



GENERAL WAVES

PHYSICS BY

Kashan Rashid

Wave

It is a disturbance in a medium.

OR

* It is a mode of transferring energy from one point to another.

Classification of Waves

1. Mechanical vs Electromagnetic
2. Transverse vs Longitudinal
3. Progressive vs Stationary (New)

Mechanical Waves

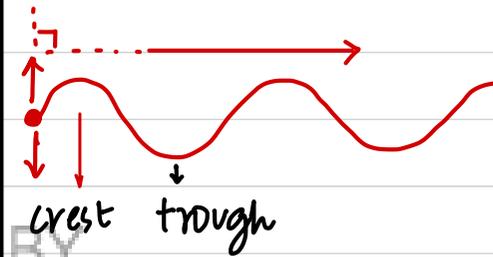
Electromagnetic Waves

- Waves which need a medium to travel.
- Cannot travel in vacuum
- Sound, water waves

- No need of medium to travel.
- They can also travel in vacuum.
- Electromagnetic Spectrum

Gamma rays, X-rays, Ultraviolet, Visible light, Infrared, Microwaves, Radiowaves.

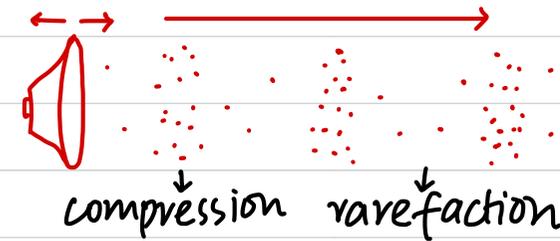
Transverse Waves



• Waves in which direction of vibration* is perpendicular to the direction of energy transfer.

- * of source
- Comprises of crests and troughs
- Electromagnetic spectrum, water waves

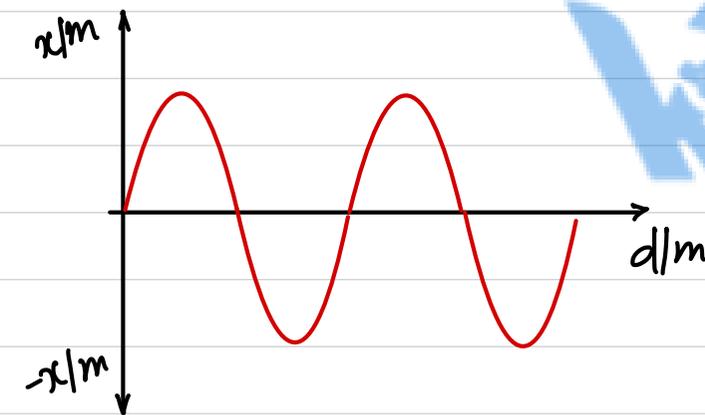
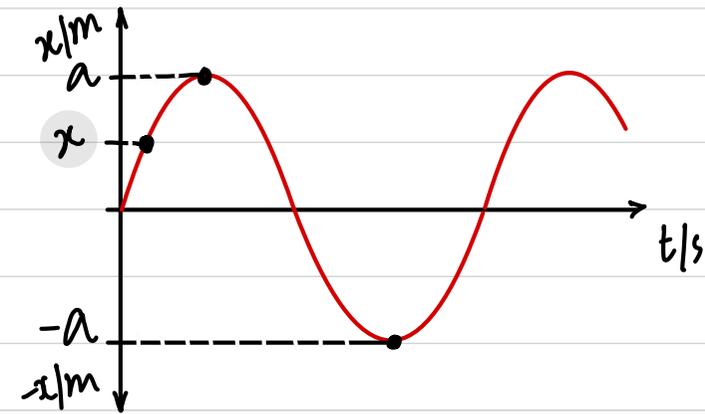
Longitudinal Waves



• Waves in which direction of vibration* is parallel to the direction of energy transfer.

- * of source
- Comprises of compressions and rarefactions.
- Sound wave

Characteristics of Waves



“Particles only vibrate about their mean position on the wave.”

1. Displacement (x)

The distance of a point on a wave from its mean position.

2. Amplitude (a)

Maximum displacement of a point on a wave from its mean position.

3. Time Period (T)

- The time taken to produce one wave
- The time taken for one wave to pass a point.



4. Frequency (f)

- The no. of waves produced per unit time
- The no. of waves passing a point per unit time.

example: 100 waves were produced in 20s.

Frequency = ?

20s — 100 waves
1s — x

$$x = \frac{100 \leftarrow N}{20 \leftarrow t}$$

N: no. of waves in time t
t: time

$$f = \frac{N}{t}$$

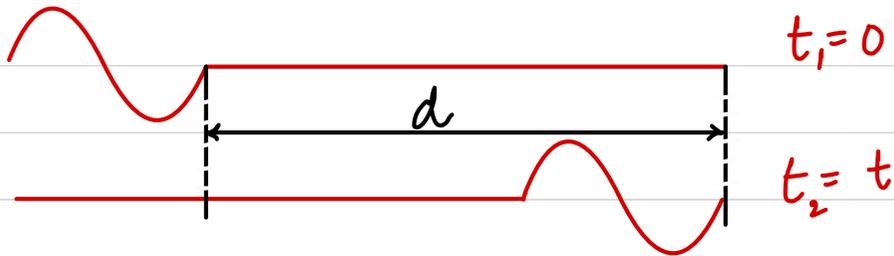


if $N=1$ so $t=T$ hence
SI Unit: Hertz (Hz)

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

5. Wavespeed (v)

The distance travelled by a waveform per unit time.



$$v = \frac{d}{t} \quad (d = N\lambda)$$

e.g. $d = 10\text{cm}$
 $\lambda = 2\text{cm}$

$$v = \frac{N\lambda}{t}$$

$$d = 5\lambda$$

$$v = f\lambda$$

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6. Intensity of a Wave (I)

Energy delivered per unit area per unit time.

OR

Power per unit area.



$$I = \frac{E}{A \times t}$$

or

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

$$I \propto \frac{1}{A}$$

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- Intensity \propto frequency {AZ content}
(For electromagnetic radiation)

- Intensity \propto (Amplitude)²

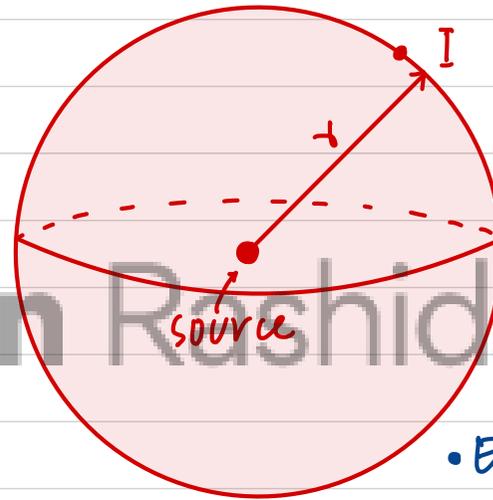
$$I \propto a^2$$

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

- Intensity $\propto \frac{1}{(\text{distance})^2}$

$$I \propto \frac{1}{d^2}$$

$$I_1 d_1^2 = I_2 d_2^2$$



$$I = \frac{P}{A} \quad (A = 4\pi r^2)$$

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

(P: constant)

$$I \propto \frac{1}{r^2}$$

- Energy spread out equally in all directions

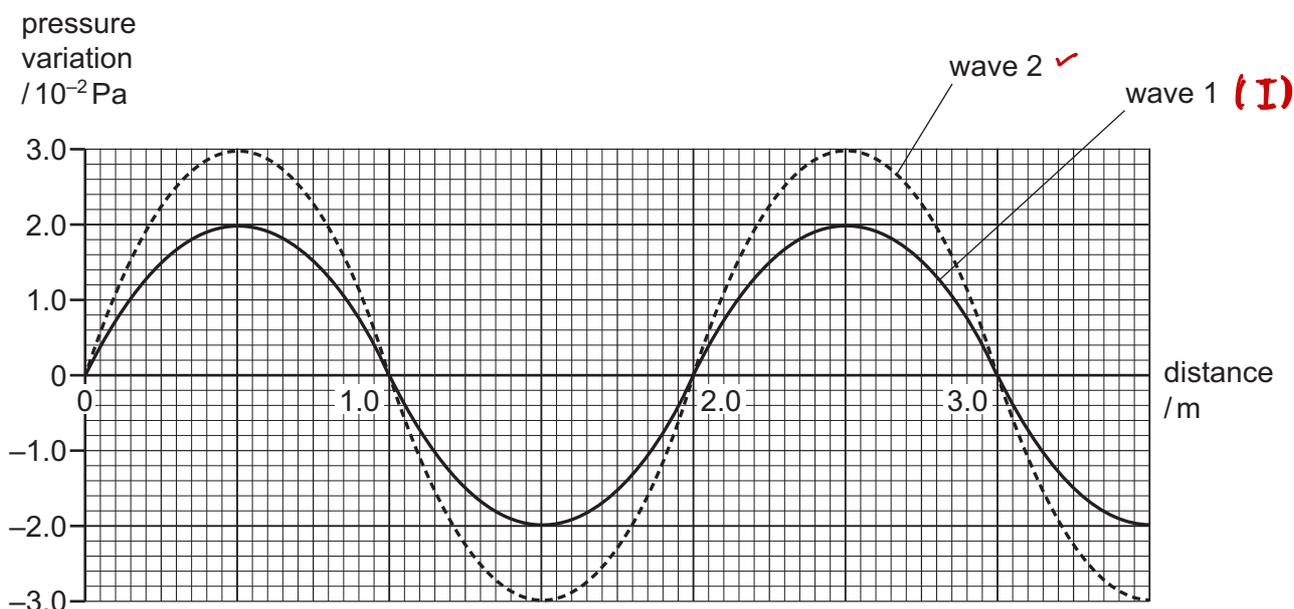
- Amplitude $\propto \frac{1}{\text{distance}}$

$$\left. \begin{array}{l} I \propto a^2 \\ I \propto \frac{1}{d^2} \end{array} \right\} a^2 \propto \frac{1}{d^2} \xrightarrow[\text{root}]{\text{square}} a \propto \frac{1}{d}$$

$$a_1 d_1 = a_2 d_2$$

23 A sound wave consists of a series of moving pressure variations from the normal, constant air pressure.

The graph shows these pressure variations for two waves at one instant in time.



Wave 1 has an intensity of $1.6 \times 10^{-6} \text{ Wm}^{-2}$.

What is the intensity of wave 2?

- A $2.4 \times 10^{-6} \text{ Wm}^{-2}$
- B $3.0 \times 10^{-6} \text{ Wm}^{-2}$
- C $3.6 \times 10^{-6} \text{ Wm}^{-2}$**
- D $4.5 \times 10^{-6} \text{ Wm}^{-2}$

$I \propto a^2$
(Ratio Method)
 $1.6 \times 10^{-6} \text{ — } (2)^2$
 $I \text{ — } (3)^2$

$I = \frac{(1.6 \times 10^{-6}) \times 9}{4}$
 $I = 3.6 \times 10^{-6} \text{ Wm}^{-2}$

$I \propto a^2$

$(2)^2 \text{ — } I$
 $(3)^2 \text{ — } x$

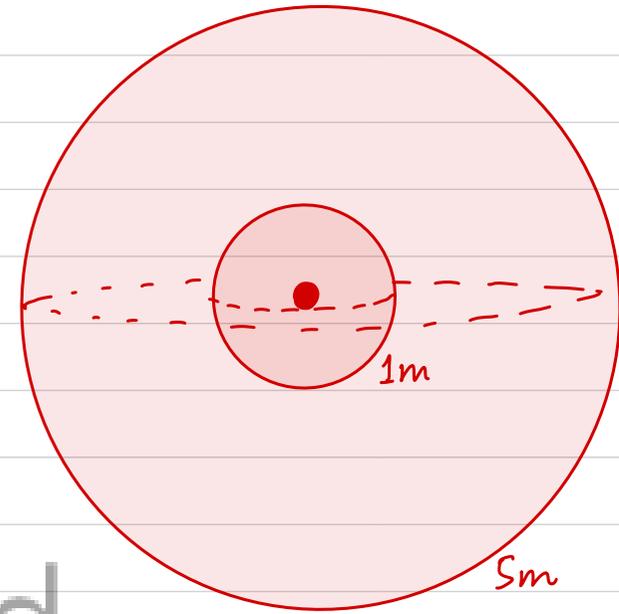
$x = \frac{9 \times I}{4}$

$x = \frac{9I}{4}$

intensity of wave 2 in terms of I.

Q MJ/1983/P1/Q.4

5 A small source of sound radiates energy equally in all directions. At a particular frequency, the intensity of the sound 1.0 m from the source is $1.0 \times 10^{-5} \text{ W m}^{-2}$, corresponding to an amplitude of oscillation of the air molecules of $70 \mu\text{m}$. Assuming that the sound is propagated without energy loss, what will be (a) the intensity of the sound, (b) the amplitude of oscillation of the air molecules, at a distance of 5.0 m from the source?



$$d_1 = 1\text{m}$$

$$I_1 = 1.0 \times 10^{-5} \text{ Wm}^{-2}$$

$$a_1 = 70 \mu\text{m}$$

$$d_2 = 5\text{m}$$

$$I_2 = ?$$

$$a_2 = ?$$

$$a) \quad I \propto \frac{1}{d^2}$$

$$I_1 d_1^2 = I_2 d_2^2$$

$$(1 \times 10^{-5})(1)^2 = I_2(5)^2$$

$$I_2 = 4.0 \times 10^{-7} \text{ Wm}^{-2}$$

$$b) \quad a \propto \frac{1}{d}$$

$$a_1 d_1 = a_2 d_2$$

$$(70)(1) = a_2(5)$$

$$a_2 = 14 \mu\text{m}.$$

7. Phase (ϕ)

It is used to tell about the state of motion of a point on a wave

"PHASE ANGLE IS DETERMINED USING RATIO METHOD"

It is represented in "angles."

degree to radian

$$180^\circ - \pi \text{ rad}$$

$$360^\circ - 2\pi \text{ rad}$$

$$90^\circ - \frac{\pi}{2} \text{ rad}$$

$$T \text{ --- } 360^\circ$$

$$t \text{ --- } \phi$$

$$\phi = \frac{t}{T} \times 360^\circ \text{ (in degree)}$$

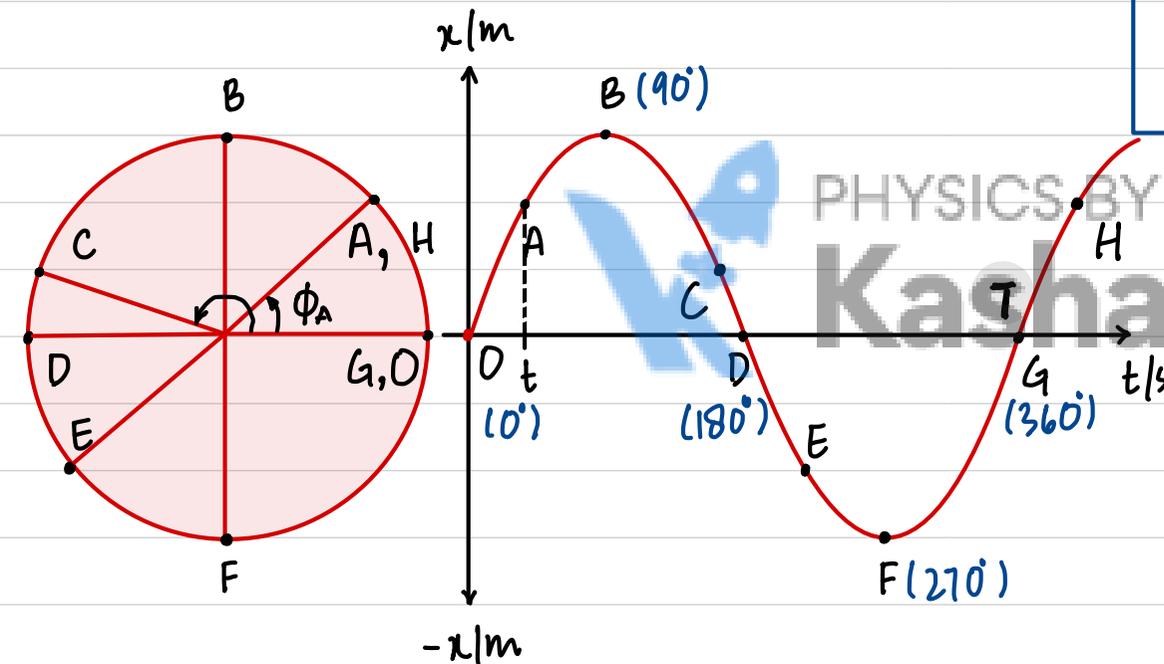
$$\phi = \frac{t}{T} \times 2\pi \text{ (in radians)}$$

$$\lambda \text{ --- } 360^\circ$$

$$d \text{ --- } \phi$$

$$\phi = \frac{d}{\lambda} \times 360^\circ$$

$$\phi = \frac{d}{\lambda} \times 2\pi$$



$$\phi_O = 0^\circ$$

$$\phi_A = 60^\circ$$

$$\phi_B = 90^\circ$$

$$\phi_C = 160^\circ$$

$$\phi_D = 180^\circ$$

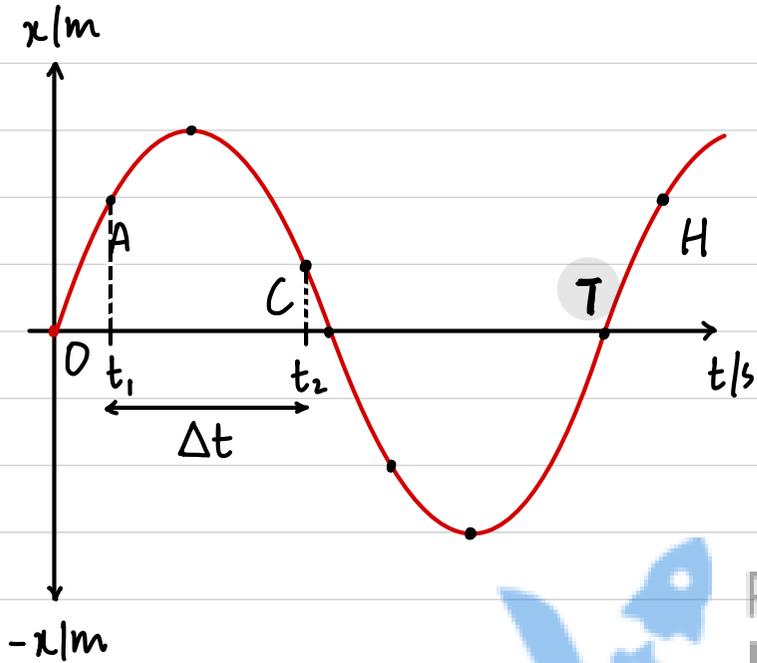
$$\phi_E = 240^\circ$$

$$\phi_F = 270^\circ$$

$$\phi_G = 360^\circ \text{ or } 0^\circ$$

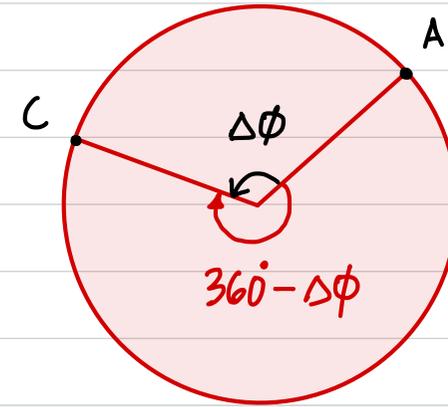
$$\phi_H = 420^\circ \text{ or } 60^\circ$$

Phase difference between two points



$$T = 360^\circ$$
$$\Delta t = \Delta \phi$$

$$\Delta \phi = \frac{\Delta t}{T} \times 360^\circ$$



similarly...

$$\lambda = 360^\circ$$

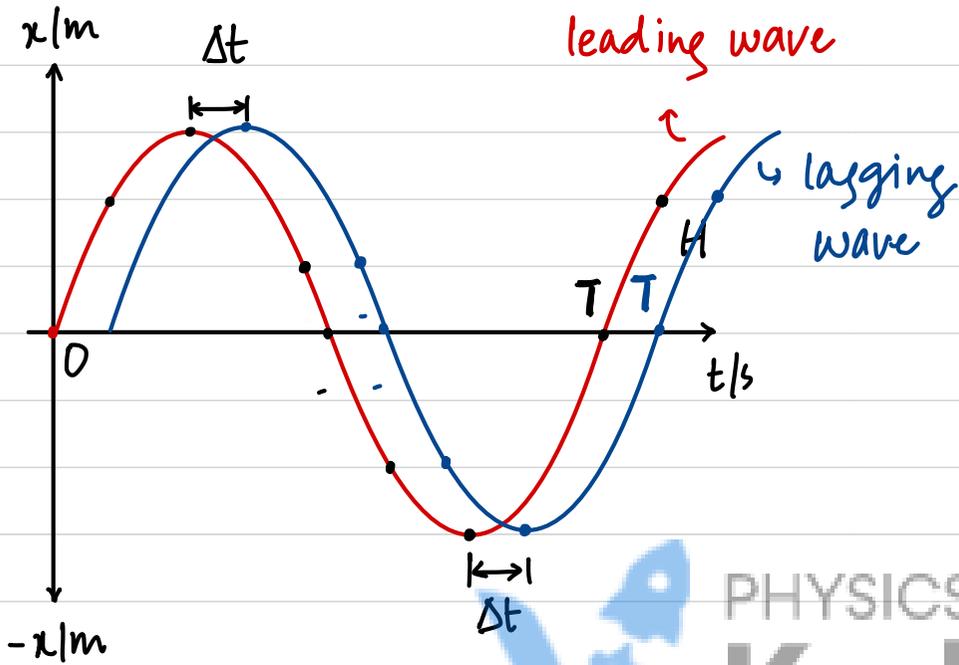
$$\Delta d = \Delta \phi$$

$$\Delta \phi = \frac{\Delta d}{\lambda} \times 360^\circ$$



Kashan Rashid

phase difference between two waves



$$T = 360^\circ$$

$$\Delta t = \Delta \phi$$

$$\Delta \phi = \frac{\Delta t}{T} \times 360^\circ$$

where Δt is the time difference between corresponding points of both waves.

leading wave has its crest/troughs produced earlier in time than the other.

Coherent Waves: Waves are said to be coherent if they have the same phase difference throughout.

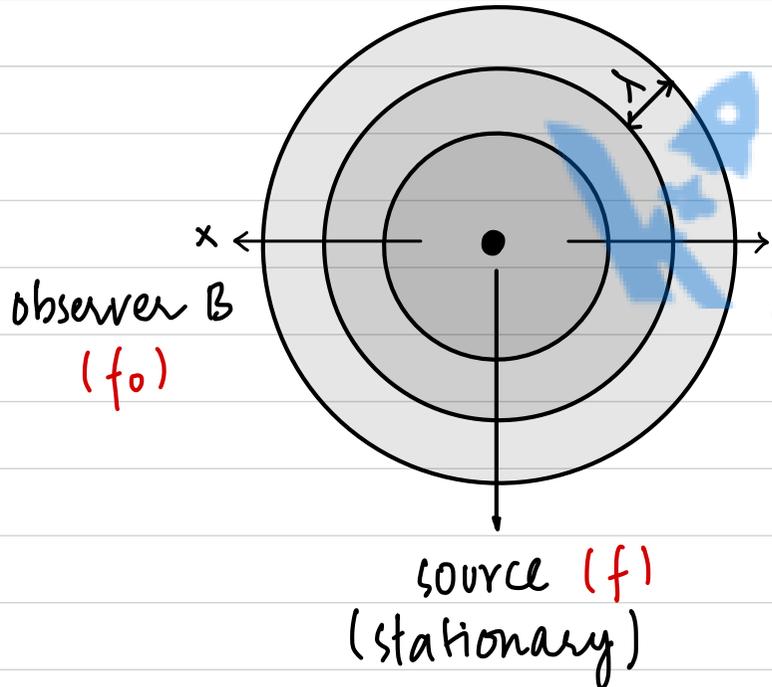
"For waves to be coherent, they must have the same frequency"

Doppler's Effect

The change in the observed frequency of the wave when the source moves relative to observer.

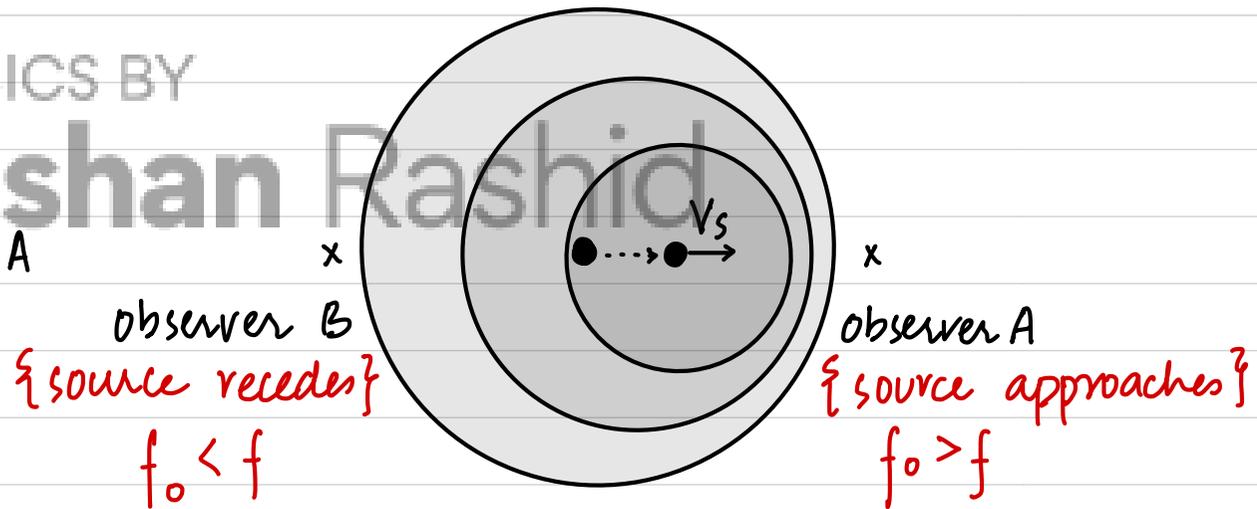
$$f_o = \frac{v}{v \pm v_s} \times f$$

observed frequency speed of wave speed of source actual/source frequency



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$$f_o = \frac{v}{v + v_s} \times f$$

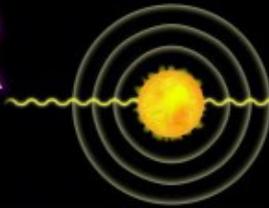
$$f_o = \frac{v}{v - v_s} \times f$$

Observed frequency is same as source's frequency as source is stationary.

(distance plus in recede so use +)

(distance minus in approach so use -)

DOPPLER EFFECT



When a star is stationary relative to an observer, the light produced looks the same no matter what direction it is seen from. Our sun is a good example of a star that is not moving much nearer or farther from the Earth.

If stars move either towards or away from our vantage point, however, the motion shifts the way their light looks to us.

RED SHIFT

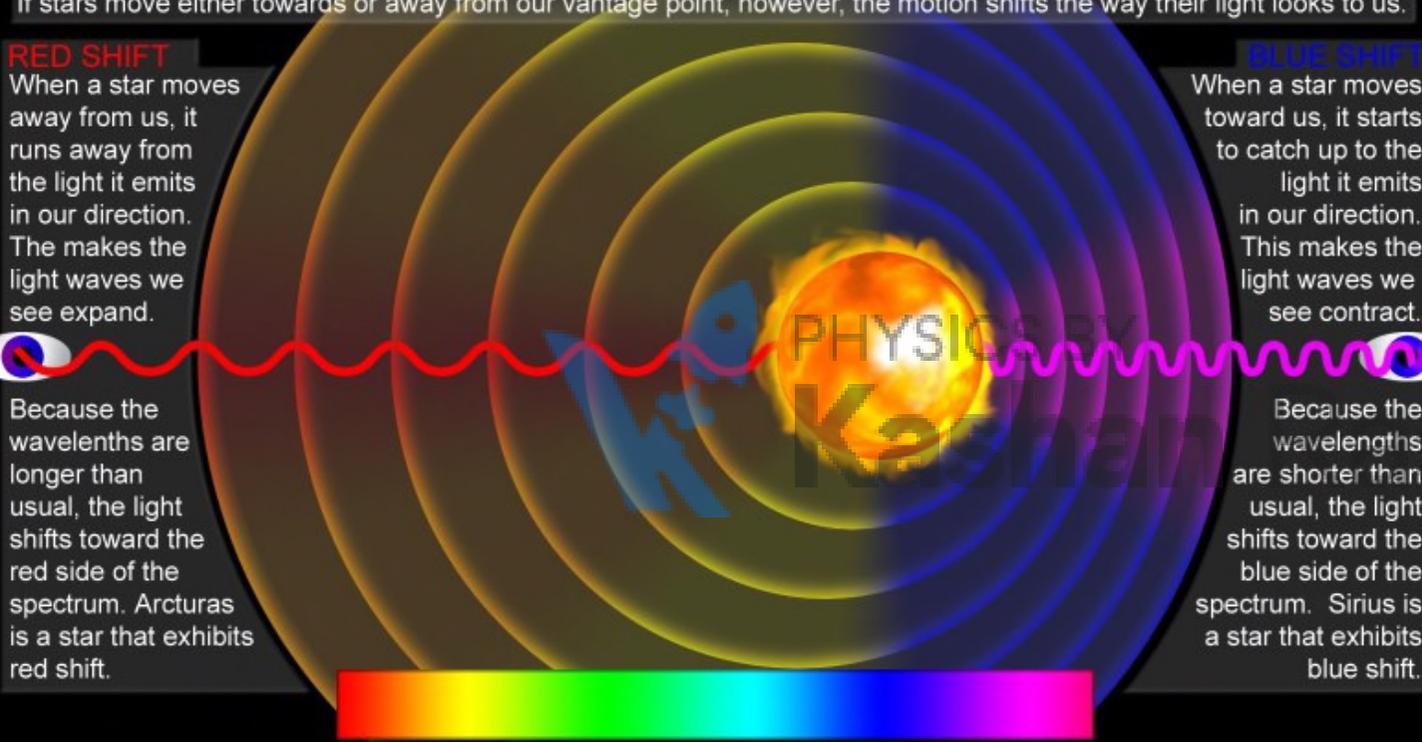
When a star moves away from us, it runs away from the light it emits in our direction. This makes the light waves we see expand.

Because the wavelengths are longer than usual, the light shifts toward the red side of the spectrum. Arcturus is a star that exhibits red shift.

BLUE SHIFT

When a star moves toward us, it starts to catch up to the light it emits in our direction. This makes the light waves we see contract.

Because the wavelengths are shorter than usual, the light shifts toward the blue side of the spectrum. Sirius is a star that exhibits blue shift.



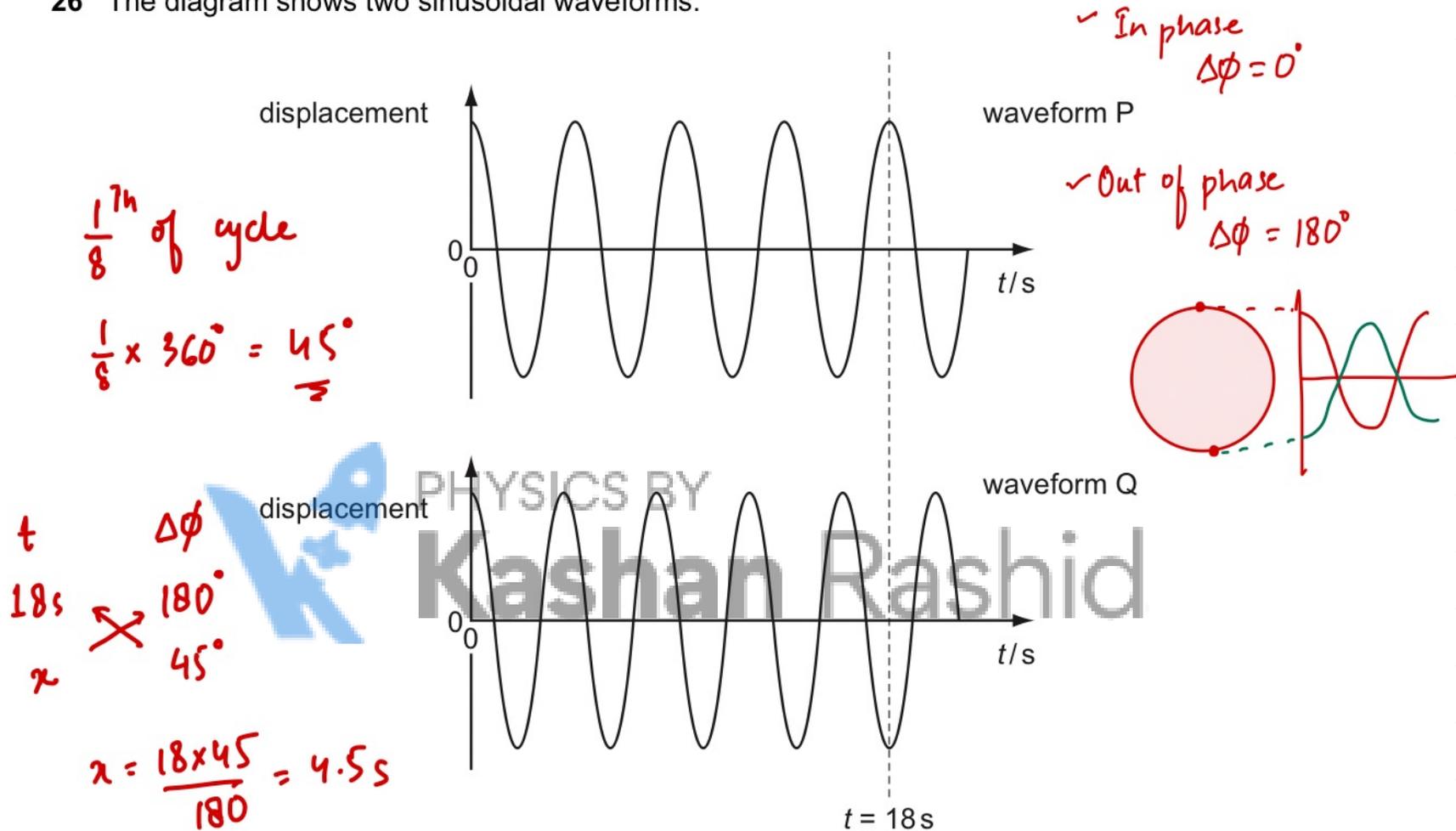
RED SHIFT BLUE SHIFT

Most shifts can not be seen with the naked eye, but astronomers can measure them to learn whether other stars are advancing or receding.

As the star moves away, there is a red shift in its color. This is due to the Doppler's Effect.

- Due to star moving away, the observed frequency is less than the actual.
- As Red color has a lower frequency hence the light coming from the star has a red shift in it.
- This also explains that the universe is expanding.

26 The diagram shows two sinusoidal waveforms.



At time $t = 0$ the waves are in phase. At the dotted line, $t = 18\text{s}$.

At which time is the phase difference between the two oscillations $\frac{1}{8}$ of a cycle?

A 4.0s

B 4.5s

C 8.0s

D 9.0s

26 A car travelling at a steady speed in a straight line passes close to a stationary observer. The observer measures the frequency of the sound from the engine.

As the car approaches, the observed frequency is 220 Hz. When the car moves away, the observed frequency is 180 Hz.

The speed of sound in air is 340 m s^{-1} .

What is the speed of the car?

A 8.5 m s^{-1}

B 31 m s^{-1}

C 34 m s^{-1}

D 38 m s^{-1}

Approach ($f_o > f$)

$$f_o = \frac{v}{v - v_s} \times f$$

$$220 = \frac{340}{340 - v_s} \times f \quad \checkmark$$

Recede ($f_o < f$)

$$f_o = \frac{v}{v + v_s} \times f$$

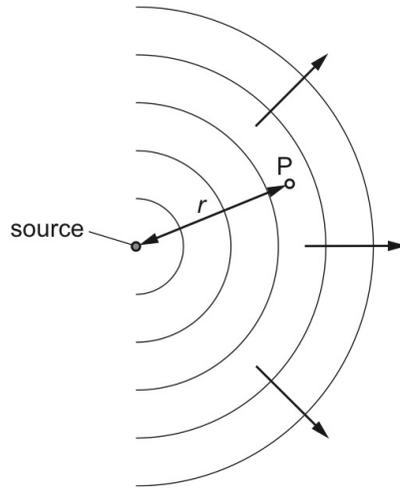
$$180 = \frac{340}{340 + v_s} \times f \quad \checkmark$$

$$\frac{220(340 - v_s)}{340} = \frac{180(340 + v_s)}{340}$$

$$v_s = 34 \text{ m s}^{-1}$$

MJ/2014/P13/Q.27

27 A small source emits spherical waves.



$$I \propto \frac{1}{r^2}$$

$$I \propto a^2$$

$$\sqrt{a^2} \propto \sqrt{\frac{1}{r^2}}$$

$$a \propto \frac{1}{r}$$

The wave intensity I at any point P, a distance r from the source, is inversely proportional to r^2 .

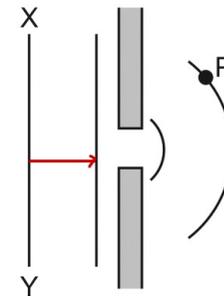
What is the relationship between the wave amplitude a and the distance r ?

- A $a^2 \propto \frac{1}{r}$ **B** $a \propto \frac{1}{r}$ C $a \propto \frac{1}{r^2}$ D $a \propto \frac{1}{r^4}$

MJ/2012/P12/Q.29

29 A monochromatic plane wave of speed c and wavelength λ is diffracted at a small aperture.

The diagram illustrates successive wavefronts.



$$v = f \lambda$$

$$c = \frac{1}{T} \lambda$$

$$T = \frac{\lambda}{c} \times 3$$

After what time will some portion of the wavefront XY reach point P?

- A $\frac{3\lambda}{2c}$ B $\frac{2\lambda}{c}$ **C** $\frac{3\lambda}{c}$ D $\frac{4\lambda}{c}$

MJ/2013/P11/Q.24

24 A light wave of amplitude A is incident normally on a surface of area S . The power per unit area reaching the surface is P .

The amplitude of the light wave is increased to $2A$. The light is then focussed on to a smaller area $\frac{1}{3}S$.

What is the power per unit area on this smaller area?

- A $36P$
- B $18P$
- C $12P$**
- D $6P$

$A \rightarrow 2A$
 \downarrow
 $P \times 4 \times 3$
 \uparrow
area

$\cdot I = \frac{P}{A}$
 $\cdot I \propto a^2$



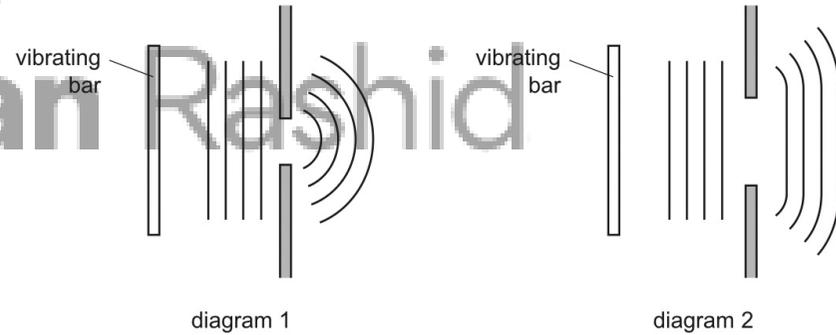
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24 Diagram 1 shows a ripple tank experiment in which plane waves are diffracted through a narrow slit in a metal sheet.

Diagram 2 shows the same tank with a slit of greater width.

In each case, the pattern of the waves incident on the slit and the emergent pattern are shown.

$\lambda \approx \text{slit size}$
 $v = f\lambda$



Which action would cause the waves in diagram 1 to be diffracted less and so produce an emergent pattern closer to that shown in diagram 2?

- A increasing the frequency of vibration of the bar
- B increasing the speed of the waves by making the water in the tank deeper
- C reducing the amplitude of vibration of the bar
- D reducing the length of the vibrating bar