Topic 9: Waves Motion
Suggested Solutions to Self-Review Questions

S1 **Answer: B**
Since the speed is independent of frequency $\rightarrow$ Speed is constant

$$v = f\lambda \Rightarrow f = \frac{v}{\lambda} \Rightarrow f \propto \frac{1}{\lambda}$$

When $\lambda \rightarrow 0$, $f \rightarrow \infty$
When $\lambda \rightarrow \infty$, $f \rightarrow 0$

[You should be familiar some of the common graphs and their features. This will help you do the questions pertaining to graphs esp. in MCQ
Some common graphs: $y = mx$; $y = mx+c$, $c \neq 0$; $y = Ax^2$; $y = 1/x$; $y = \sqrt{x}$; $y = \ln x$; $y = e^x$; $y = e^{-x}$.]

S2 **Answer: B**

$$2\frac{1}{2}T = 10 \text{ cm} \times 2.00 \text{ ms cm}^{-1}$$

T = 8.00 ms
$f = 1/T$ = 1/(8.00 ms) = 125 Hz

S3 **Answer: C**
The diagram indicates that the wavelength (distance between consecutive rarefactions/ compressions) is 8 m.

$$v = f\lambda$$

$$\therefore f = \frac{v}{\lambda} = \frac{12}{8} = 1.5 \text{ Hz}$$

S4 **Answer: D** (recall that any point on the string is undergoing SHM)
Statement A: False. Speed of the element at P is zero, as it is at its highest point of motion.
Statement B: False. This is a travelling wave, so all points on the wave are in SHM and hence displacement of the element at Q varies sinusoidally with time.
Statement C: False. Each element of the wave is performing the same SHM with the same amplitude. So the (total) energy of each element is the same.
Statement D: True. Since every element on the wave is in SHM, $a = -\omega^2 x$. For S, the displacement is maximum, therefore the magnitude of a is also maximum. The negative sign of the acceleration indicates the direction of the acceleration which is pointing towards the equilibrium position i.e. in the negative direction.

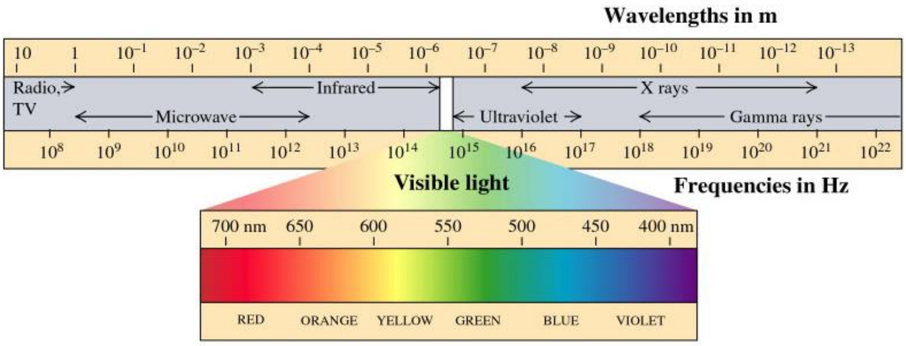
S5 $c = 3.0 \times 10^8$ m s^{-1}

Since $f = \frac{c}{\lambda}$, hence, maximum frequency corresponds to smallest wavelength.

$$\text{Max } f = \frac{3.0\times10^8}{(400\times10^{-9})} = 7.5\times10^{14} \text{ Hz}$$

S6 **Answer: C**

Students are expected to memorise the sequence of EM wave spectrum as well as the estimated corresponding wavelength range.



S7 From the 1st graph, $3T = 14.5$ ms $\Rightarrow$ $T = 4.83$ ms

From the 2nd graph, $\frac{3}{2}\lambda = 2.7\text{ m} \quad \Rightarrow \lambda = 1.80$ m

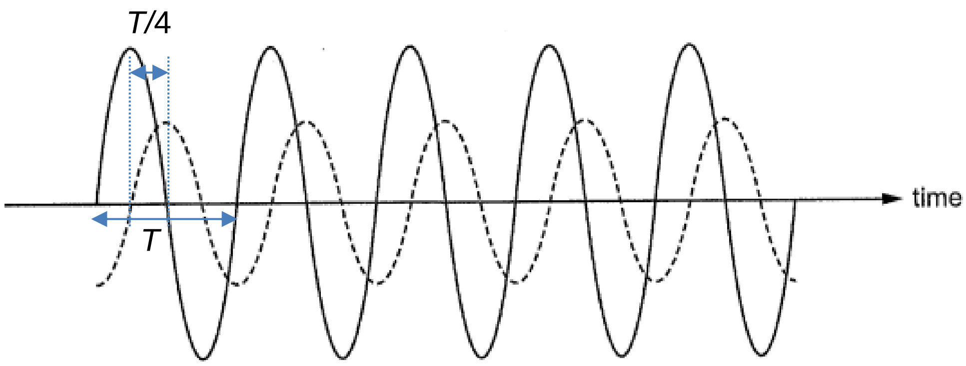
Therefore, $v = f\lambda = \frac{\lambda}{T} = \frac{1.80}{4.83\times10^{-3}} = 372\ \text{m s}^{-1}$

S8 **Answer: B**

Using $\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda} \Rightarrow \Delta\phi = 2\pi \times \frac{(0.20\text{ m})}{(\frac{320\text{ m s}^{-1}}{400\text{ Hz}})} = \frac{\pi}{2}\text{ rad}$.

S9 **Answer: C**

It is given that both waves have the same frequency, hence the same period.



$$\frac{\Delta\phi}{2\pi} = \frac{\Delta t}{T}$$

$$\Delta\phi = \frac{T/4}{T} \times 2\pi = \frac{\pi}{2}\text{ rad}$$

One is a sine wave and the other one is a cosine wave lagging behind by a quarter of period. Hence, the phase difference between the waves must be 90° or $\pi/2$ rad.

Students chose B or D must have erroneously focused on the intersection points between the waves.

S10 **(a)** Intensity $\propto \dfrac{1}{r^2}$ where r is the distance from the source

$$\frac{I_2}{I_1} = \left(\frac{r_1}{r_2}\right)^2 \quad \Rightarrow \quad I_2 = \left(\frac{4.3\ \text{m}}{3.1\ \text{m}}\right)^2 \times 0.026\ \text{W m}^{-2} = 0.0500\ \text{W m}^{-2}$$

(b) Energy $= \langle P \rangle \times$ time

$=$ Intensity $\times$ Area $\times$ time

$= (0.026\ \text{W m}^{-2}) \times (4\pi) \times (4.3\ \text{m})^2 \times (60 \times 60)\text{s}$

$= 2.17 \times 10^4$ J

S11 **Answer: A**

Intensity $\propto A^2 f^2$ where A is the amplitude and f is the frequency.

$$\frac{I_2}{I_1} = \left(\frac{A_2}{A_1}\right)^2 \left(\frac{f_2}{f_1}\right)^2 = \left(\frac{0.5\ \text{cm}}{1.5\ \text{cm}}\right)^2 \left(\frac{6.0\ \text{Hz}}{3.0\ \text{Hz}}\right)^2$$

$$I_2 = \frac{4}{9} I$$

S12 **Answer: E**

After passing through P2, the wave has a polarisation angle of 30°.

The polarising axis of P_3 must be perpendicular to the polarising axis of P_2 for minimum intensity of light to emerge.

Hence, $\theta = 30^o + 90^o = 120^o$ and $30^o + 90^o + 180^o = 300^o$

S13 After passing through the first polariser, unpolarised light is polarised and light intensity is halved.

Apply Malus' Law:

$$I = \frac{I_0}{2}\cos^2\left(30^0\right) = \frac{I_0}{2}\left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3I_0}{8} = 0.375\ I_0$$

Learning Outcomes	Self-Review Question
(a) show an understanding of and use the terms displacement, amplitude, period, frequency, phase difference, wavelength and speed.	S2, S8, S9
(b) deduce, from the definitions of speed, frequency and wavelength, the equation $v = f\lambda$.	S3
(c) recall and use the equation $v = f\lambda$.	S1, S5, S7
(d) show an understanding that energy is transferred due to a progressive wave.	
(e) recall and use the relationship, intensity $\propto$ (amplitude)^2.	S11
(f) show an understanding of and apply the concept that a wave from a point source and travelling without loss of energy obeys an inverse square law to solve problems.	S10
(g) analyse and interpret graphical representations of transverse and longitudinal waves.	S3, S4, S7
(h) show an understanding that polarisation is a phenomenon associated with transverse waves.	
(i) recall and use Malus' law (intensity $\propto$ $\cos^2\theta$) to calculate the amplitude and intensity of a plane polarised electromagnetic wave after transmission through a polarising filter.	S12, S13
(j) *determine the frequency of sound using a calibrated oscilloscope.	
(k) *determine the wavelength of sound using stationary waves.	