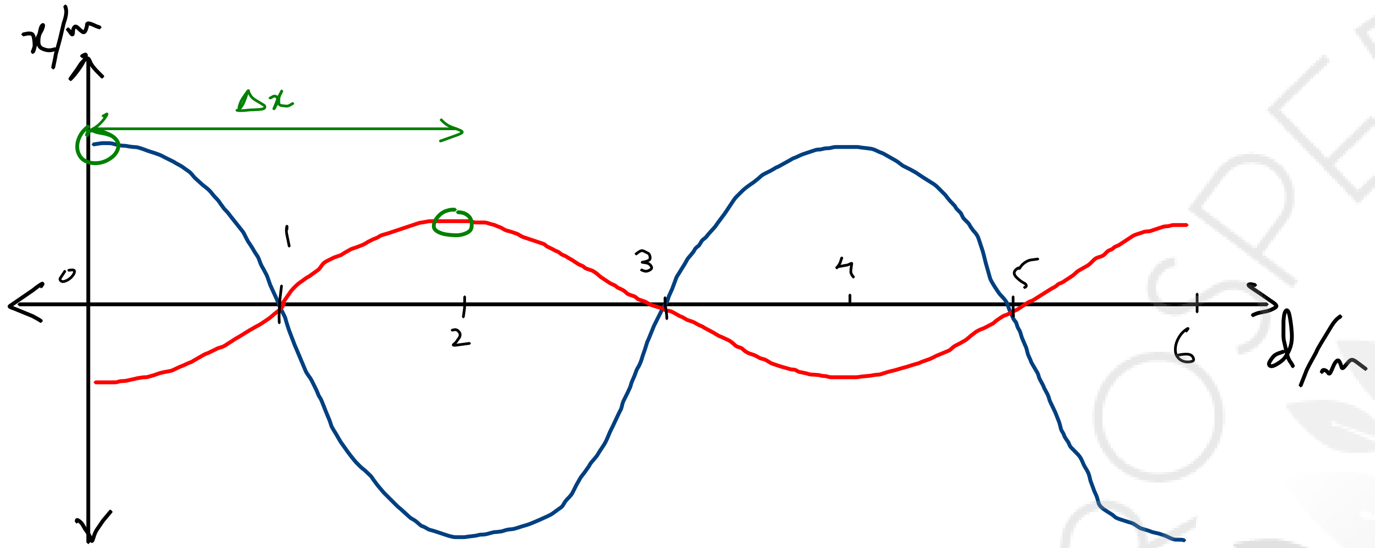
26 A wave pulse moves along a stretched rope in the direction shown.

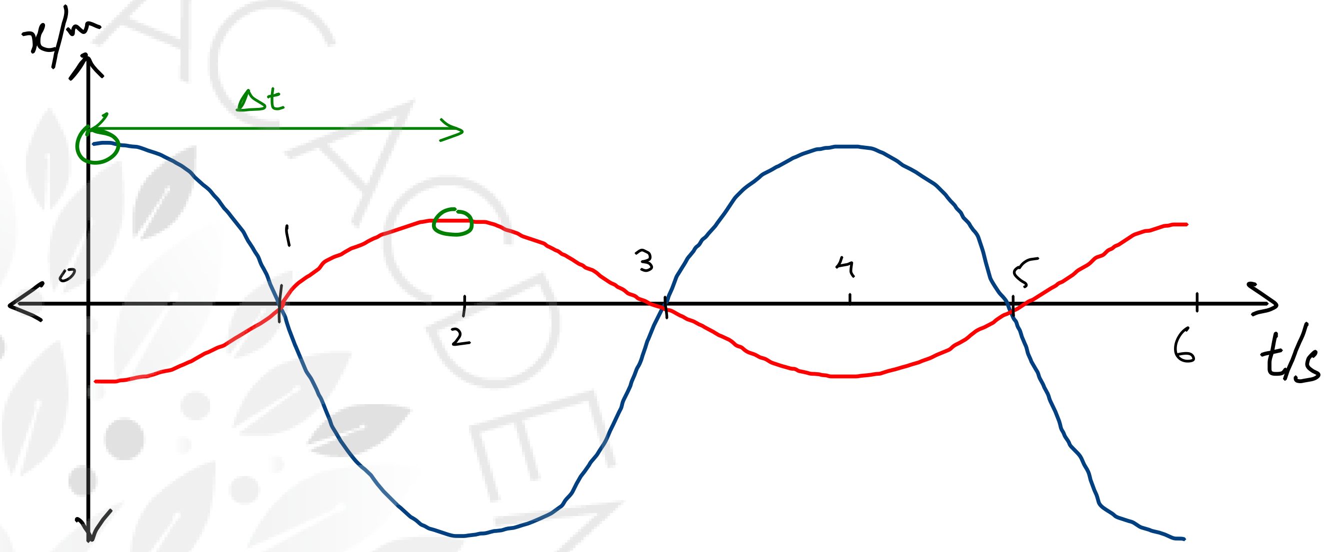


Which diagram correctly shows the variation with time *t* of the displacement *s* of the particle P in the rope?



Phase difference between 2 waves:-





Phase difference $= \frac{\Delta x}{\lambda} \times 360°$

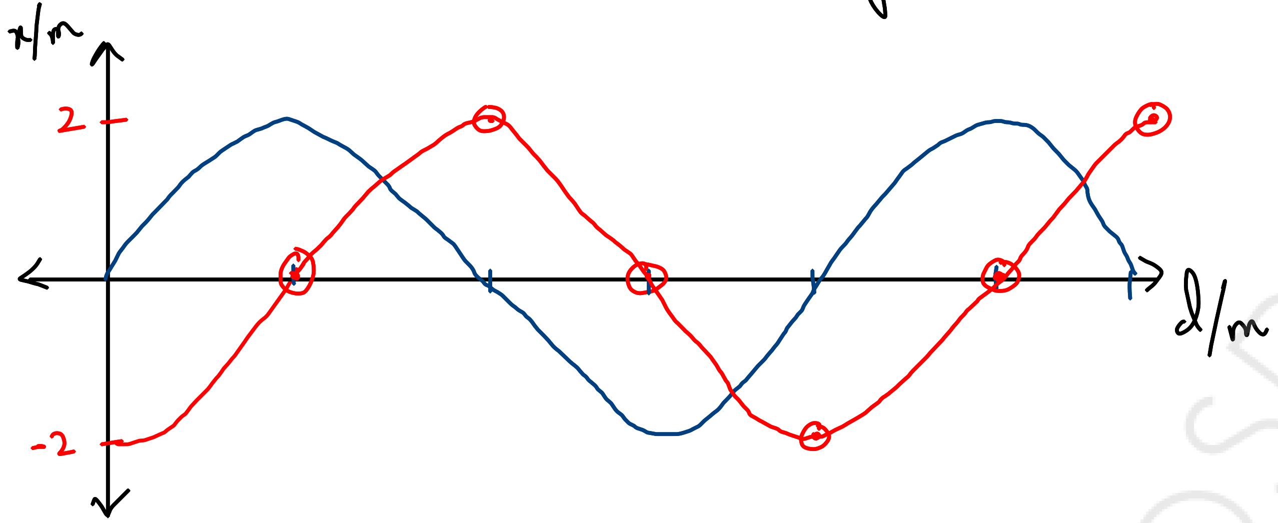
λ same
T same

Phase difference $= \frac{\Delta t}{T} \times 360°$

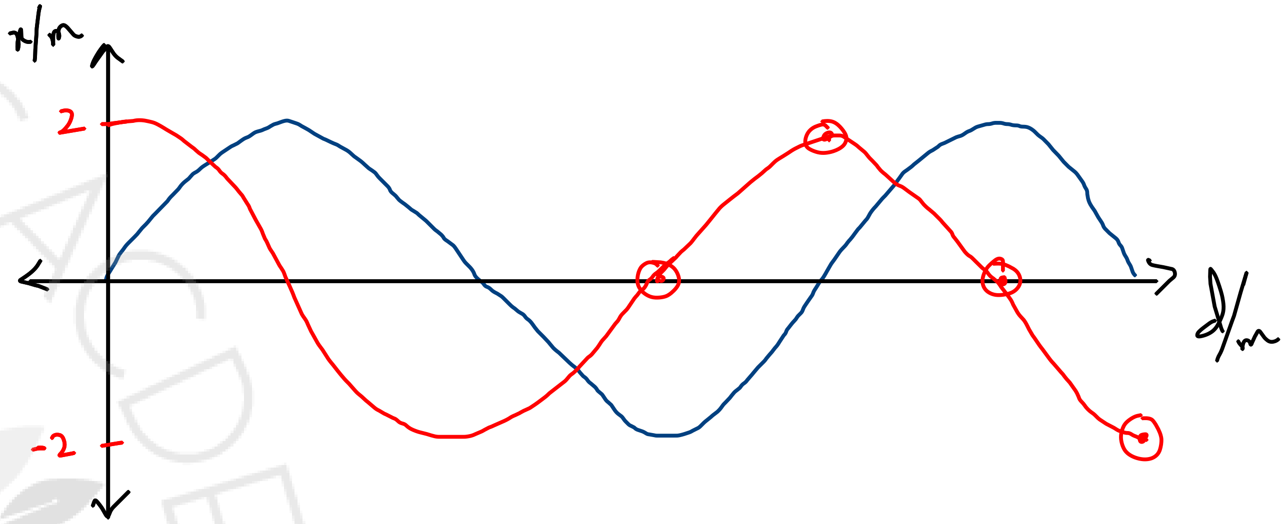
$\frac{2}{4} \times 360° = 180°$

$\frac{2}{4} \times 360° = 180°$

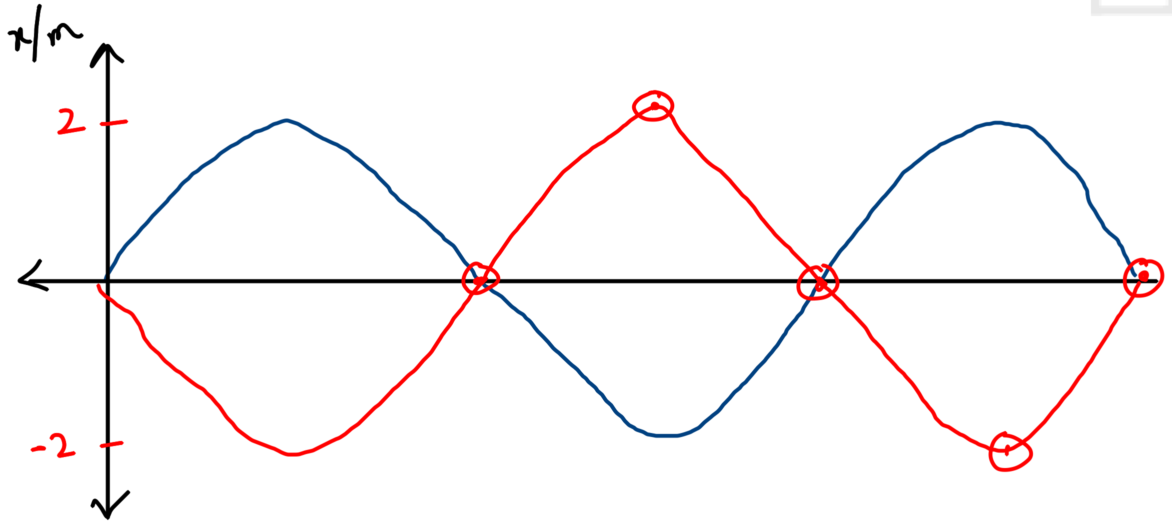
Q. Draw the wave 90° out of phase:-



Q. Draw the wave 270° out of phase:-



Q. Draw the wave 180° out of phase:-



Velocity of a wave :-

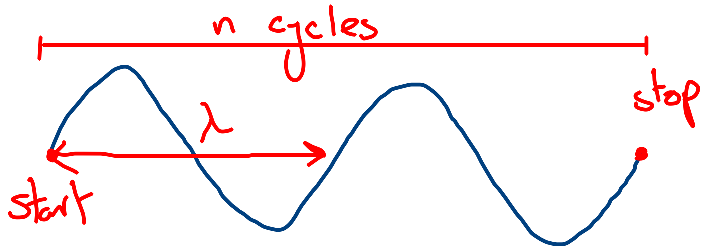
Derivation 1 :-

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$v = \lambda \times \frac{1}{T} \Rightarrow v = f\lambda$$

($\frac{1}{T} \rightarrow f$)

Derivation 2 :-



$$\text{speed} = \frac{\text{distance}}{\text{time}} \Rightarrow v = \frac{n\lambda}{t} \Rightarrow \boxed{v = f\lambda}$$

($\frac{n}{t} \rightarrow f$)

24 The speed v of waves in deep water is given by the equation

$$v^2 = \frac{g\lambda}{2\pi}$$

where λ is the wavelength of the waves and g is the acceleration of free fall.

A student measures the wavelength λ and the frequency f of a number of these waves.

Which graph should he plot to give a straight line through the origin?

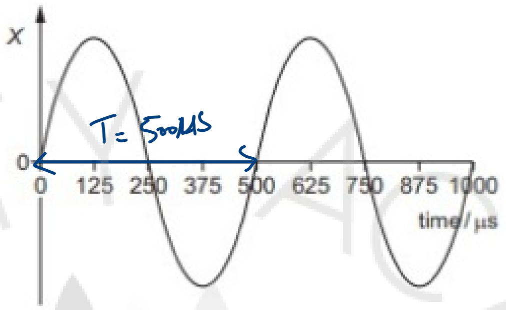
A f^2 against λ

B f against λ^2

C f against $\frac{1}{\lambda}$

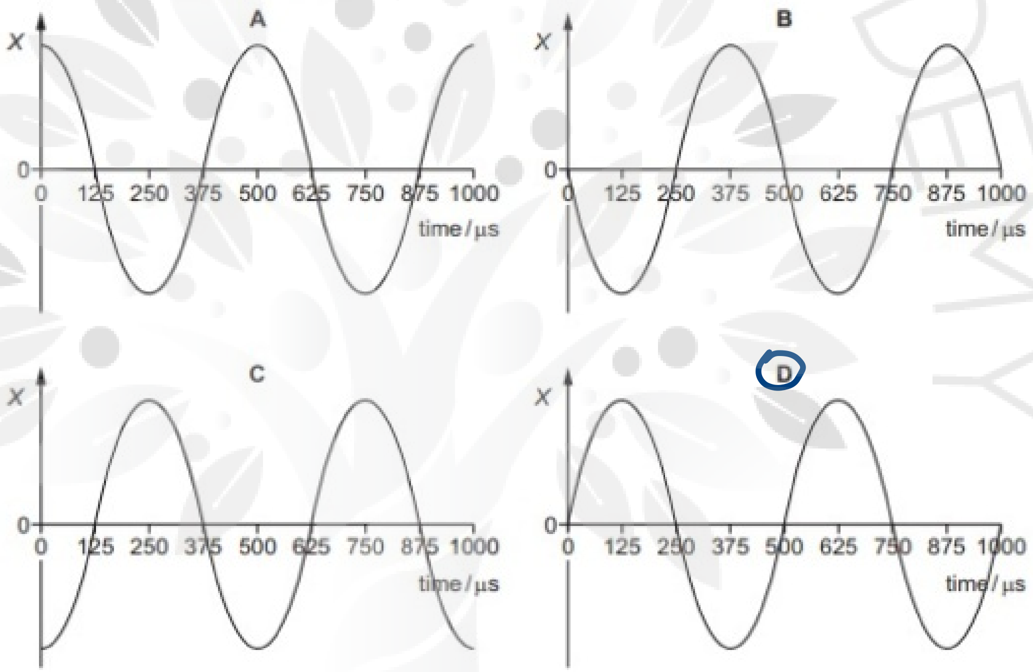
D f^2 against $\frac{1}{\lambda}$

25 The graph shows the variation with time of the displacement X of a gas molecule as a continuous sound wave passes through a gas.

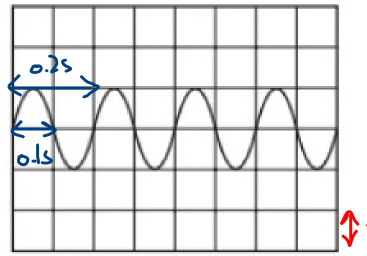


The velocity of sound in the gas is $330\,m\,s^{-1}$. All the graphs below have the same zero time as the graph above.

What is the displacement-time graph for a molecule that is a distance of 0.165 m further away from the source of the sound?



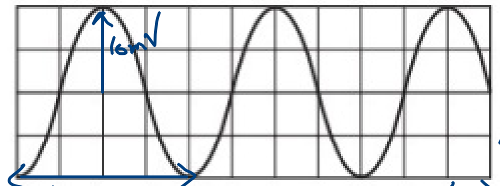
4 A whale produces sound waves of frequency 5 Hz. The waves are detected by a microphone and displayed on an oscilloscope.



What is the time-base setting on the oscilloscope?

A $0.1\,ms\,div^{-1}$ **B** $1\,ms\,div^{-1}$ **C** $10\,ms\,div^{-1}$ **D** $100\,ms\,div^{-1}$

23 The diagram shows the waveform of a signal displayed on a cathode-ray oscilloscope.



The time-base is set at 5.0 ms per division.

The Y-gain is set at 5.0 mV per division.

What are the amplitude and the frequency of the signal?

	amplitude / mV	frequency / Hz
A	10	50
B	10	100
C	20	50
D	20	100

5 **(a)** A source of sound has frequency *f*. Sound of wavelength λ is produced by the source.

(i) State

1. what is meant by the *frequency* of the source,

Number of complete waves produced in 1s by the source. [1]

2. the distance moved, in terms of λ, by a wavefront during *n* oscillations of the source.

distance = $n\lambda$ [1]

(ii) Use your answers in **(i)** to deduce an expression for the speed *v* of the wave in terms of *f* and λ.

$v = \frac{d}{t} = \frac{n\lambda}{t} \Rightarrow v = f\lambda$

[2]

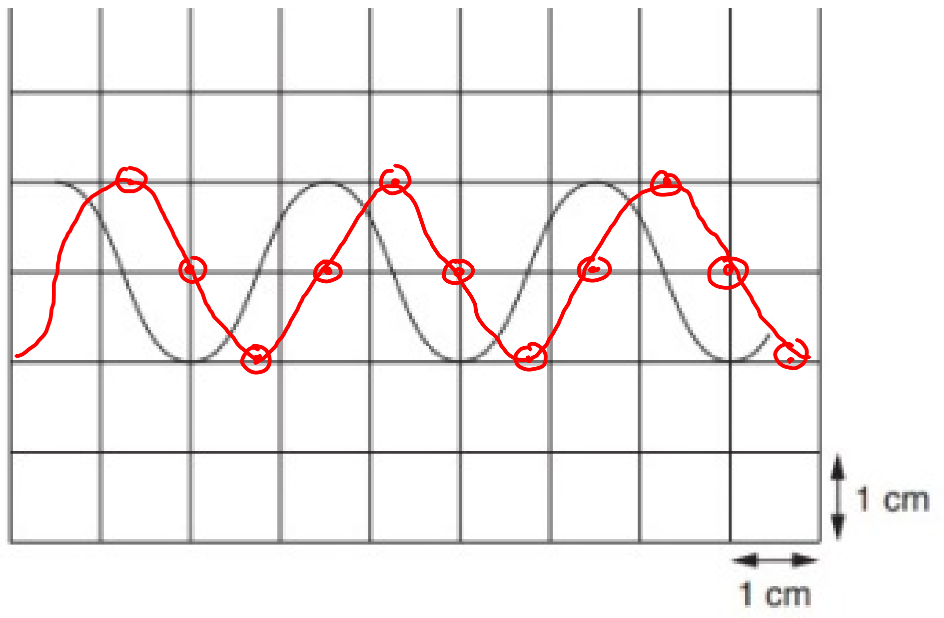


Fig. 5.1

The time-base setting of the c.r.o. is 2.0 ms cm^{-1}.

(i) Determine the frequency of the sound wave.

T = 6 ms

$f = \frac{1}{6 \times 10^{-3}} = 167.77$

frequency = 170 Hz [2]

(ii) A second sound wave has the same frequency as that calculated in **(i)**. The amplitude of the two waves is the same but the phase difference between them is 90°.

On Fig. 5.1, draw the waveform of this second wave. [1]

5 **(a)** By reference to vibrations of the points on a wave and to its direction of energy transfer, distinguish between transverse waves and longitudinal waves.

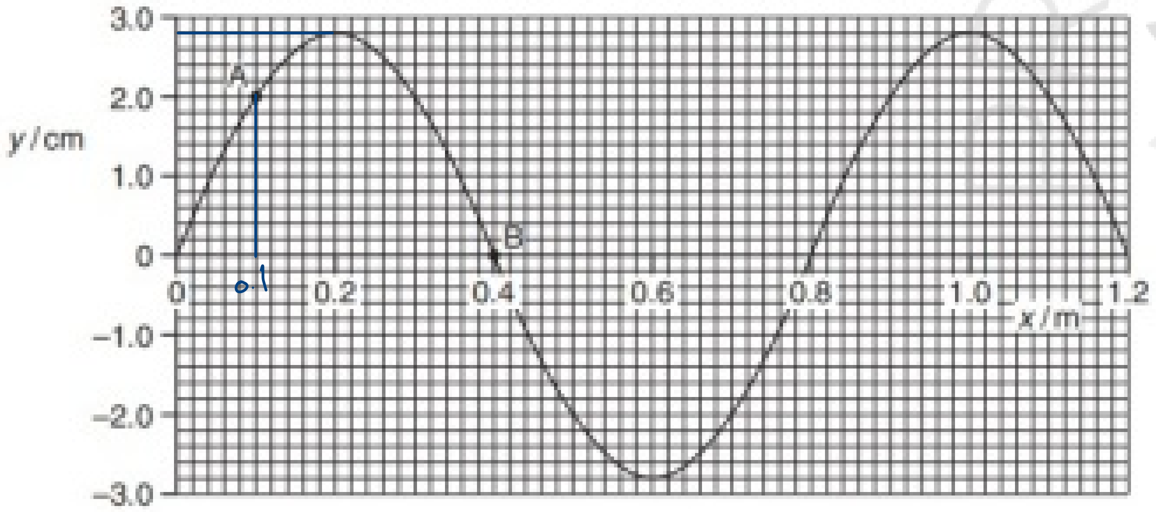
In transverse waves, vibrations are perpendicular to direction of energy transfer while in longitudinal it is parallel to direction of energy transfer

....[2]

(b) Describe what is meant by a *polarised* wave.

Vibration of particles is restricted to one plane only that is perpendicular to the direction of propagation of the wave. [2]

(c) The variation with distance x of the displacement y of a transverse wave is shown in Fig. 5.1.



(i) Use Fig. 5.1 to determine

1. the amplitude of the wave,

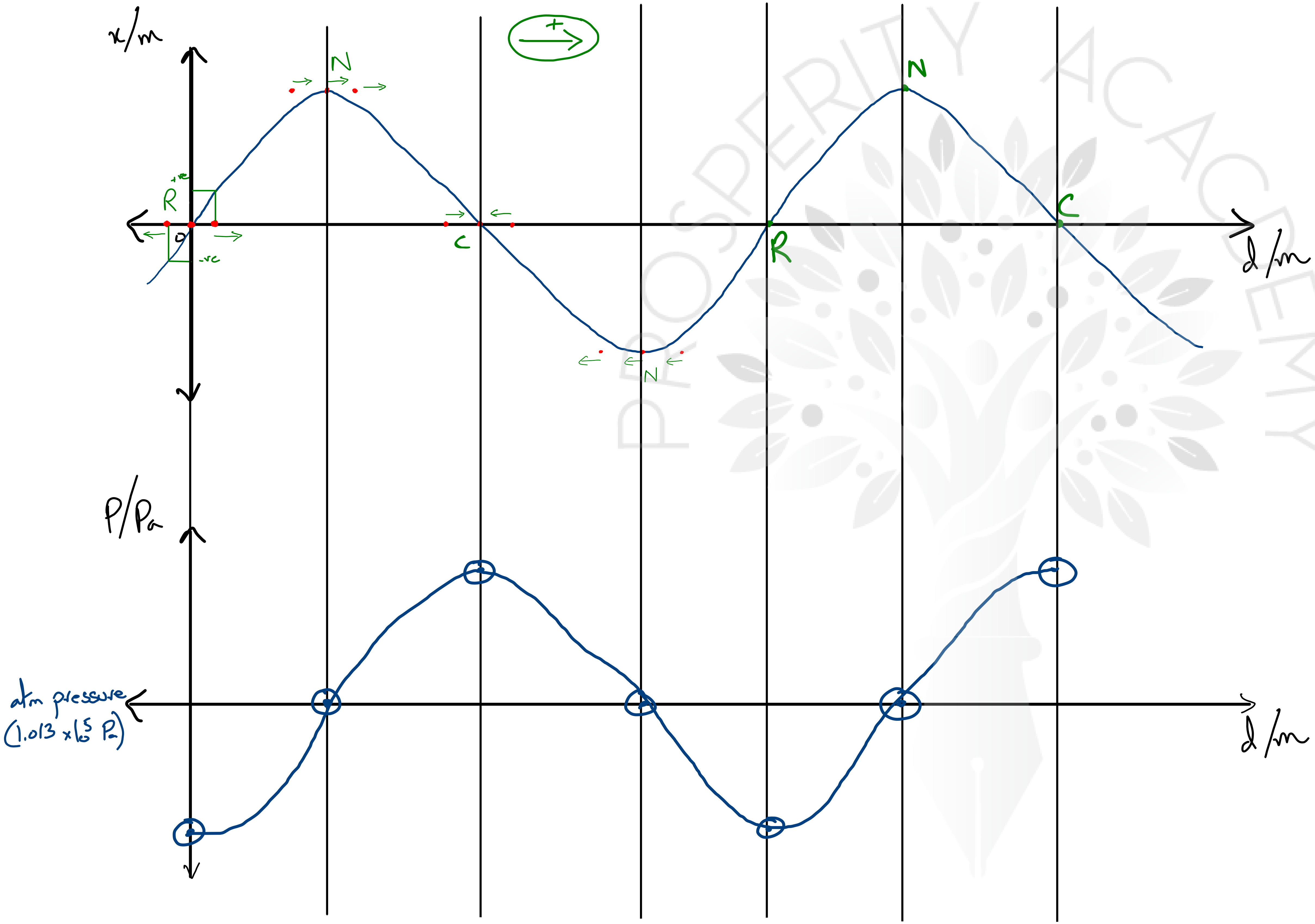
amplitude = 2.8 cm [1]

2. the phase difference between the points labelled A and B.

$\frac{0.4-0.1}{0.8} \times 360° = 135°$

phase difference = 135° [2]

How to work out compression and rarefactions?



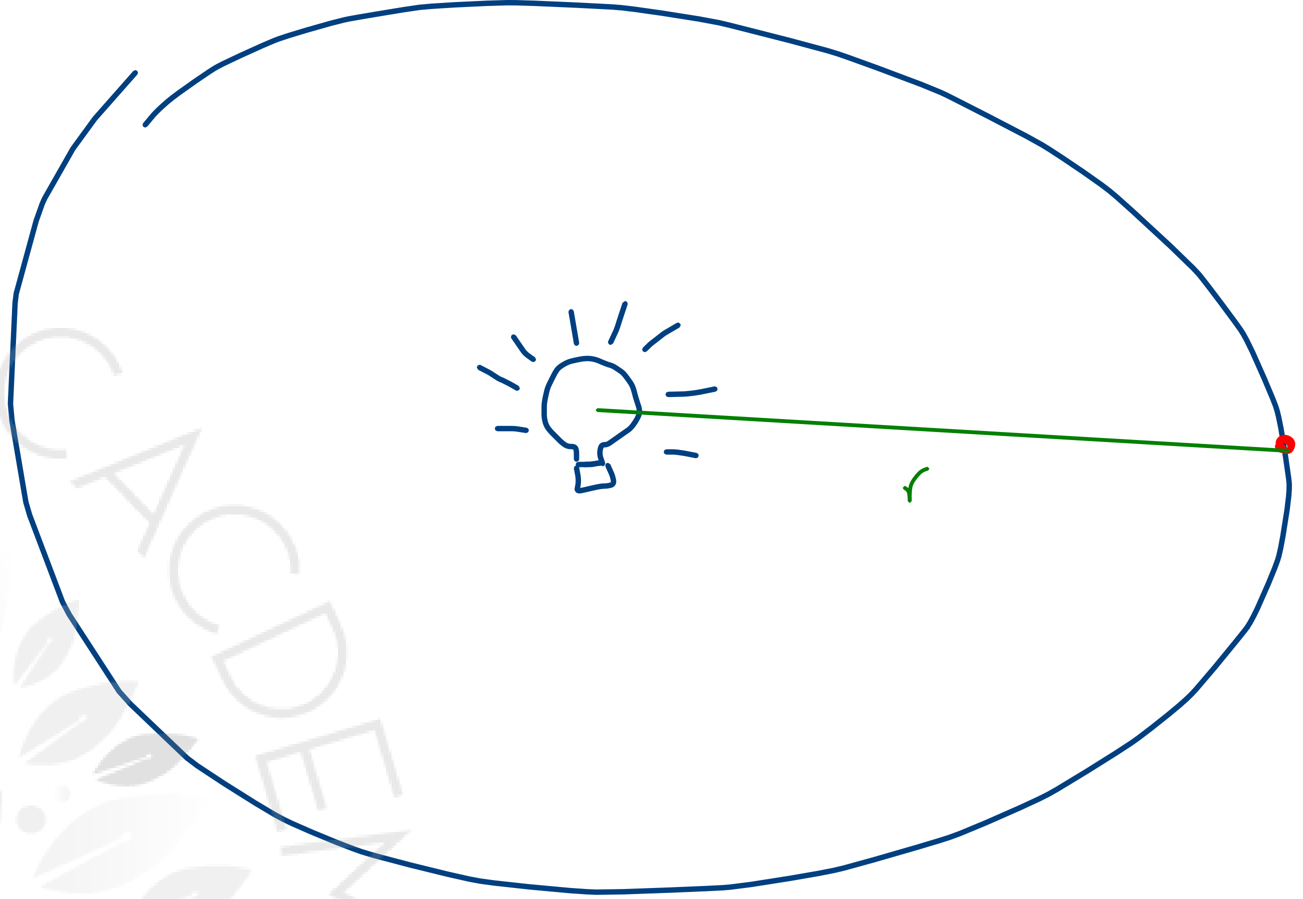
- At any point, consider 3 particles.
  1) At that point
  2) Slightly to the left of that point
  3) Slightly to the right of that point.
- Mark their displacement vectors as per your convention
- •→ •→ •→ or ←• ←• ←• : Normal pressure
- •→ • ←• : Compression
- ←• • •→ : Rarefaction

Intensity of a wave:-

It is the power incident per unit area. Scalar (Wm^{-2})

$$I = \frac{P}{A} \Rightarrow P = \frac{dW}{dt} = \frac{\Delta W}{\Delta t} \Rightarrow I = \frac{\Delta W}{A \times \Delta t}$$

↳ most of the time the S.A is $4\pi r^2$ (S.A of a sphere)



$$I = \frac{P}{4\pi r^2}$$

Learn these relationships:-

1) $I \propto \text{amplitude}^2$

$$I = K a^2$$

$$\frac{I_1}{a_1^2} = K = \frac{I_2}{a_2^2}$$

* $$\frac{I_1}{a_1^2} = \frac{I_2}{a_2^2}$$

2) $I \propto \frac{1}{\text{distance}^2}$

$$I = \frac{K}{r^2}$$

$$I_1 r_1^2 = K = I_2 r_2^2$$

* $$I_1 r_1^2 = I_2 r_2^2$$

3) $I \propto \text{frequency}^2$ (Not as important)

Q. Amplitude of a wave is A, and intensity is I

Which amplitude is necessary for Intensity to be doubled?

$$I \propto a^2 \Rightarrow \frac{I_1}{a_1^2} = K = \frac{I_2}{a_2^2}$$

$$\frac{I}{A^2} = \frac{2I}{a_2^2}$$

$$\sqrt{a_2^2} = \sqrt{2A^2}$$

$$a_2 = \sqrt{2} \times A$$

Q. At a distance r, the intensity is I.

Which distance is necessary for Intensity to be doubled?

$$I \propto \frac{1}{r^2} \Rightarrow I_1 r_1^2 = K = I_2 r_2^2$$

$$I r^2 = 2I \times r_2^2 \Rightarrow \sqrt{r_2^2} = \sqrt{\frac{r^2}{2}} \Rightarrow r_2 = \frac{r}{\sqrt{2}}$$

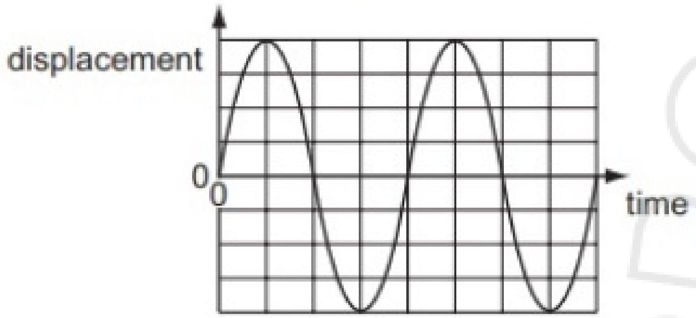
22 A source of sound of constant power P is situated in an open space. The intensity I of sound at distance r from this source is given by

$$I = \frac{P}{4\pi r^2}.$$

How does the amplitude a of the vibrating air molecules vary with the distance r from the source?

A $a \propto \frac{1}{r}$ **B** $a \propto \frac{1}{r^2}$ **C** $a \propto r$ **D** $a \propto r^2$

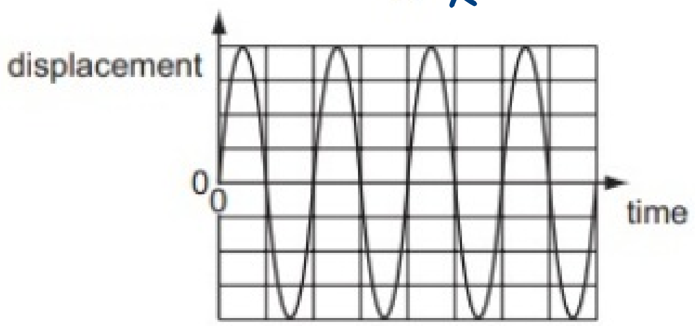
26 The diagram shows a graph of displacement against time for a sound wave.



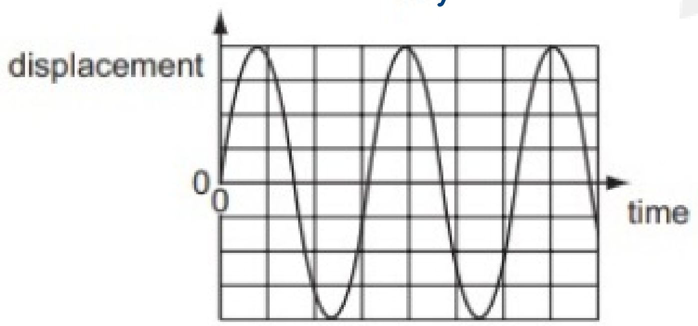
The intensity of the sound is halved.

Which graph shows the displacement of this sound wave?

A



B



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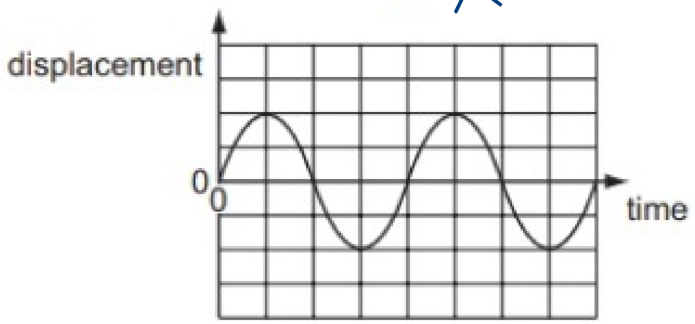
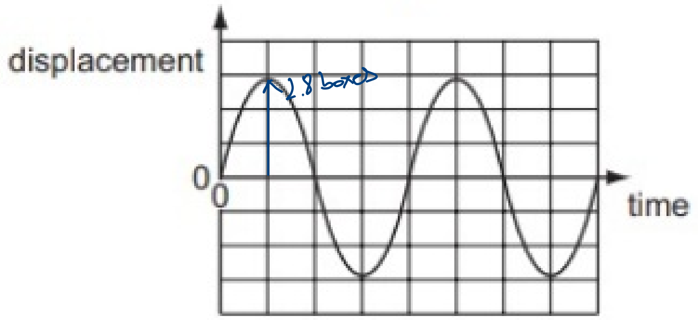


D



22 A sound wave reduces in intensity but maintains a constant frequency as it travels through air.

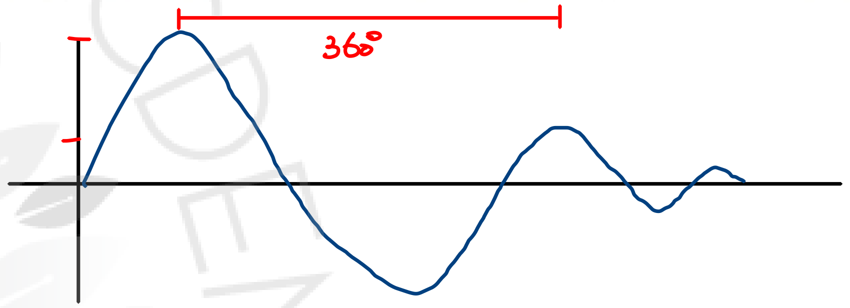
Which statement is correct?

A The maximum displacement of the particles changes between one particle and the next particle.

B The phase difference between adjacent particles is zero.

C The wavelength is the distance between two particles that have a phase difference of 180°.

D Two particles that have a phase difference of 360° have the same maximum displacement.



5 A student is studying a water wave in which all the wavefronts are parallel to one another. The variation with time t of the displacement x of a particular particle in the wave is shown in Fig. 5.1.

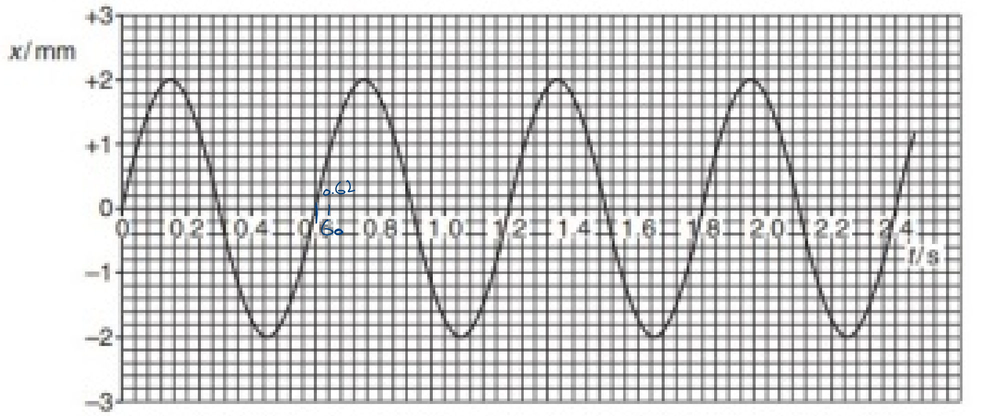
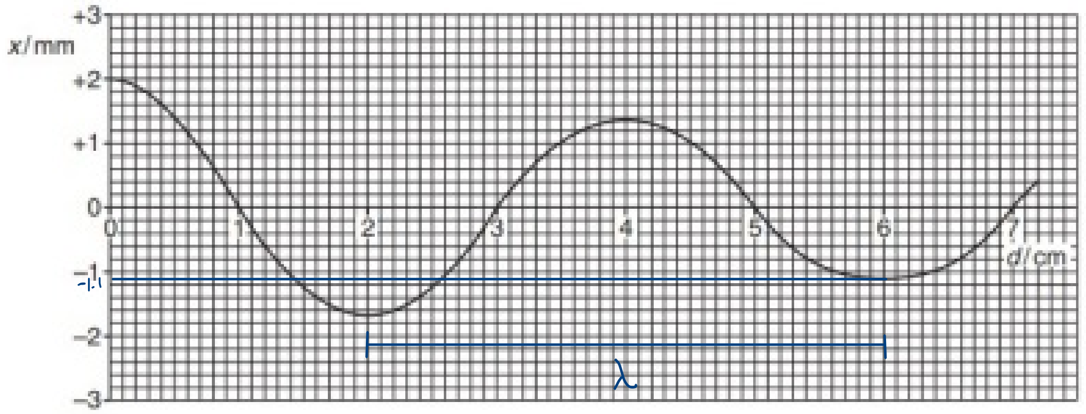


Fig. 5.1

The distance d of the oscillating particles from the source of the waves is measured. At a particular time, the variation of the displacement x with this distance d is shown in Fig. 5.2.



(a) Define, for a wave, what is meant by

(i) *displacement*,

distance moved by particle from its mean position

....[1]

(ii) *wavelength*.

distance between 2 consecutive points in phase.

....[1]

 9702/22/O/N/10

(b) Use Figs. 5.1 and 5.2 to determine, for the water wave,

(i) the period T of vibration,

T = 0.60 s [1]

(ii) the wavelength λ,

λ = 4.0 cm [1]

(iii) the speed v.

$v = f\lambda \Rightarrow v = \frac{1}{0.6} \times (4 \times 10^{-2}) = 0.067\ ms^{-1}$

(c) (i) Use Figs. 5.1 and 5.2 to state and explain whether the wave is losing power as it moves away from the source.

The wave is losing power as the amplitudes decrease with distance

....[2]

(ii) Determine the ratio

$$\frac{\text{intensity of wave at source}}{\text{intensity of wave 6.0 cm from source}}.$$

$\frac{I_1}{a_1^2} = \frac{I_2}{a_2^2} \Rightarrow \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{2^2}{(1.1)^2} = 400 : 121$ or 3.3057

ratio = 3.3 [3]

4 (a) For a progressive wave, state what is meant by

(i) the *period*,

Time taken for one complete wave to form.

[1]

(ii) the *wavelength*.

distance between 2 consecutive points in phase.

[1]

(b) Fig. 4.1 shows the variation with time t of the displacement x of two progressive waves P and Q passing the same point.

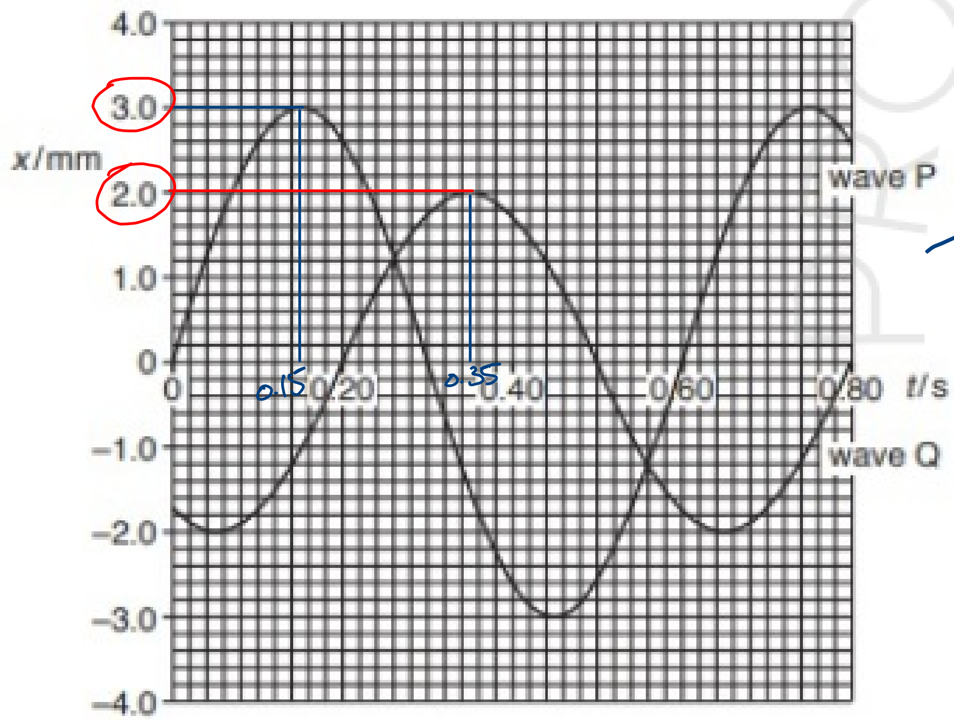


Fig. 4.1

$T = 0.60$

$0.2 : 10$

$x : 7.5$

$x = 0.15$

The speed of the waves is 20 cm s^{-1}.

(i) Calculate the wavelength of the waves.

$f = \frac{1}{0.60}$

$v = f\lambda$

$20 = \frac{1}{0.60} \times \lambda \Rightarrow \lambda = 12$

wavelength = 12 cm [2]

(ii) Determine the phase difference between the two waves.

$\frac{\Delta t}{T} \times 360° = \frac{0.35 - 0.15}{0.60} \times 360°$

phase difference = 120° ° [1]

(iii) Calculate the ratio

$\frac{\text{intensity of wave Q}}{\text{intensity of wave P}}$.

$\frac{I_Q}{a_Q^2} = \frac{I_P}{a_P^2} \Rightarrow \frac{I_Q}{I_P} = \frac{a_Q^2}{a_P^2} = \frac{(2)^2}{(3)^2} = \frac{4}{9}$

$= 0.44$

ratio = 0.44 [2]

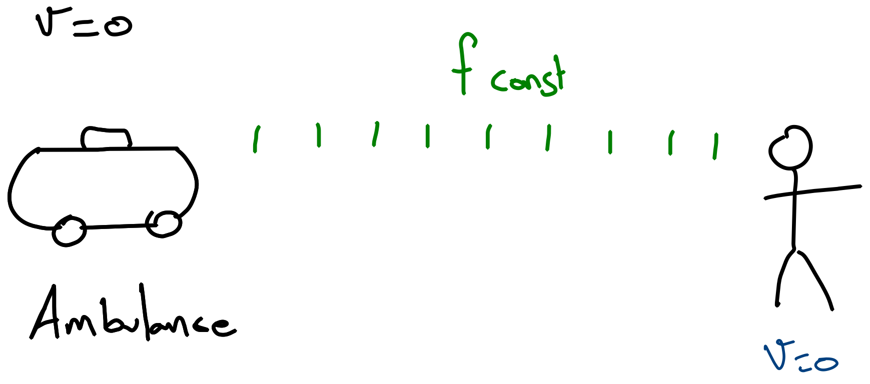
(iv) The two waves superpose as they pass the same point. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.45$ s.

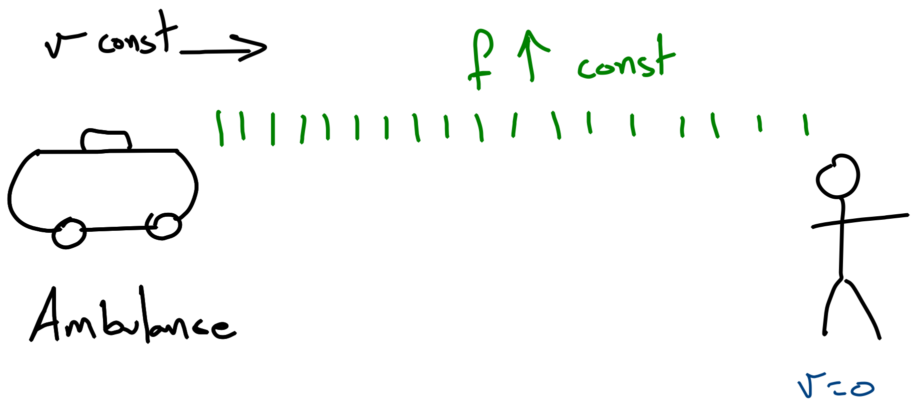
displacement = ... mm [1]

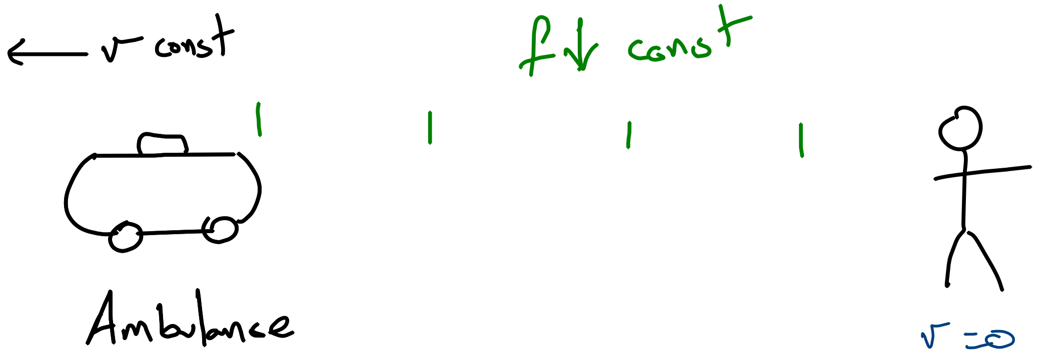
[Total: 8]

Doppler's effect:-

Change in observed frequency due to relative motion between observer and source.







$$f_o = \frac{v}{v \pm v_s} f_s$$

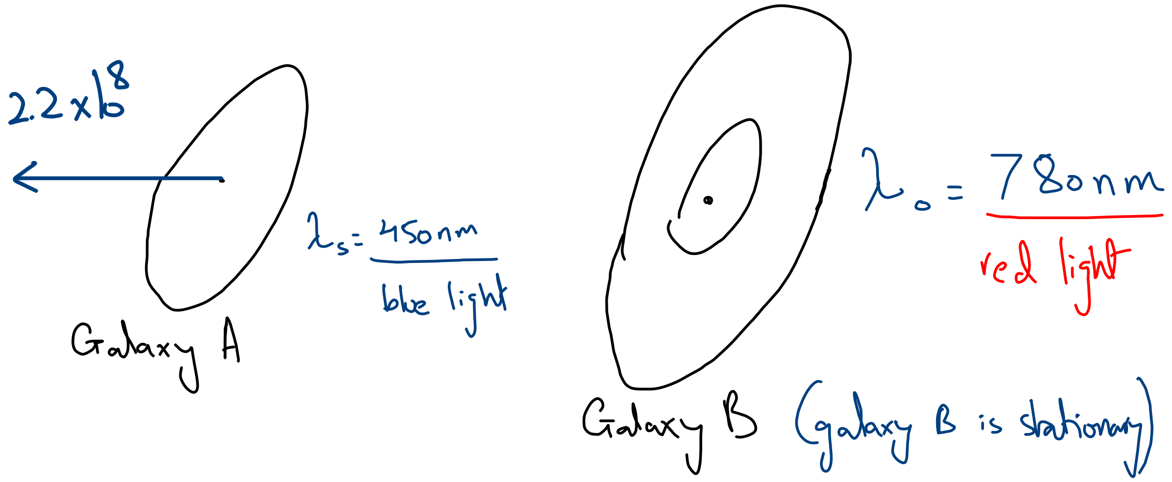
f_o: observed frequency
f_s: source frequency
v: speed of wave in medium
v_s: speed of the source (constant)

Approach:-

$$f_o = \frac{v}{v - v_s} f_s$$

Separation:-

$$f_o = \frac{v}{v + v_s} f_s$$



$c = 3 \times 10^8$ (speed of light in vacuum)

Redshift:- Wavelength of light stretched to longer wavelengths due to separation velocity between galaxies

With what velocity is A travelling B?

$v = f_s \lambda_s$

$3 \times 10^8 = f_s (450 \times 10^{-9})$

$f_s = 6.67 \times 10^{14}$

$v = f_o \lambda_o$

$(3 \times 10^8) = f_o (780 \times 10^{-9})$

$f_o = 3.85 \times 10^{14}$

$f_o < f_s \rightarrow$ separate

$$f_o = \frac{v}{v - v_s} f_s$$

$$3.85 \times 10^{14} = \frac{3 \times 10^8}{3 \times 10^8 - v_s} \times (6.67 \times 10^{14})$$

$v_s = 2.2 \times 10^8$

24 A vehicle carries a microwave transmitter that emits microwaves of a constant frequency. A stationary observer has a microwave receiver.

The vehicle moves directly towards the observer at constant speed. The observer detects microwaves of frequency F_o.

The vehicle then accelerates, still moving towards the observer, travels at higher steady speed for a time and then decelerates until it stops.

What is the variation in the frequency of the microwaves that are detected by the observer?

A The observed frequency will fall, then remain steady then return to the frequency F_o.

B The observed frequency will fall, then remain steady then rise to a higher frequency than F_o.

C The observed frequency will rise, then remain steady then fall to a lower frequency than F_o.

D The observed frequency will rise, then remain steady then return to the frequency F_o.

24 A jet aircraft travels at a speed of $0.8v$ where v is the speed of sound. The aircraft approaches a stationary observer. The frequency of sound emitted by the aircraft is 100 Hz.

Which frequency does the observer hear?

A 56 Hz **B** 180 Hz **C** 400 Hz **D** 500 Hz

24 A siren emits sound of frequency 1000 Hz. The siren moves at $20\,m\,s^{-1}$ towards an observer who is standing still.

The speed of sound in the air is $330\,m\,s^{-1}$.

Which expression would correctly give the frequency heard by the observer?

A $\dfrac{1000 \times 330}{330 + 20}$

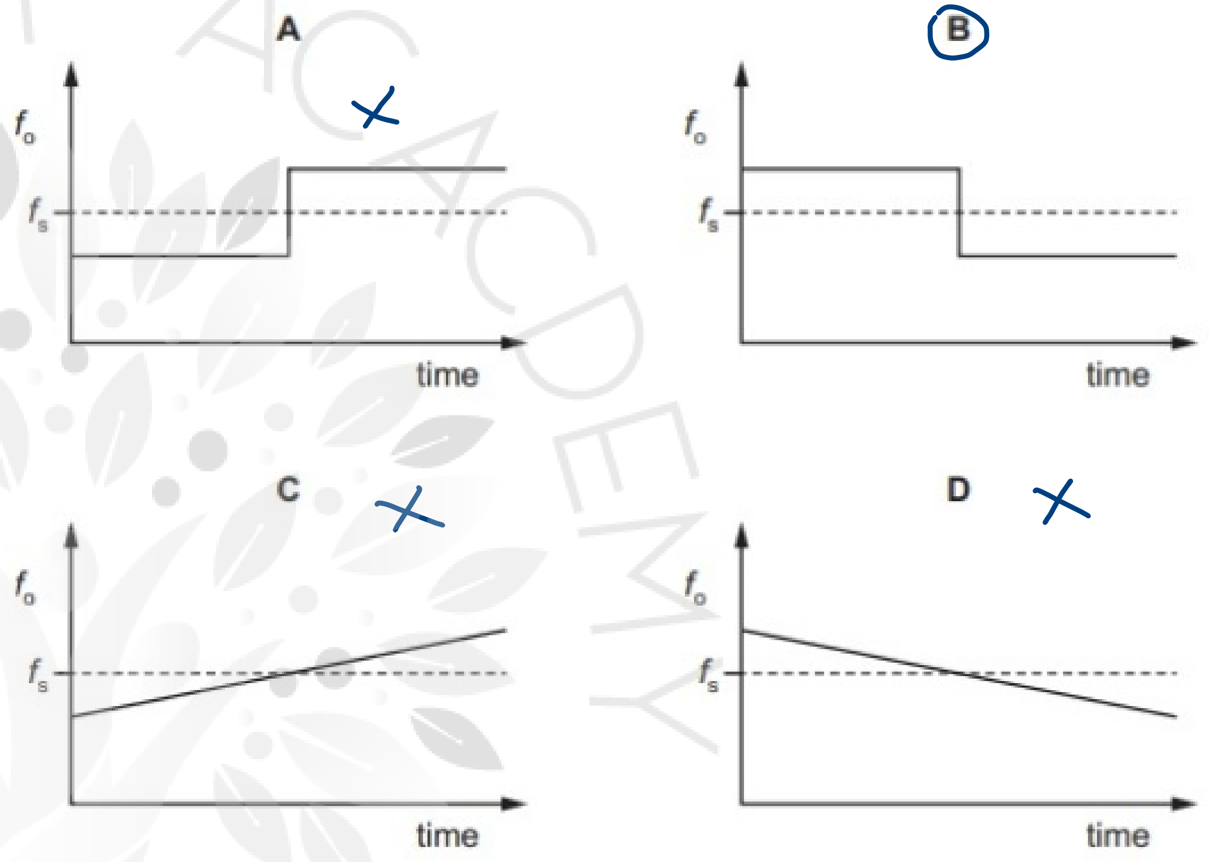
B $\dfrac{1000 \times 330}{330 - 20}$

C $\dfrac{1000\,(330 + 20)}{330}$

D $\dfrac{1000\,(330 - 20)}{330}$

25 A source emitting sound of a single frequency f_s travels at constant speed directly towards an observer. The source then passes the observer and continues to move directly away from the observer. The velocity of the source remains constant.

Which graph represents the variation with time of the frequency f_o of the sound heard by the observer?



4 (a) By reference to the direction of the propagation of energy, state what is meant by a *longitudinal* wave and by a *transverse* wave.

longitudinal: The vibration of particles is parallel to the direction of propagation of energy of the wave

transverse: The vibration of particles is perpendicular to the direction of propagation of energy of the wave.

[2]

(b) The intensity of a sound wave passing through air is given by

$$I = Kv\rho f^2 A^2$$

where I is the intensity (power per unit area),
K is a constant without units,
v is the speed of sound,
ρ is the density of air,
f is the frequency of the wave
and A is the amplitude of the wave.

$f = \frac{1}{T} = \frac{1}{s} = s^{-1}$

Show that both sides of the equation have the same SI base units.

$I = \frac{P}{A} = \frac{W}{A \times t} = \frac{Kg\,m^2 s^{-2}}{m^2 \times s} \Rightarrow Kg\,s^{-3}$

$Kg\,s^{-3} = m\,s^{-1} \times Kg\,m^{-3} \times s^{-2} \times m^2$

$Kg\,s^{-3} = Kg\,s^{-3}$ shown

(c) (i) Describe the *Doppler effect*.

It is the change in observed frequency due to relative motion between source and observer. [1]

(ii) A distant star is moving away from a stationary observer.

State the effect of the motion on the light observed from the star.

Light will be redshifted / The wavelength of light will be stretched to higher wavelengths / The observed frequency of light will be lesser than source frequency [1]

(d) A car travels at a constant speed towards a stationary observer. The horn of the car sounds at a frequency of 510 Hz and the observer hears a frequency of 550 Hz. The speed of sound in air is 340 m s^{-1}.

f_o

Calculate the speed of the car.

$f_o = \frac{v}{v - v_s} f_s \Rightarrow 550 = \frac{340}{340 - v_s} \times 510$

$340 - v_s = \frac{340}{550} \times 510$

$-v_s = \left(\frac{340 \times 510}{550}\right) - 340 \Rightarrow v_s = 24.7$

speed = 25 m s^{-1} [3]

[Total: 10]

4 (a) State what is meant by the *Doppler effect*.

Apparent change in observed frequency due to relative motion between the source and observer.

[2]

(b) A child sits on a rotating horizontal platform in a playground. The child moves with a constant speed along a circular path, as illustrated in Fig. 4.1.

$f_o = \frac{v}{v + v_s} f_s$

$f_o = \frac{330}{330 + 7.5} \times 950 = 930$

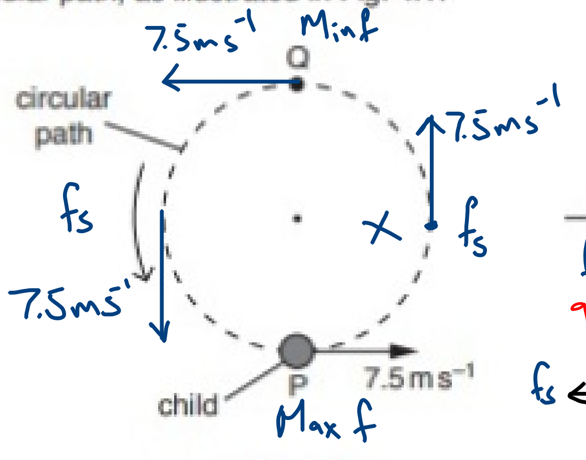
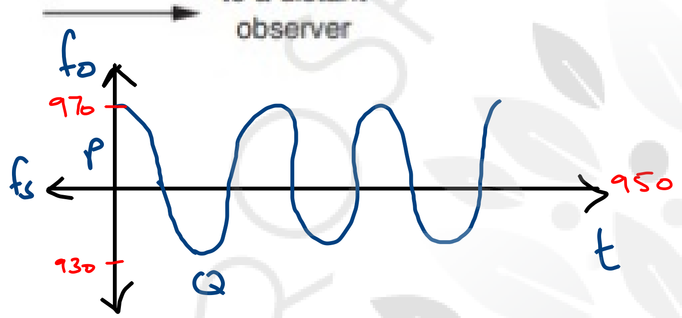


Fig. 4.1



An observer is standing a long distance away from the child. During one particular revolution, the child, moving at a speed of 7.5 m s⁻¹, starts blowing a whistle at point P and stops blowing it at point Q on the circular path.

The whistle emits sound of frequency 950 Hz. The speed of sound in air is 330 m s⁻¹.

(i) Determine the maximum frequency of the sound heard by the distant observer.

$f_o = \frac{v}{v - v_s} f_s \Rightarrow f_o = \frac{330}{330 - 7.5} \times 950 \Rightarrow f_o = 972.1$

maximum frequency = 970 Hz [2]

(ii) Describe the variation in the frequency of the sound heard by the distant observer.

The frequency decreases from 970 Hz to 950 Hz at point X (marked on diagram) and then to 930 Hz at point Q.

[2]

[Total: 6]

Electromagnetic Spectrum (Learn everything on this slide):-

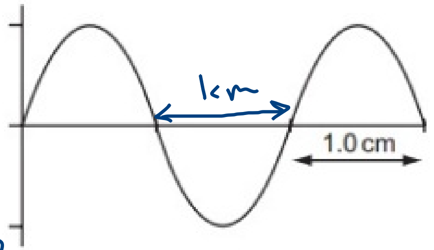
1) Group of transverse waves
2) They travel at 3×10^8 in vacuum

	Wavelengths	Avg λ	Avg f	Uses
Radio waves	$10^3 < \lambda \leq 10^0$	$10^2 / 10^1$	$3\times10^8 / 10^2$	FM radio / RC cars
Micro waves	$10^0 < \lambda \leq 10^{-3}$	10^{-2}	$3\times10^8 / 10^{-2}$	Microwave ovens / Network signals
Infrared waves	$10^{-3} < \lambda \leq 10^{-6}$	10^{-5}	$3\times10^8 / 10^{-5}$	Infrared cameras / TV remotes
Visible light	$10^{-6} = \lambda$	10^{-6}	$3\times10^8 / 10^{-6}$	We use this to see! (Duh!)
Ultraviolet	$10^{-6} < \lambda \leq 10^{-8}$	10^{-7}	$3\times10^8 / 10^{-7}$	Disinfections
X rays	$10^{-8} < \lambda \leq 10^{-10}$	10^{-9}	$3\times10^8 / 10^{-9}$	X-ray scans
Gamma rays	$10^{-10} < \lambda \leq 10^{-12}$	10^{-11}	$3\times10^8 / 10^{-11}$	Cancer treatment / Detecting radiation / leakages / PET scans

Raging martians invaded Venus using Xray Guns.

Red: 780nm   Green: 550nm   Blue: 400nm

31 The diagram shows a cathode-ray oscilloscope display of an electromagnetic wave.



The time base setting is $0.20\,\mu s\,cm^{-1}$.

Which statement is correct?

A The frequency of the wave is 2.5 MHz and it lies in the radio wave region of the electromagnetic spectrum.

B The frequency of the wave is 2.5 MHz and it lies in the microwave region of the electromagnetic spectrum.

C The frequency of the wave is 5.0 MHz and it lies in the radio wave region of the electromagnetic spectrum.

D The frequency of the wave is 5.0 MHz and it lies in the microwave region of the electromagnetic spectrum.

26 What are the names of the electromagnetic waves that have wavelengths in a vacuum of 100 pm and of 100 μm?

	wavelength 100 pm	wavelength 100 μm
A	γ-rays	infrared
B	γ-rays	red light
C	X-rays	infrared
D	X-rays	red light

23 The table lists possible orders of magnitude of the wavelengths of some of the principal radiations of the electromagnetic spectrum.

Which row shows the correct orders of magnitude of the wavelengths?

	wavelength / m			
	microwaves	infra-red	ultraviolet	X-rays
A	10^{-6}	10^{-10}	10^{-12}	10^{-14}
B	10^{-4}	10^{-8}	10^{-10}	10^{-12}
C	10^{-2}	10^{-6}	10^{-8}	10^{-10}
D	10^{2}	10^{-4}	10^{-6}	10^{-8}

5 **(a)** State one property of electromagnetic waves that is **not** common to other transverse waves.

Travel in vacuum at $3 \times 10^8\ ms^{-1}$ .... [1]

(b) The seven regions of the electromagnetic spectrum are represented by blocks labelled A to G in Fig. 5.1.

Fig. 5.1

A typical wavelength for the visible region D is 500 nm.

(i) Name the principal radiations and give a typical wavelength for each of the regions B, E and F.

B: name: Microwaves .... wavelength: 1×10^{-2} .... m

E: name: Ultraviolet .... wavelength: 1×10^{-7} .... m

F: name: X rays .... wavelength: 1×10^{-9} .... m

[3]

(ii) Calculate the frequency corresponding to a wavelength of 500 nm.

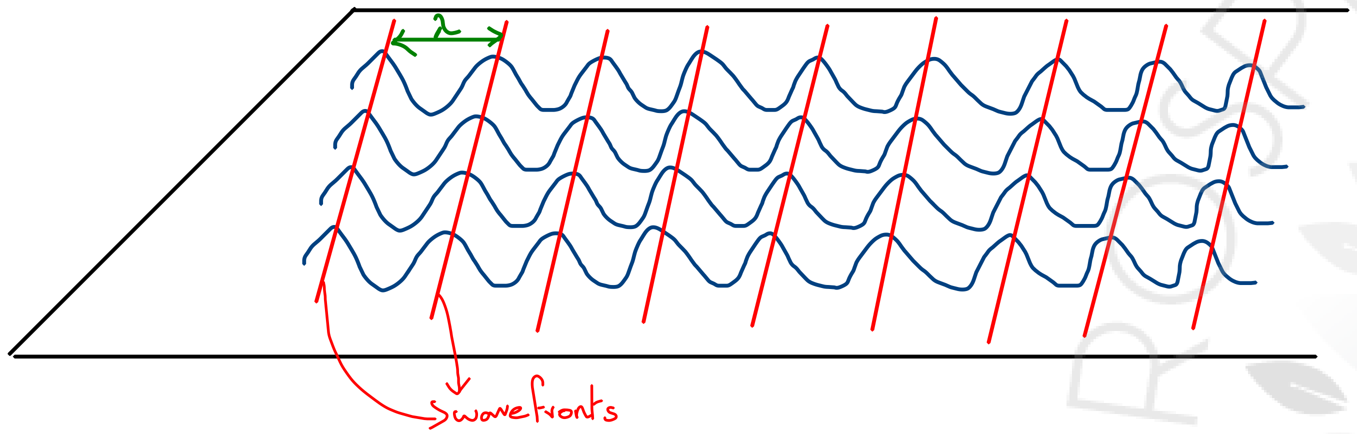
$v = f\lambda \Rightarrow 3 \times 10^8 = f(500 \times 10^{-9})$

$f = 6 \times 10^{14}$

frequency = 6×10^{14} .... Hz [2]

General Wave properties:-

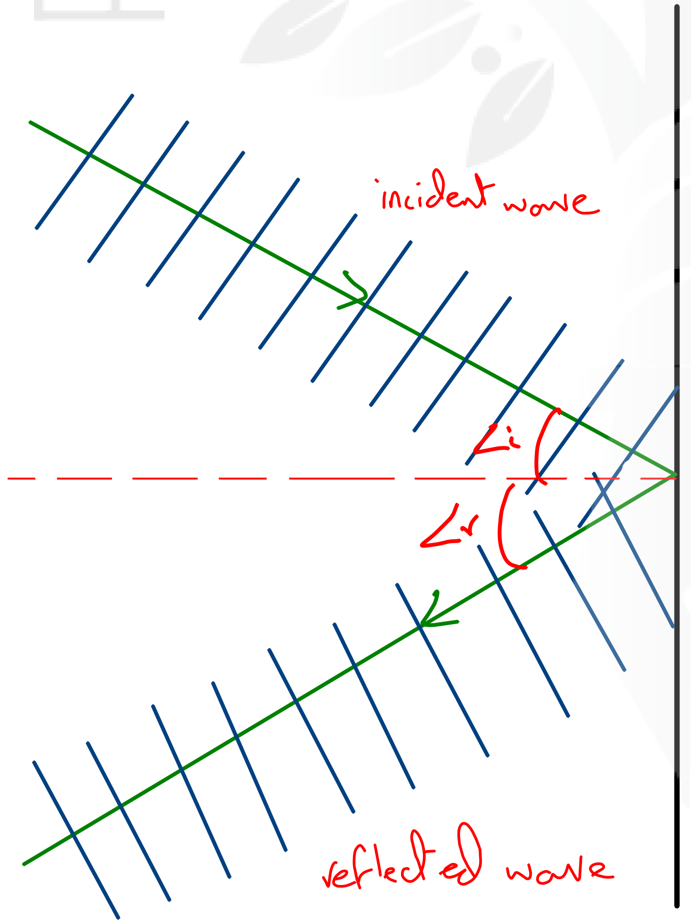
Wavefront:- It is an imaginary line joining all points in phase on different waves.



Reflection:-

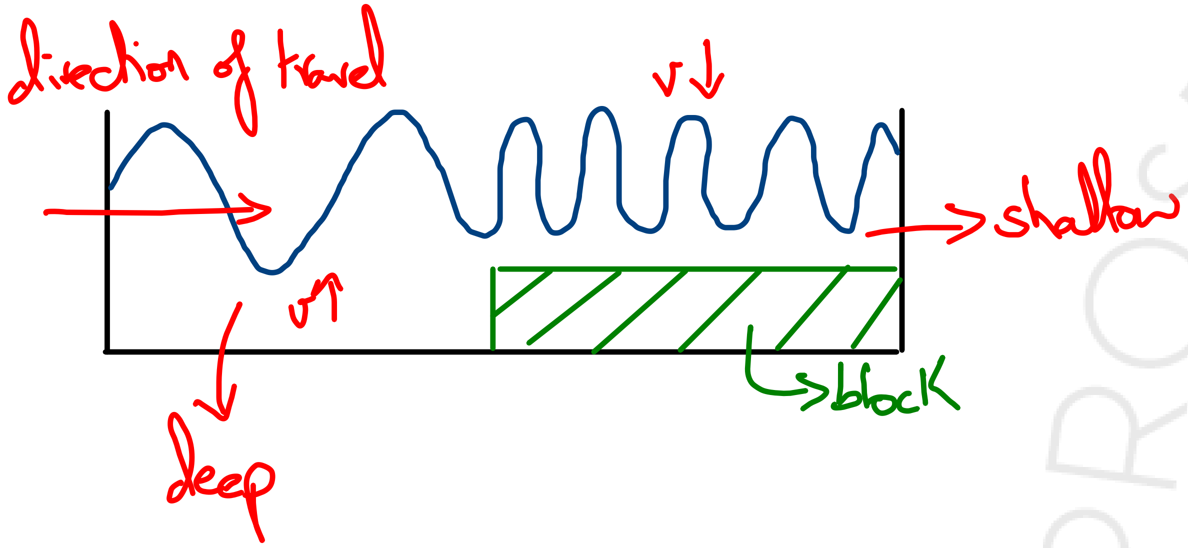
1) Incident wave, reflected wave and normal all lie on same plane

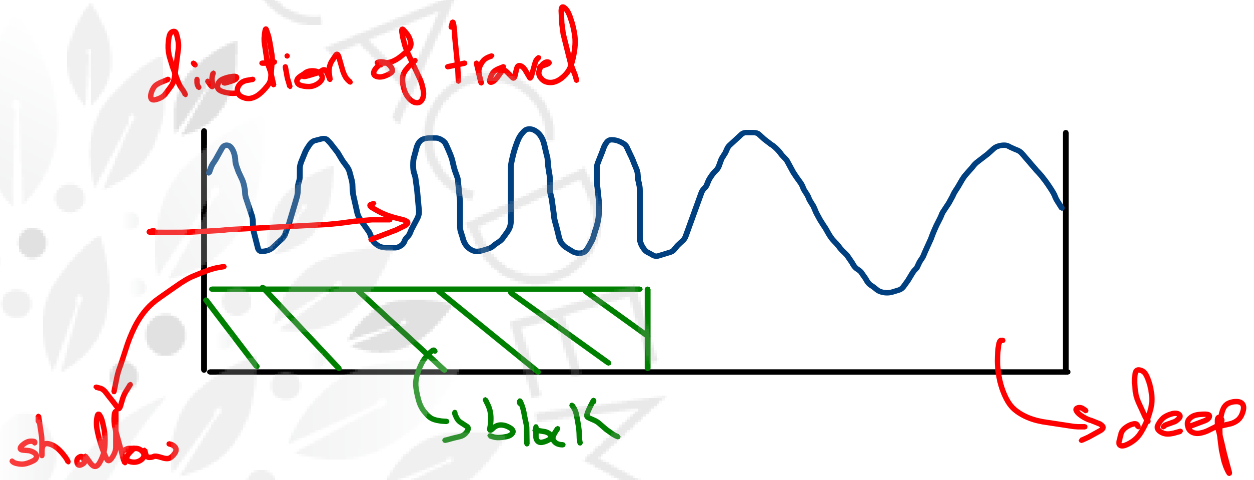
2) $\angle i = \angle r$



Refraction :- The bending of a wave as it passes from a rare to a denser medium or vice versa

velocity change





1) frequency will remain same
2) λ decreased
3) $\downarrow v = f \lambda \downarrow$ → wave bends

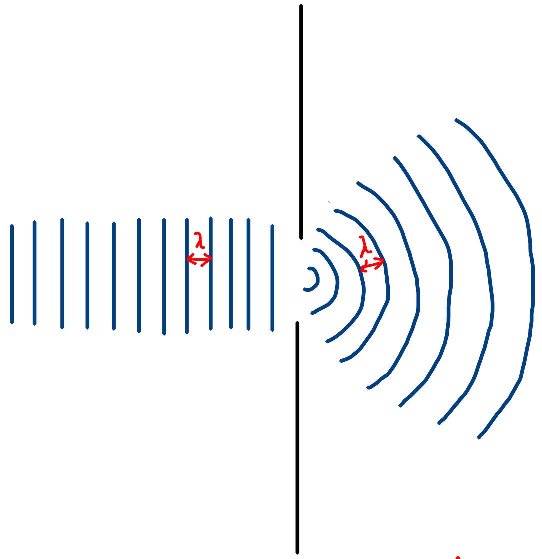
1) frequency will be same
2) λ has increased
3) $\uparrow v = f\lambda \uparrow$, velocity has increased.

Diffraction :-

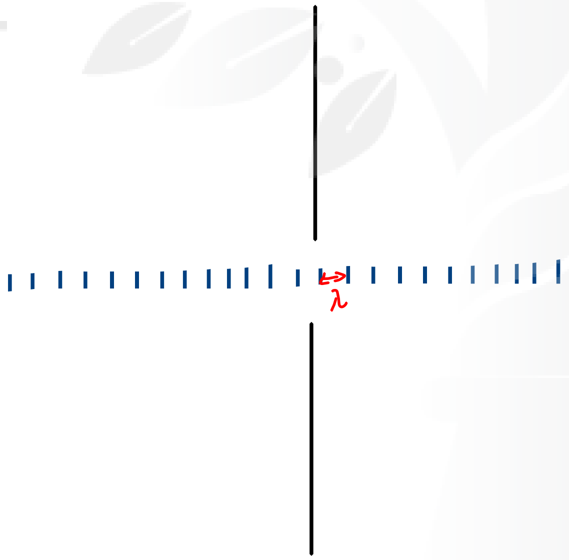
Spreading of a wave into a region where it would have not been experienced if it travelled in straight lines as it passes a narrow slit or edge.

Spreading of a wave into its geometric shadow as it passes a slit or edge

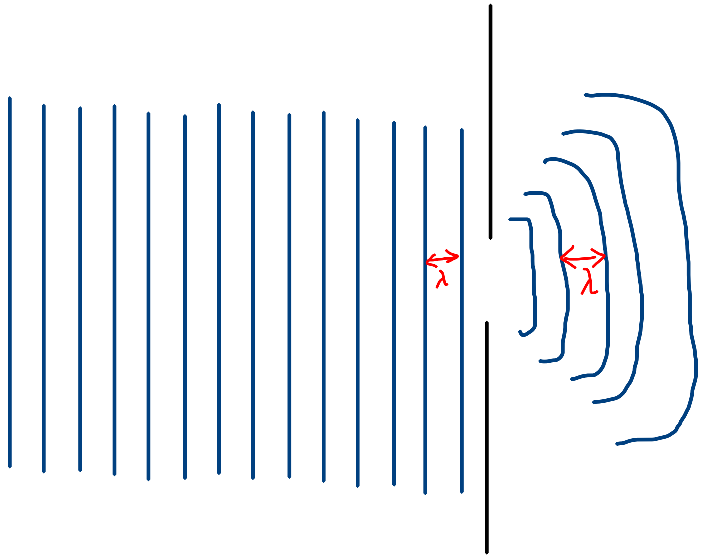
diffraction is most significant when slit size ≃ wavelength



circular diffraction



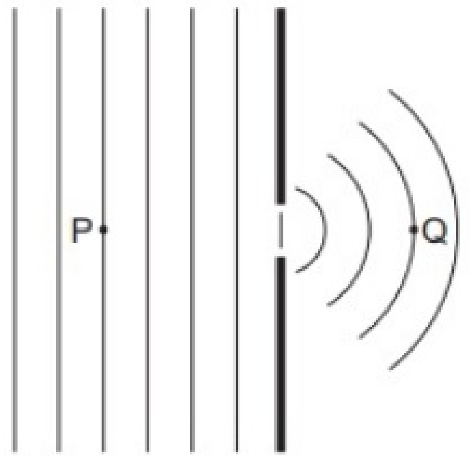
very less diffraction



less diffraction

- λ doesnot change (be careful when drawing)
  - frequency is also same
  - velocity is same

28 Plane wavefronts in a ripple tank pass through a gap as shown.



Which property of the wave will be different at Q compared with P?

A velocity

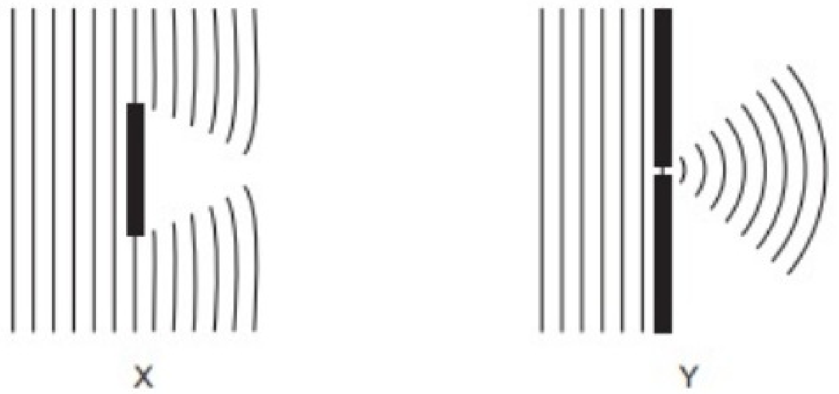
B frequency

C amplitude

D wavelength

27 Diagrams X and Y show the passage of water waves around an obstacle and through a gap.

The thick lines are barriers to the waves and each thin line represents a wavefront.



Which statement is correct?

A Diagrams X and Y both illustrate diffraction.

B Diagrams X and Y both illustrate interference.

C Only diagram X illustrates interference.

D Only diagram Y illustrates diffraction.

28 Which electromagnetic wave would cause the most significant diffraction effect for an atomic lattice of spacing around 10^{-10} m?

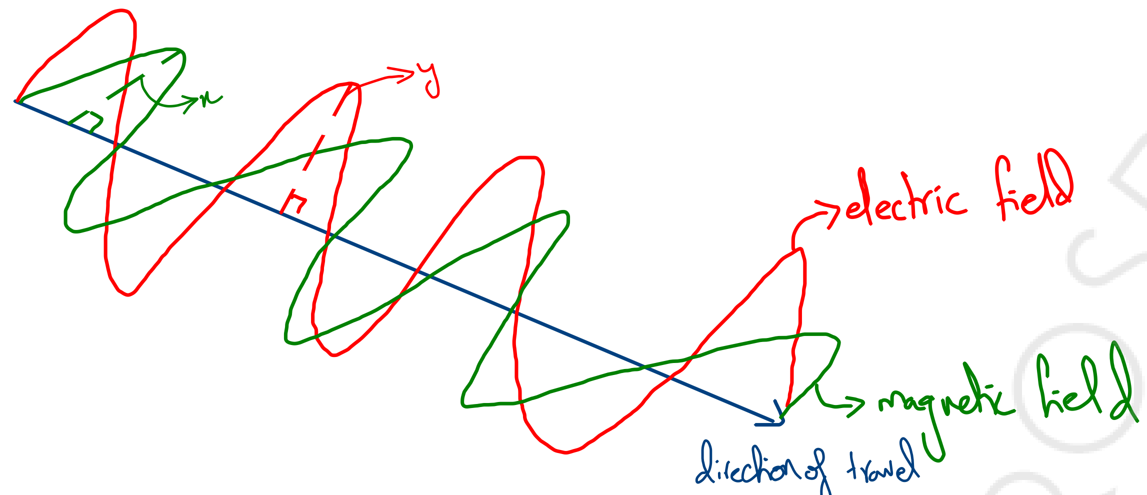
A infra-red

B microwave

C ultraviolet

D X-ray

Polarisation :- It is the process of confining the oscillations of particles in one direction only.

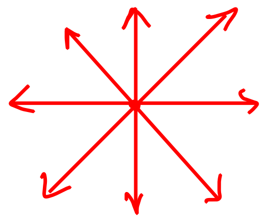


electromagnetic waves have a charge of zero because the electric fields and magnetic fields are perpendicular to each other

When we will talk about polarisation we shall only take the electric field component

Unpolarised :-

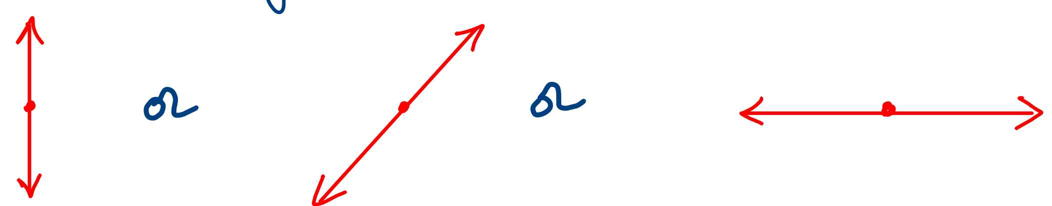
The oscillation of particles / electric field vector is in random directions but always perpendicular to direction of travel



: notation for unpolarised light

Polarised :-

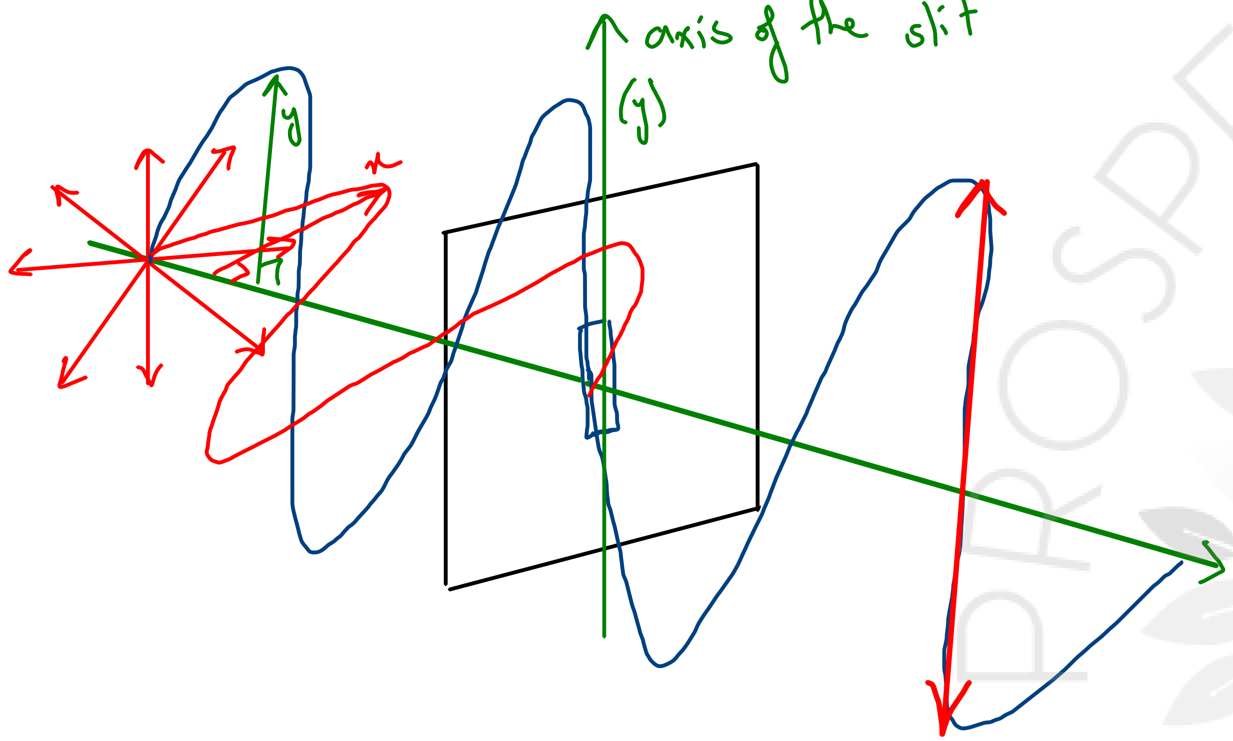
The oscillation of particles / electric field vector is in one direction only and always perpendicular to direction of travel



: notation for polarised light

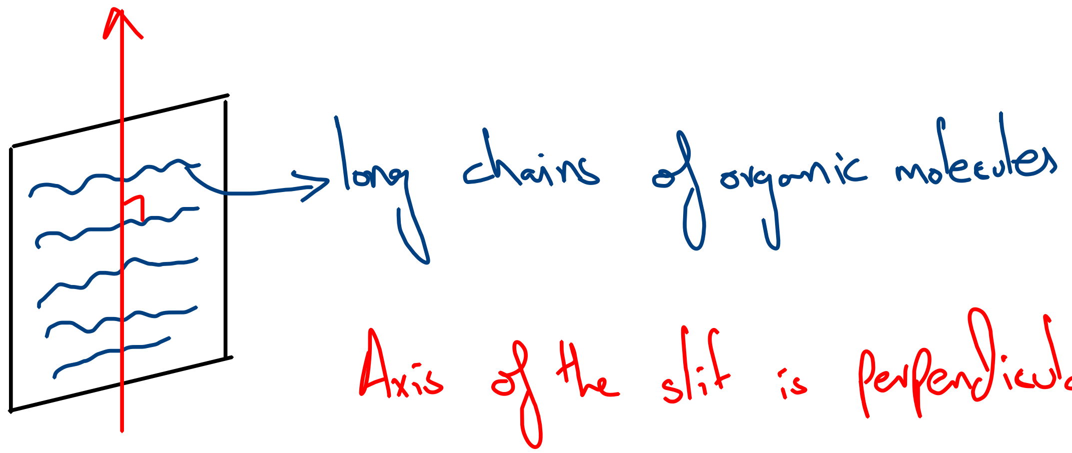
How to Polarise light?

Use a polaroid sheet / filter which acts as a polariser.



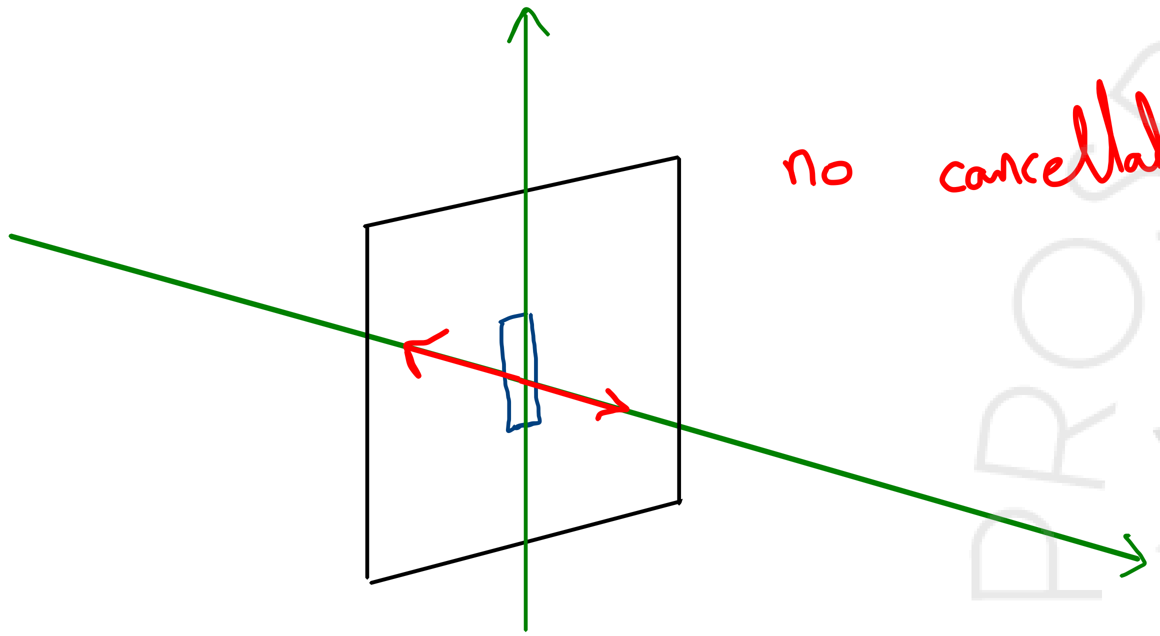
- The direction of oscillations if parallel to the axis of the slit, will completely pass through
- The direction of oscillations if completely perpendicular to the axis of the slit, will completely get blocked

What is a polaroid filter?



Axis of the slit is perpendicular to the chains of molecules

- Only transverse waves show polarisation
- Longitudinal waves dont show polarisation



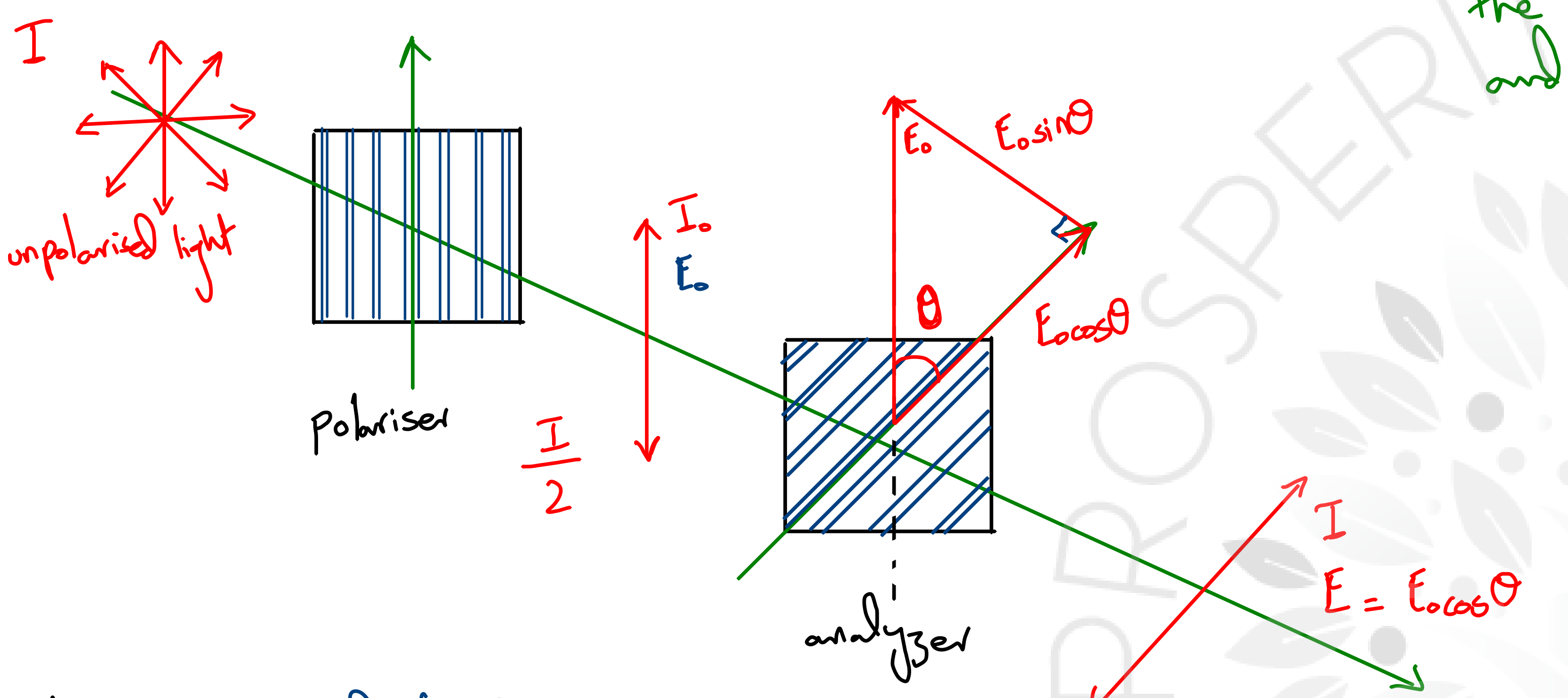
no cancellation takes place if longitudinal

Polarisation is of 2 types:-

1) Partial polarisation:- Vibrations not fully restricted to one direction (reflection off water)

2) Full / Completly plane polarised:- Vibrations are fully restricted to one direction only

Malus' Law :-



θ: the angle between the electric field vector and axis of the slit

Note :- Unpolarised light will have its intensity halved when it passes through a polaroid filter

$$I = I_o \cos^2\theta$$

incident intensity (I_o)

resultant intensity (I)

angle b/w axis of slit and incident light (θ)

1) $I \propto a^2$ (Recall)

2) Amplitude $\propto$ Electric field strength $\Rightarrow a \propto E$ / $a^2 \propto E^2$

3) $I \propto a^2$ and $a^2 \propto E^2 \Rightarrow I \propto E^2$

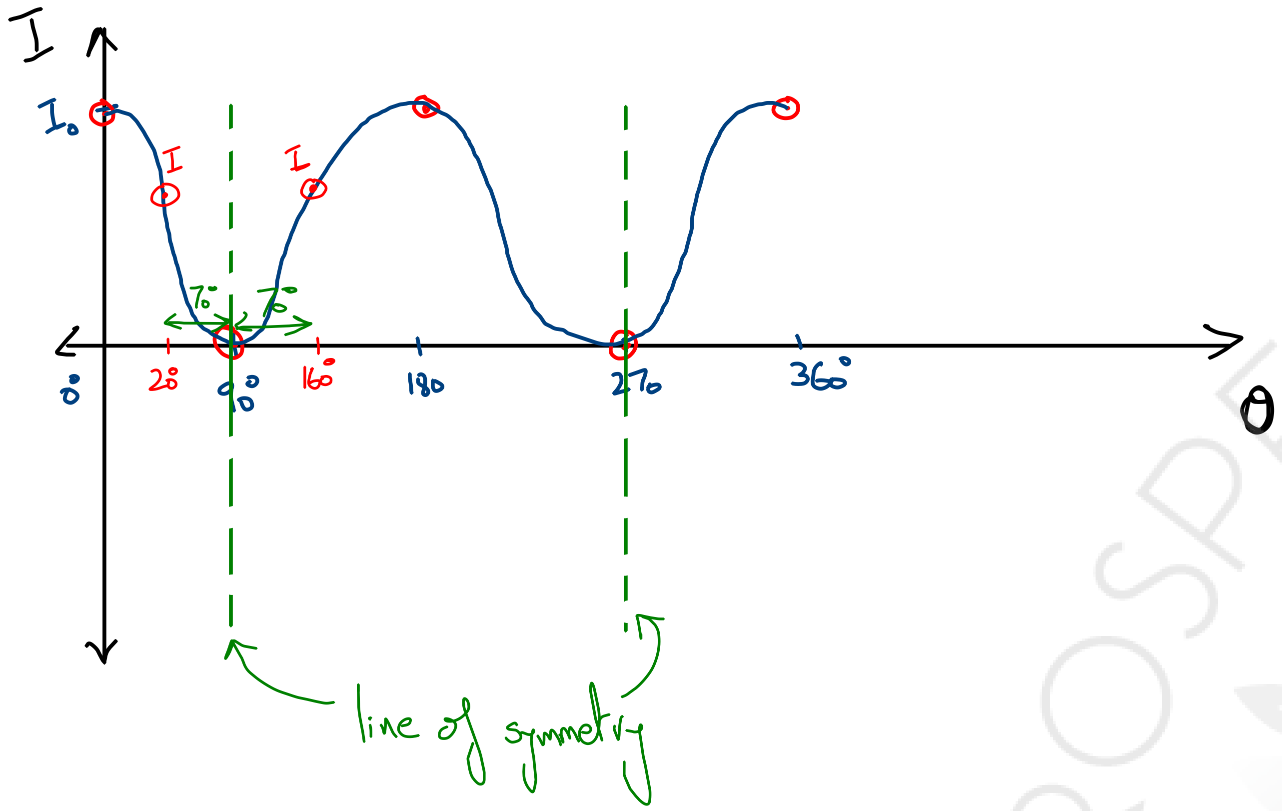
$$I = KE^2$$

$$\frac{I_1}{E_1^2} = K = \frac{I_2}{E_2^2} \Rightarrow \frac{I_1}{E_1^2} = \frac{I_2}{E_2^2}$$

$$\frac{I_o}{\cancel{E_o^2}} = \frac{I}{\cancel{E_o^2}\cos^2\theta}$$

$$I = I_o \cos^2\theta$$

* Only works for incident light that is already polarised.



Uses of polarisation :-

- Glare reduction glasses
- 3D movies
- To improve TV signals
- Stress analysis of materials

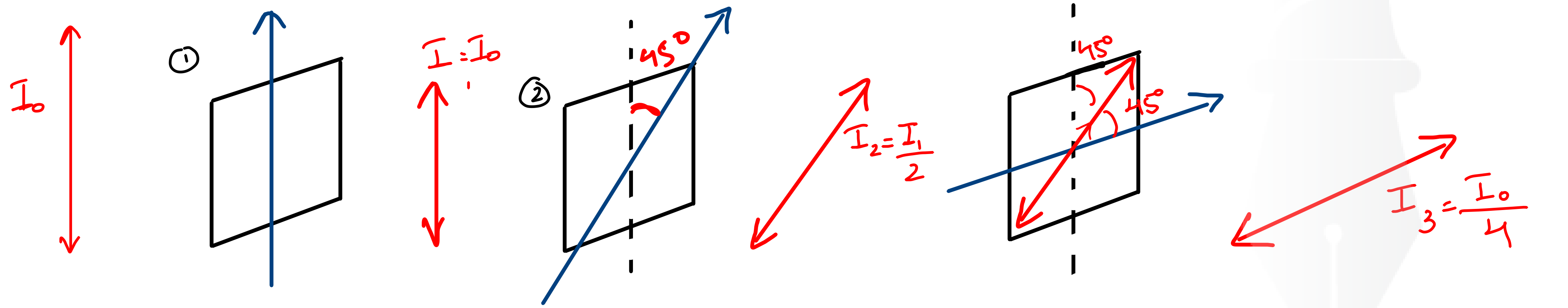
Q. Light reflected from the surface of the water is partially plane polarised. Describe briefly, how you would demonstrate this.

1) Make the reflected light incident on a polaroid filter.
2) Rotate the filter about its axis
3) You will see maximums and minimums of intensity.

c) Vertically plane polarised light is incident on three polarising filters.

The transmission axis of the first polaroid is vertical. The transmission axis of the second polaroid is 45° to the vertical and the transmission axis of the last filter is horizontal.

Show that the intensity of the light emerging from the final filter is not zero [4m]



① $I_1 = I_o \cos^2\theta \quad (\theta = 0)$

$I_1 = I_o [\cos(0)]^2$

$I_1 = I_o$

$I_2 = I_1 \times \cos^2\theta$

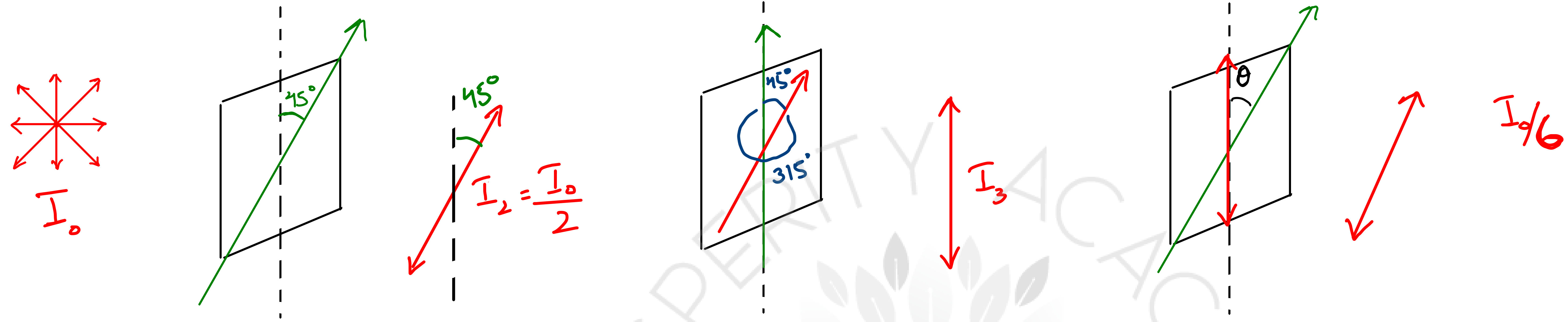
$I_2 = I_1 \times \cos^2(45)$

$I_2 = \frac{I_1}{2} = \frac{I_o}{2}$

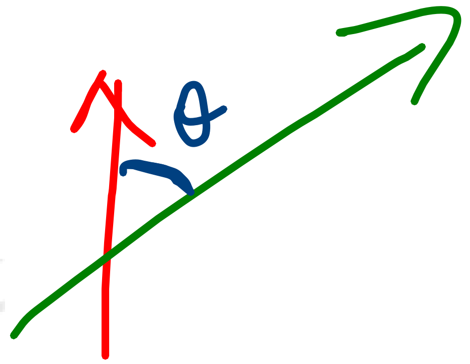
$I_3 = I_2 \times \cos^2\theta$

$I_3 = I_2 \times [\cos(45)]^2$

$I_3 = \frac{I_2}{2} \Rightarrow \boxed{I_3 = \frac{I_o}{4}}$



Q. If the resultant intensity is $I_0/6$, then what is the angle θ?



$$I_3 = I_2 \cos^2\theta$$

$$I_3 = \frac{I_0}{2}\left[\cos(315)\right]^2$$

$$I_3 = \frac{I_0}{4}$$

$$\frac{I_0}{6} = \frac{I_0}{4}\cos^2\theta$$

$$\sqrt{\frac{4}{6}} = \sqrt{\cos^2\theta}$$

$$\cos^{-1}\left(\sqrt{\frac{4}{6}}\right) = \theta$$

$$\theta = 35.26^\circ \simeq 35.3^\circ$$

5 A beam of vertically polarised monochromatic light is incident on a polarising filter, as shown in Fig. 5.1.

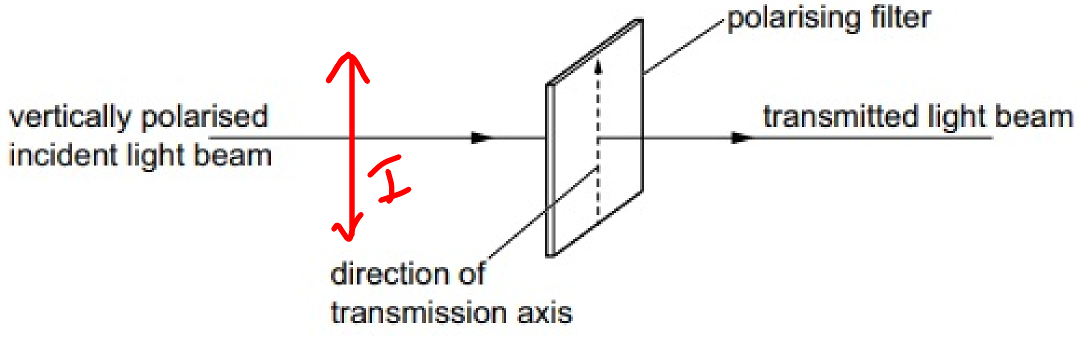


Fig. 5.1

The transmission axis of the filter is initially vertical and the transmitted light beam has the same intensity as the incident light beam.

The filter may be rotated about the direction of the light beam to change the angle of the transmission axis to the vertical.

(a) State one angle of the transmission axis to the vertical that results in no transmitted light beam.

angle = 90° or 270° ° [1]

(b) The filter is now positioned with its transmission axis at angle θ to the vertical, as shown in Fig. 5.2.

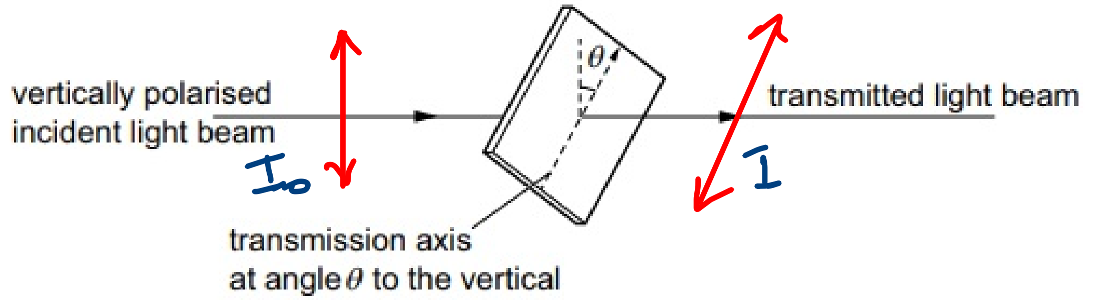


Fig. 5.2

The ratio $\frac{\text{intensity of transmitted light}}{\text{intensity of incident light}}$ is equal to 0.75.

$\frac{I}{I_o} = 0.75$

(i) Calculate angle θ.

$I = I_o \cos^2\theta$

$\cos^2\theta = \frac{I}{I_o}$

$\sqrt{\cos^2\theta} = \sqrt{0.75}$

$\theta = \cos^{-1}(\sqrt{0.75})$

$\theta = 30°$

θ = 30° ° [2]

(ii) Calculate the ratio

$\frac{\text{amplitude of transmitted light}}{\text{amplitude of incident light}}$. $\frac{a}{a_o}$

$I \propto a^2$

$I = Ka^2$

$\frac{I_1}{a_1^2} = K = \frac{I_2}{a_2^2}$

$\frac{I_o}{a_o^2} = \frac{I}{a^2}$

$\frac{a^2}{a_o^2} = \frac{I}{I_o}$

$\sqrt{\left(\frac{a}{a_o}\right)^2} = \sqrt{0.75}$

$\frac{a}{a_o} = 0.866$

ratio = 0.87 [2]

[Total: 5]

(c) A beam of vertically polarised monochromatic light is incident normally on a polarising filter, as shown in Fig. 5.1.

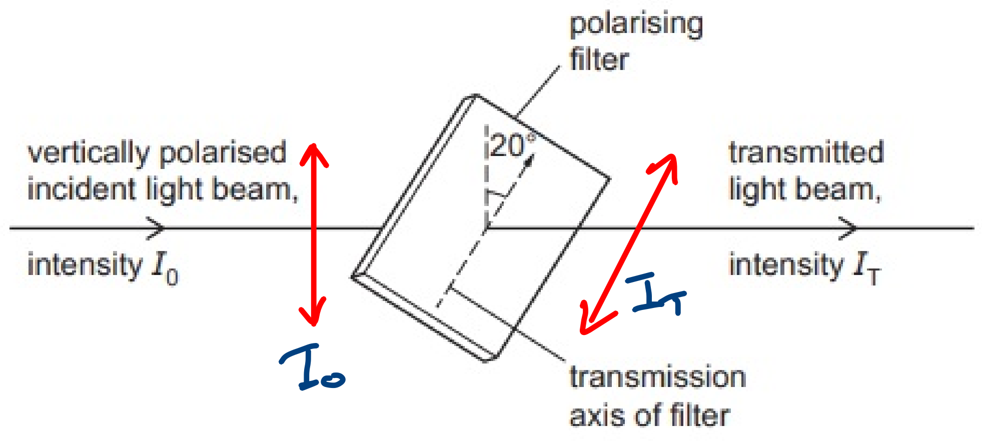


Fig. 5.1

The filter is positioned with its transmission axis at an angle of 20° to the vertical.
The incident light has intensity I_0 and the transmitted light has intensity I_T.

(i) By considering the ratio $\frac{I_T}{I_0}$, calculate the ratio

$$\frac{\text{amplitude of transmitted light}}{\text{amplitude of incident light}}.$$

Show your working.

$I_T = I_0 \cos^2\theta$

$\frac{I_T}{I_0} = \cos^2(20°)$

$\frac{I_T}{I_0} = 0.8830$

$\frac{I_T}{a_T^2} = \frac{I_0}{a_0^2}$

$\sqrt{\frac{I_T}{I_0}} = \sqrt{\frac{a_T^2}{a_0^2}}$

$\sqrt{0.8830} = \frac{a_T}{a_0} \Rightarrow 0.939$

ratio = ... 0.94 .... [3]

(ii) The filter is now rotated, about the direction of the light beam, from its starting position shown in Fig. 5.1. The direction of rotation is such that the angle of the transmission axis to the vertical initially increases.

Calculate the minimum angle through which the filter must be rotated so that the intensity of the transmitted light returns to the value that it had when the filter was at its starting position.

$160 - 20°$

angle = ... 140° .... ° [1]

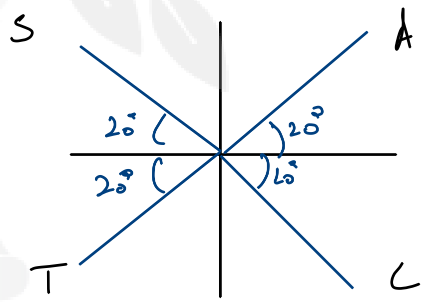
[Total: 10]

$\frac{I_T}{I_0} = \cos^2\theta$

$0.8830 = \cos^2\theta$

$\pm\sqrt{0.8830} = \cos\theta$

$\alpha = 20°$



$\theta = 20, 160°, 200°, 340°$

4 (a) Polarisation is a phenomenon associated with light waves but not with sound waves.

(i) State the meaning of polarisation.

The process of confining oscillations of the electric field vector in one direction only but still perpendicular to direction of propagation

.... [1]

(ii) State why light waves can be plane polarised but sound waves cannot.

Light waves are transverse while sound waves are longitudinal

.... [1]

(b) Two polarising filters A and B are positioned so that their planes are parallel to each other and perpendicular to a central axis line XY, as shown in Fig. 4.1.

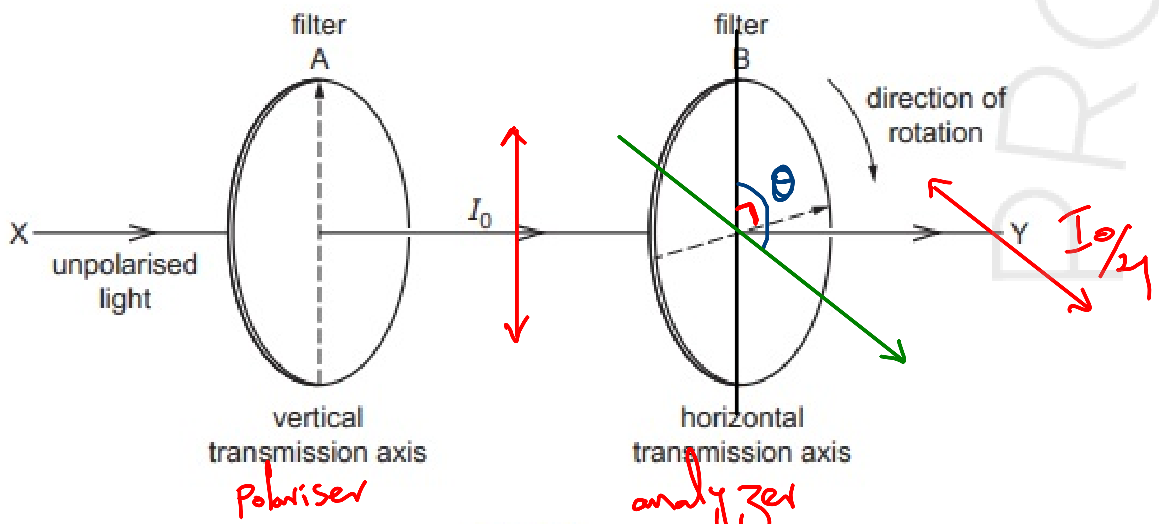


Fig. 4.1

The transmission axis of filter A is vertical and the transmission axis of filter B is horizontal.

Unpolarised light of a single frequency is directed along the line XY from a source positioned at X. The light emerging from filter A is vertically plane polarised and has intensity I_0.

Filter B is rotated from its starting position about the line XY, as shown in Fig. 4.1.

After rotation, the intensity of the light emerging from filter B is $\frac{1}{4}I_0$.

Calculate the angle of rotation of filter B from its starting position.

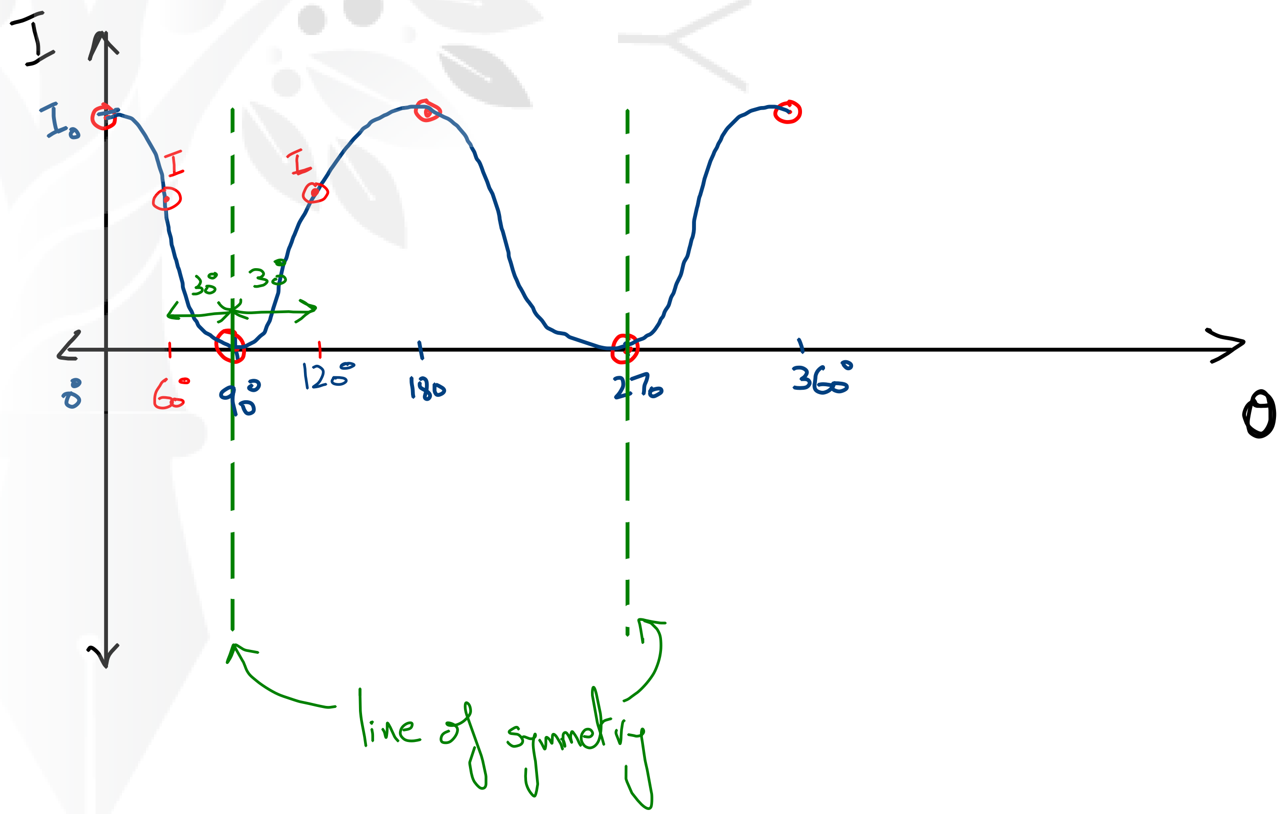
$$\frac{I_0}{4} = I_0 \times \cos^2\theta$$

$$\sqrt{\frac{1}{4}} = \sqrt{\cos^2\theta}$$

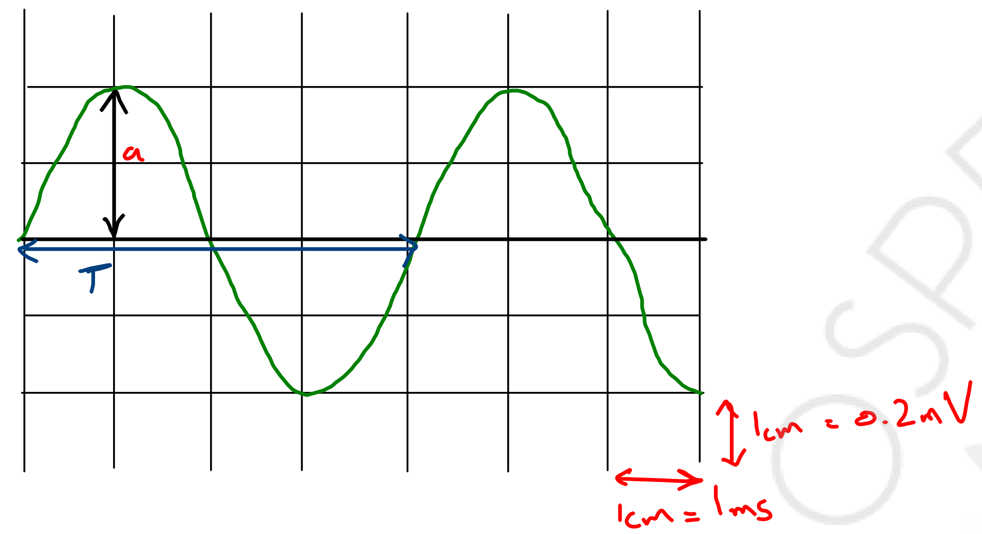
$$\theta = \cos^{-1}\left(\sqrt{\tfrac{1}{4}}\right) \Rightarrow \theta = 60^\circ / 120^\circ$$

$$120^\circ - 90^\circ = 30^\circ$$

angle of rotation = 30 ° [3]



C.R.O (Cathode ray oscilloscope)



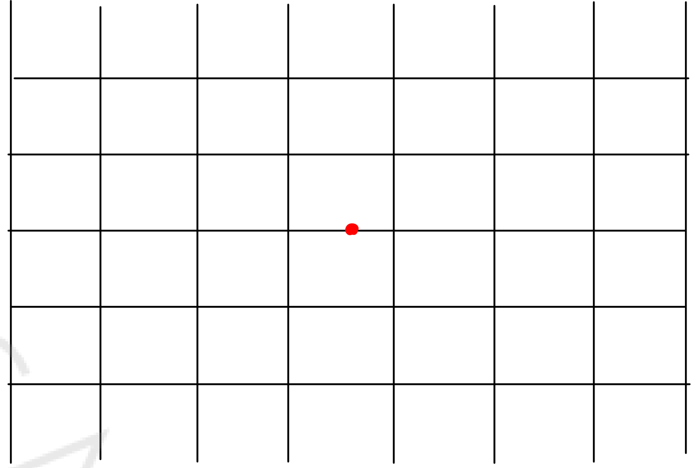
time base setting: $1 ms\ cm^{-1}$

y plate sensitivity: $0.2 mV\ cm^{-1}$

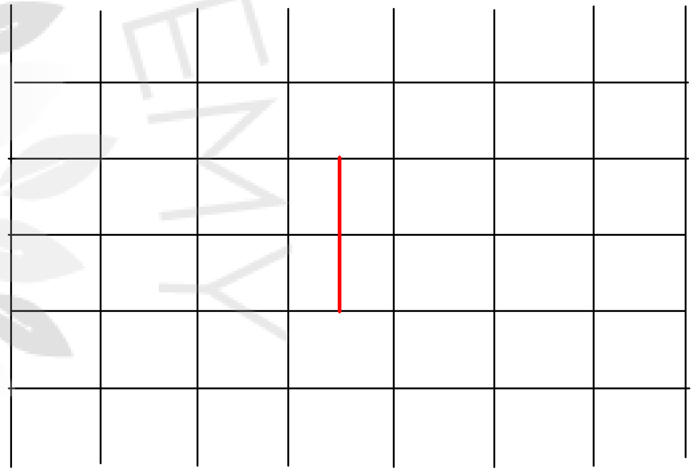
$1cm : 1ms$
$4cm : T$
$T = 4ms^{-1}$

$0.2mV : 1cm$
$a : 2cm$
$a = 0.4mV$

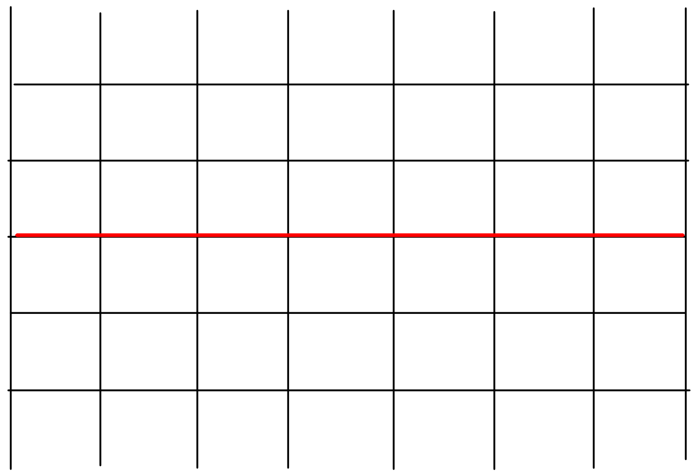
$a = 0.4mV$
$T = 4ms^{-1}$
$f = \frac{1}{4 \times 10^{-3}}$



y plates are off
time base is also off

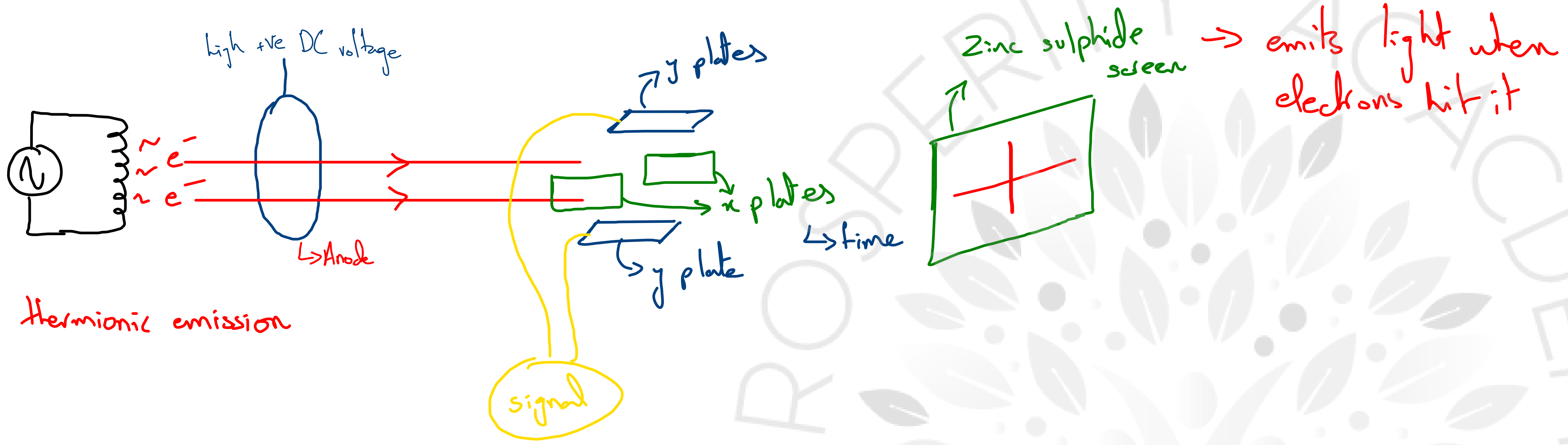


y plates are on
time base is off



y plates are off
time base is on

Working of a CRO :-



y plate sensitivity :- Basically setting axis for displacement

time base setting :- Basically setting axis for time