4.2 Travelling Waves

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Course	DP IB Physics
Section	4. Waves
Topic	4.2 Travelling Waves
Difficulty	Medium

To be used by all students preparing for DP IB Physics SL
Students of other boards may also find this useful

1

The correct answer is **B** because:

- Two points which are $\frac{\pi}{2}$ apart (90°) are $\frac{1}{4}\lambda$ out of phase
- Therefore, 1 λ is:
  - $\lambda = 4 \times 1$ cm = 0.04 m
- The wave speed, v is defined as:
  - $v = f\lambda$
- Substituting in the values gives:
  - $v = 200 \times 0.04 = 8$ m s^{-1}

A is incorrect as	λ is incorrectly calculated as 0.02 m
B is incorrect as	λ was calculated using 1 cm not 4 cm and λ in cm were not converted into m
C is incorrect as	λ in cm were not converted into m

Remember to convert to SI units as soon as possible in all calculations.

2

The correct answer is **B** because:

- In Hz, frequency, $f = 97 - 99 \times 10^6$ Hz
- We can approximate $f = 97 - 99 \times 10^6$ Hz to $f = 100 \times 10^6$ Hz
- Since radio waves are an electromagnetic wave, $v = 3.00 \times 10^8$ m s^{-1}
- The wave speed, v is defined as:
  - $v = f\lambda$
- Rearranging for wavelength, λ gives:
  - $\lambda = \frac{v}{f}$
- Substituting in the values gives:
  - $\lambda = \frac{3.00 \times 10^8}{100 \times 10^6} = 3.00$ m

Remember that all electromagnetic waves travel at the speed of light (which value is given on the data booklet). Therefore, make sure you recognise the names of all types of electromagnetic radiations!

3

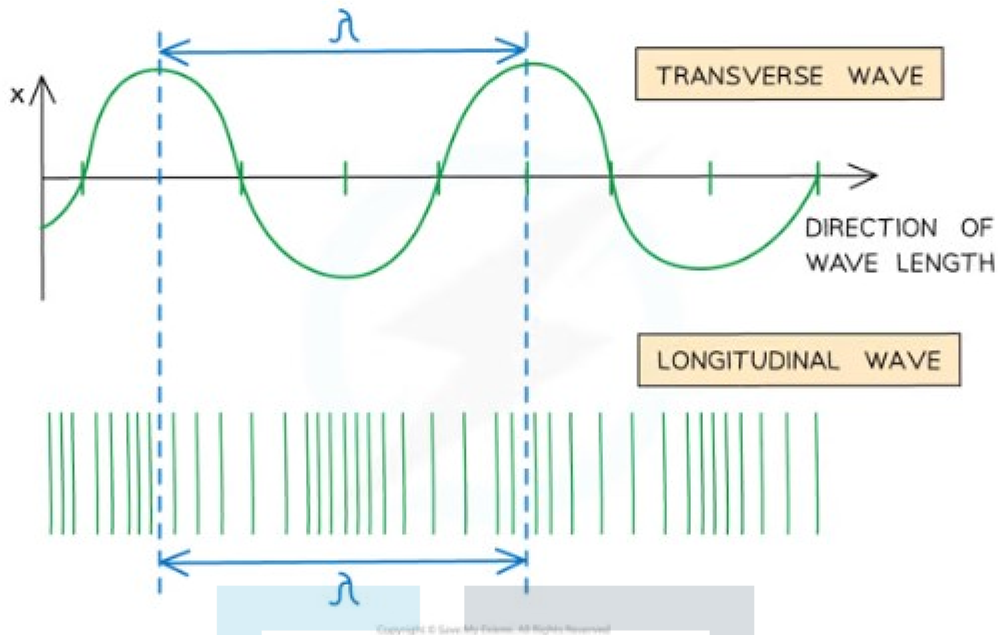
The correct answer is **D** because:

- In a longitudinal wave is made up of compressions and rarefactions
  - Compressions are areas of high density
  - Rarefactions are areas of low density
- 1 wavelength is the distance between two compressions (or distance two between rarefactions)
  - Therefore, successive compressions and rarefactions are always **half** of a wavelength apart

A & **B** are incorrect as	the question only mentions distance, so speed should be not be included in the answer
B is incorrect as	1 λ would be the distance between a compression and another compression (or rarefaction to another rarefaction)

Any other information in the question is a red herring. You only need to think about the wavelength.

1 wavelength is the distance between one compression to another (or one rarefaction to another) in a longitudinal wave.



4

The correct answer is **C** because:

- The number of wavelengths separating the points is P
  - $\frac{1.7}{0.4}$ = 4.25 wavelengths
- Therefore, these points are 0.25 λ out of phase
- Converting this to a phase difference gives:
  - 25 × 360° = 90°

5

The correct answer is **C** because:

- The waves are travelling through the vacuum of space
  - This eliminates longitudinal waves, since they need a medium to travel in
- Therefore, option III is correct, and option IV is incorrect
- The waves from the Sun are in the electromagnetic spectrum, so they all have the same speed, the speed of light
  - option II is correct
- If the waves have different wavelengths, they will also have different frequencies since they have the same speed
- There is not enough information to know if this is the case or not
  - option I is incorrect
- Therefore, only options II and III are correct

A vacuum is a space devoid of any matter. Since longitudinal waves are waves that propagate energy through vibrations of matter particles, they do not travel through space.

The reason that electromagnetic waves have difference frequencies because of different wavelengths is only because they all have the same speed (speed of light). This is seen from the equation $v = f\lambda$. If v is to stay constant, if f increases, then λ must decrease and vice versa.

6

The correct answer is **C** because:

- The correct order for the electromagnetic spectrum, starting from the short-wavelength / high-frequency end is:
  - gamma – x-ray – ultraviolet – visible light (from blue to red) – infrared – microwaves – radio waves

A is incorrect as	x-rays have a shorter wavelength than the others in this row
B is incorrect as	green light has a shorter wavelength than red and orange
D is incorrect as	microwaves have a longer wavelength than the others in this row

Mnemonics are the best way to remember long lists like this one. A favourite for the EM spectrum is **G**ranny **X**'s **U**mbrella **V**anishes **I**n **M**isty **R**ain

7

The correct answer is **C** because:

- You should recall that:
  - the range of wavelengths of visible light are 400 - 700 nm
  - the speed of light, $c = 3 \times 10^8$ ms^{-1} (from data booklet)
- The wave speed, v is defined as:
  - $v = f\lambda$
- Rearranging for wavelength, λ gives:
  - $\lambda = \frac{v}{f}$
- You can either calculate for the top and bottom ranges of wavelength, or take an average
- Since the possible answers are close, it would be better in this case to find the actual range
  - If $\lambda = 400$ nm, $f = \frac{3 \times 10^8}{400 \times 10^{-9}} = \frac{300 \times 10^6}{400 \times 10^{-9}} = 7.5 \times 10^{14}$ Hz
  - If $\lambda = 700$ nm, $f = \frac{3 \times 10^8}{700 \times 10^{-9}} = \frac{300 \times 10^6}{700 \times 10^{-9}} = 4.3 \times 10^{14}$ Hz
- Only option **C** falls in this range

This question expects you to fill in the values for the wavelength of visible light. You should learn typical wavelengths of the EM spectrum, as you will be expected to know this.

Mental Maths tip: when working with standard form, it often makes the calculation easier to make the numbers in the calculation to a similar magnitude as done in the model answer.

$\frac{300 \times 10^6}{400 \times 10^{-9}}$ can roughly be done by $\frac{3}{4}$ = 0.75 whilst $\frac{300 \times 10^6}{700 \times 10^{-9}}$ can roughly be calculated as $\frac{3}{7}$ = just less than $\frac{1}{2}$ (which would be $\frac{3}{6}$) around 0.40. All the options are to 10^{14} so you don't need to worry too much about the power of 10 in your calculations.

8

The correct answer is **C** because;

- The speed of sound waves depends on how close the molecules are in a medium
- Therefore, in air, they have a constant speed
  - This means option I is correct
- Light is an electromagnetic wave, and travels at the maximum speed possible (at the speed of light), which is much faster than sound
  - Therefore, option II is the wrong way around and is incorrect, we see lighting before we hear thunder
- The wave equation is used for all waves:
  - Therefore, option III is correct
- Similar to option 1, the denser the medium, the faster sound travels in it
  - It has been suggested than animals can give earthquake alerts because they feel the vibrations in the ground
  - This means option IV is correct
- Overall, I, II and IV are correct

9

The correct answer is **C** because:

- Ultrasound waves are longitudinal
- Polarisation involves restricting vibrations one plane
- This can only be done if the vibrations of the wave are perpendicular to the direction of the energy transfer
    - This only happens in transverse waves
- In longitudinal waves, the vibrations are parallel to the direction of the energy transfer
    - Therefore, these cannot be polarised as they always vibrate in one plane

10

The correct answer is **B** because:

- The range of wavelength of visible light is:
    - 400 – 700 nm = 400 – 700 × 10^{-9} m
- Therefore, in the middle this is roughly 500 nm (5 × 10^{-7} m)
- To estimate the range of wavelengths of audible sound we use the wave equation
    - Wave speed, $v = f\lambda$ where f is the frequency and λ is the wavelength
- The audible range of frequencies and the speed of sound in air are:
    - f = 20 – 20 000 Hz
    - Let's use the approximate average and say that f = 10 000 Hz
- The speed of sound if roughly 330 m s^{-1}
    - Let's approximate and say that v = 300 m s^{-1}
- Substituting this into the wavelength equation gives:
    - $\lambda = \frac{v}{f} = \frac{300}{10\,000} = 0.03 = 3 \times 10^{-2}$ m
- Therefore, the ratio of the wavelengths are:
    - $\frac{10^{-2}}{10^{-7}} = 10^5$

The important part for this question is the power of tens, rather than the actual values.