Tutorial Topic 11: Waves

Properties of Waves

1. (a) Distinguish between longitudinal and transverse waves.
   (b) What are some of the phenomenon that is associated with transverse waves but is not observed with longitudinal waves?
   (c) Fig. 1 shows 2 graphs which refer to the same wave. Calculate the speed of the wave

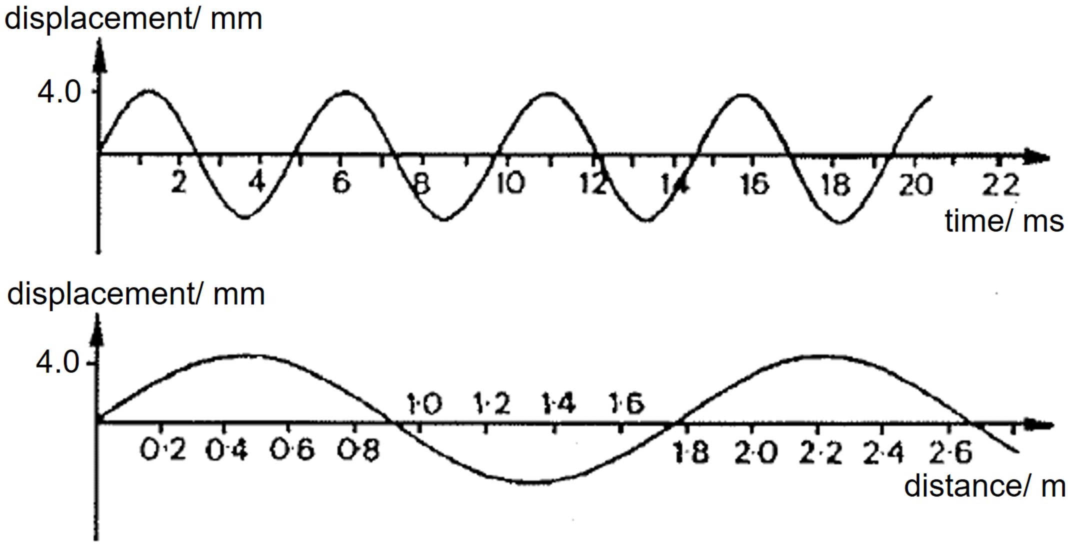

Fig. 1

2. During a lab demonstration, 2 set of ripple tanks and wave generators are being set up in the lab and activated. Water waves having a wavelength of 0.05 m are being generated in both tanks. 2 polystyrene balls A and B are then placed respectively in each tank and have their motions being tracked using a software. The displacement-time graph of the balls are being plotted as shown in Fig. 2.

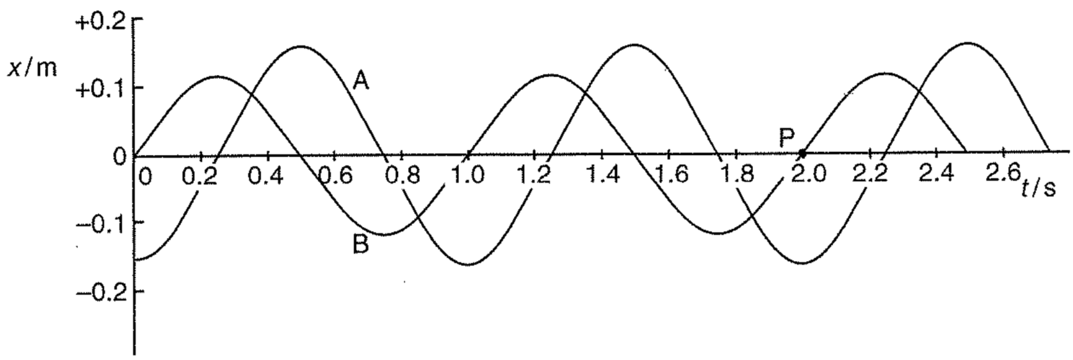

Fig. 2

(a) State which of these term(s): *period*, *frequency*, *angular frequency* and *amplitude* will be the same between the oscillations of A and B.
(b) Determine the period of oscillation for particle B.
(c) Determine the speed of the wave that is being generated in the ripple tank.
(d) Calculate the speed with which B is traveling at the point marked P.
(e) Calculate the phase difference between the oscillations.
(f) Write an equation for the oscillation of A to show how x is related to t.

3. Parallel water waves travelling with a velocity of 2.0 m s^{-1} and a frequency of 10 Hz strike a straight wall as shown in Fig. 3. The wavefronts make an angle of 60° with the wall as shown. What is the phase difference between two points 5.0 cm apart along the wall?

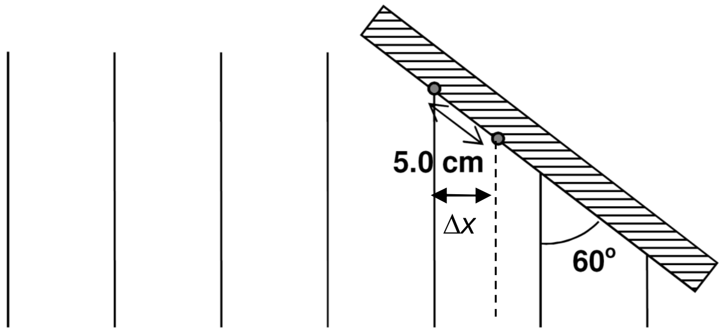

Fig. 3

4. Fig. 4a below shows an instantaneous position of a string as a transverse wave travels along it from left to right.

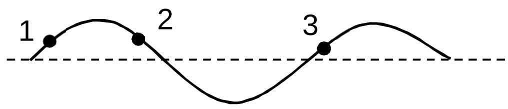

Fig. 4a

(a) Draw arrows on Fig. 4a to indicate the directions of the velocities of the points 1, 2 and 3 on the string.

(b) Fig.4b show a progressive transverse and a progressive longitudinal wave respectively.

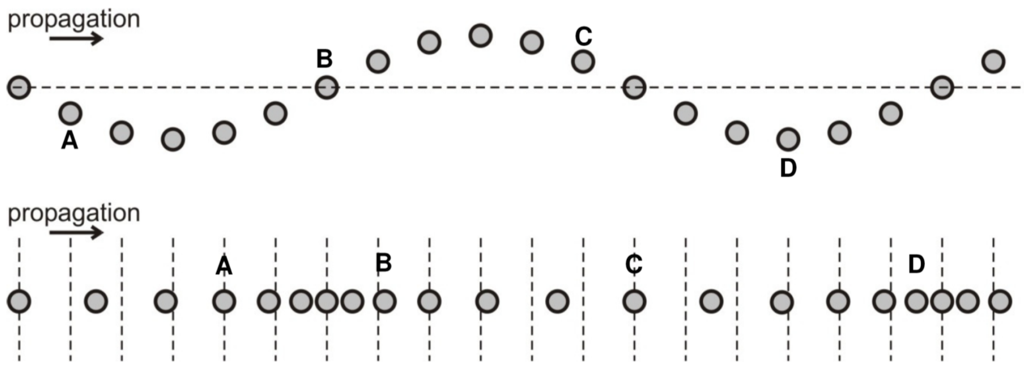

Fig. 4b

On each of the diagrams above, identity a point or points at which

(i) the velocity is zero.

(ii) the acceleration is zero.

(iii) the velocity is in the same direction as the displacement.

(iv) the acceleration is in the same direction as velocity.

Energy and Intensity

5. A satellite passing the planet Neptune communicates with its controller on the Earth using a microwave transmitter with output power 22.0 W and wavelength 79 600 μm. Neptune is 4.35×10^{12} m from the Earth at the time when the communication takes place.

   (a) Calculate the time taken for a signal to travel from the satellite to the Earth.
   (b) Assuming that the power transmitted by the satellite is radiated uniformly in all directions, calculate the power received on the Earth by a dish aerial of effective area 260 m^2.
   (c) The actual power received at the dish aerial is 1.2×10^{-15} W. Suggest why the actual power received is greater than that calculated in **(b)**.

6. A small source of sound emits energy uniformly in all directions.
   For a particular frequency, the intensity of sound at a distance of 1.0 m from the source is 1.0×10^{-5} W m^{-2}, and corresponds to an amplitude of oscillation of the air molecules of 70 *μ*m. Assuming sound is propagated without any loss of energy, find, at a distance 5.0 m from the source,

   (a) the intensity of sound.
   (b) the amplitude of oscillation of the air molecules.

7. Waves from a point source pass through an area that is 2.0 cm wide as shown in Fig. 7.

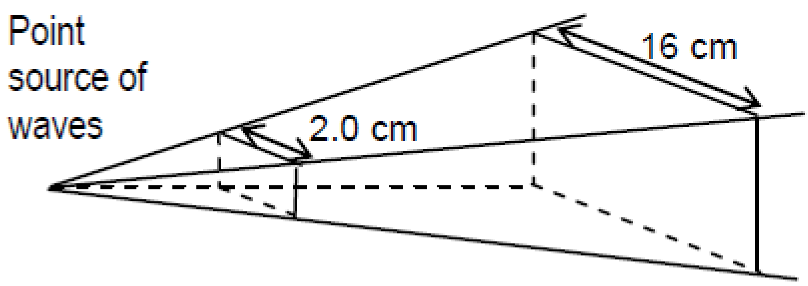

Fig. 7

   Within this area, the intensity of the waves is *I* and their amplitude is *A*. The waves reach a second area of width 16 cm.

   What will be the intensity and amplitude of the waves when they reach the second area?

Cathode Ray Oscilloscope

8. A microphone detects a musical note of frequency *f*. The microphone is connected to a cathode ray oscilloscope (c.r.o). The signal from the microphone is observed on the c.r.o as illustrated in Fig. 8

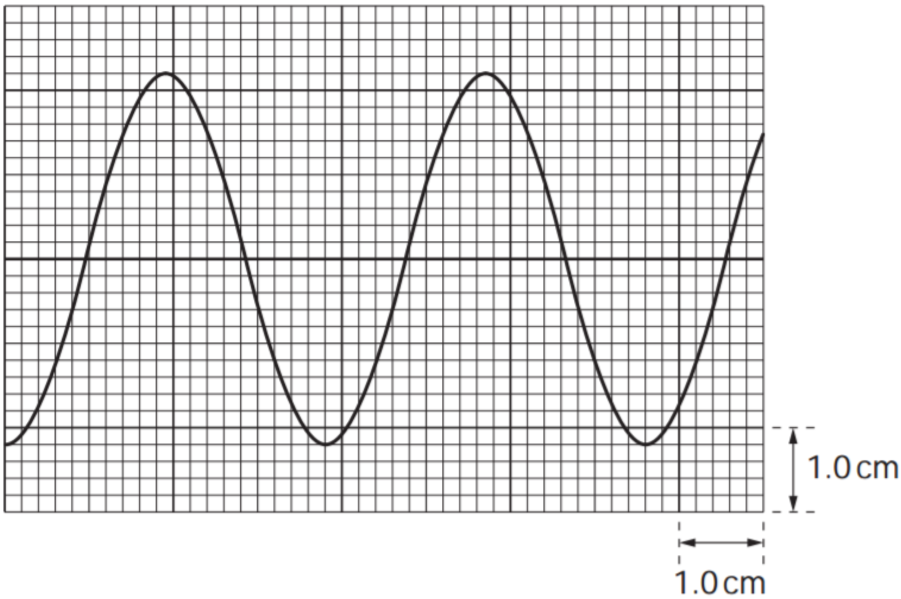

Fig. 8

The time-base setting of the c.r.o. is 0.50 ms cm^{-1}. The Y-plate setting is 2.5 mV cm^{-1}. Use Fig. 8 to determine

(a) The amplitude of the signal
(b) The frequency, *f*
(c) The actual uncertainty in *f* caused by reading the scale on the c.r.o.
(d) State *f* with its actual uncertainty

Polarization and Malus' Law

9. Which effect provides direct experimental evidence that light is a transverse wave, rather than a longitudinal, wave motion?

A. Light can be diffracted.
B. Light can be reflected.
C. Two coherent light waves can be made to interfere.
D. The intensity of light from a point source falls off inversely as the square of the distance from the source.
E. Light can be polarized.

( )

10. Fig. 10 below shows the arrangement of three polarising sheets in the path of a ray of unpolarised light. The polarising plane of each sheet is indicated by a dashed line.

The amplitude *A* of a polarised light ray as it passes through a polariser at an angle of θ to the plane of polarisation is

$$A = A_0 \cos\theta$$

where A_0 is the amplitude of the original light ray.

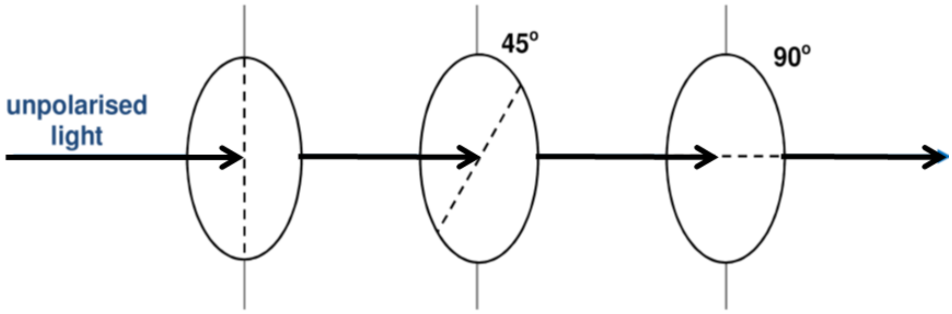

Fig. 10

(a) If the intensity of the unpolarised light is I, deduce the intensity of light emerging from the remaining two polarising sheets, in terms of I.

(b) Deduce the intensity of light emerging from the last polarising sheet if the middle sheet is removed.

Putting them altogether

11. A progressive wave moves past two points P and Q, which are separated by a distance of 0.90 m. A graph showing how the displacement y at P varies with time t is shown in Fig. 11a below.

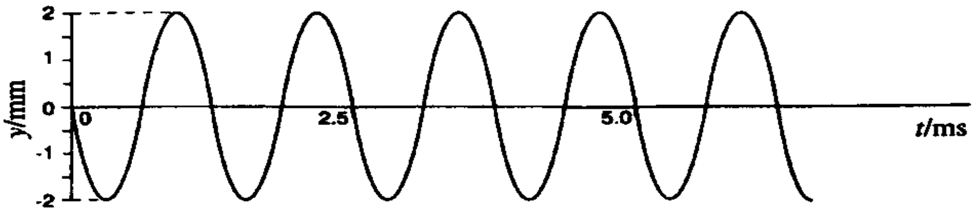

Fig. 11a

Another graph showing how the displacement of the wave at time t = 0 varies with distance x from P is also shown in Fig. 11b below.

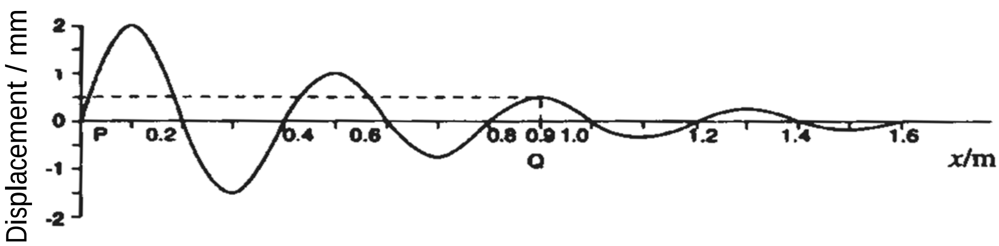

Fig. 11b

(a) Using data from the graphs, deduce for this wave
- (i) the speed
- (ii) the phase difference between the oscillations at P and those at Q
- (iii) the ratio $\dfrac{\text{amplitude at P}}{\text{amplitude at Q}}$
- (iv) the ratio $\dfrac{\text{intensity at P}}{\text{intensity at Q}}$

(b) Light waves, sound waves in air and surface water waves are different forms of waves. Using your answers to (a), suggest, with a reason, which of these might be the wave being considered.

(c) (i) Suggest an experimental method to obtaining the first graph.
(ii) Discuss whether the same method could be used for the second graph.

Challenge problem

12. Fig. 12 below shows that a horizontally-polarized light with intensity I_0 is passed through a sequence of N ideal polarizers whose transmission axes are inclined at increasing angles $m\theta$ from the horizontal, where $m = 1, 2, 3, \ldots, N$ and $\theta = \frac{\pi}{2N}$.

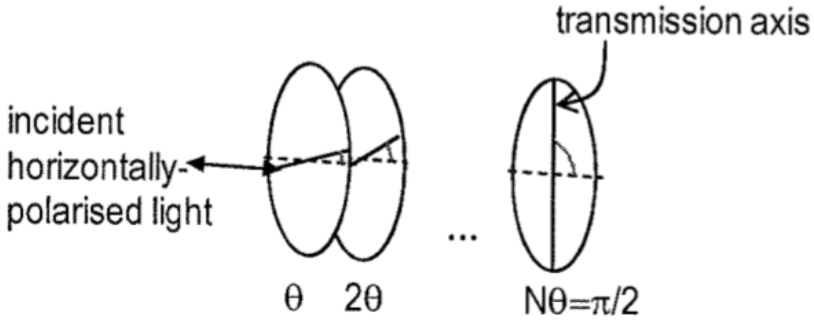

Fig. 12

(i) Derive an expression for the intensity of the light transmitted through the N^{th} polarizer.
Hint: You can try to approach the question using the idea of geometric progression that you have learnt in H2 Maths

(ii) Hence, evaluate the value of I_N when the light passes through infinitely many polarizers i.e. $N \to \infty$
Hint: You might need to make use if the following approximations:

$$\cos\theta \cong 1 - \frac{1}{2}\theta^2, \text{ when } \theta \text{ is small}$$
$$(1 - x)^n \approx 1 - nx \text{ , when } x \text{ is small}$$