4.1 Oscillations

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Course	DP IB Physics
Section	4. Waves
Topic	4.1 Oscillations
Difficulty	Medium

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

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The correct answer is **D** because:

- The total energy, E_T is equal to the sum of the kinetic and potential energy of the oscillating system
  - This means that when the potential energy = 0 then the kinetic energy is at a maximum
- This means $E_T = \frac{1}{2}mv^2$
- From circular motion it is stated that $v = \omega r$
  - In this case, the radius, r is the displacement x
  - Since this is the **maximum** kinetic energy, $x = x_0$ (the amplitude)
- Therefore, the total energy can be written as:
  - $E_T = \frac{1}{2}m\omega^2 x_o^2$ where m = mass, ω^2 = the *square* of the angular frequency, and x_0^2 is the square of the amplitude
- Since mass, m is constant, this means $E_T \propto \omega^2$ and $E_T \propto x_0^2$

2

The correct answer is **A** because:

- The defining equation of SHM states that acceleration $a = -\omega^2 x$
- The negative sign shows that the vectors on each side of the equation, acceleration a, and displacement x, are pointing in opposite directions

3

The correct answer is **B** because:

- A phase difference of $\frac{\pi}{4}$ is the same as 45° of $\frac{1}{16}$ of a cycle out of phase
  - This is shown by graph **B**

A is incorrect as	this is a phase difference of $\frac{\pi}{2}$ or 90° or $\frac{1}{4}$ cycle out of phase
C is incorrect as	this is a phase difference of π or 180° or $\frac{1}{2}$ cycle out of a phase
D is incorrect as	this is a phase difference of 0 (or 2π)

Try not to get mixed up with $\frac{\pi}{4}$ (45°) and $\frac{1}{4}$ cycle out of a phase (90°). 1 full cycle is 360°, or 2π.

4

The correct answer is **C** because:

- In SHM, the restoring force is always towards the equilibrium position
    - Therefore, acceleration is always towards the equilibrium position
- Since the equilibrium position is at Y, the direction is towards Z (as it will pass through Y then continue to Z)
- The particle will be at maximum velocity (and therefore, kinetic energy) at point Y
    - So, a particle moving from maximum displacement to equilibrium must be accelerating
- It then **decelerates** again from Y to Z, but at this point the restoring force would be pointing towards Y

A is incorrect as	maximum kinetic energy occurs at equilibrium, and maximum potential energy at maximum displacement, so both options are wrong

B is incorrect as	total energy is equal to the maximum kinetic energy, at point Y, the equilibrium, instead of point X
D is incorrect as	the restoring force is always towards equilibrium, point Y in this diagram. We do not have enough information to say whether the particle is accelerating or decelerating

5

The correct answer is **C** because:

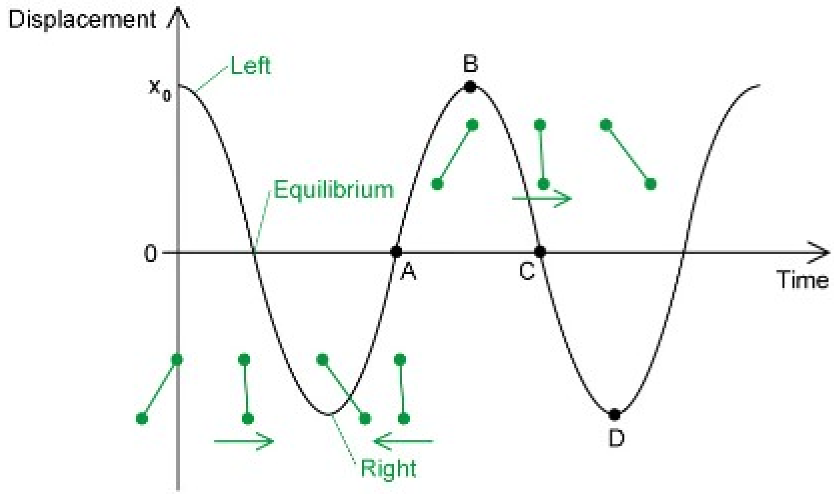
- The angular frequency $\omega = \frac{2\pi}{T}$ where T is the time period
- Therefore, ω is **inversely** proportional to T:
  - $\omega \propto \frac{1}{T}$
- Therefore, if T is multiplied by 3, then ω must be **divided** by 3

Remember to look at the circular motion equations in the data booklet to help with simple harmonic motion too. The equations are relevant because both circular motion and simple harmonic motion are **periodic**.

6

The correct answer is **C** because:

- When time = 0, the bob starts at the left as stated in the question
- The bob then passes through equilibrium, reaches maximum displacement on the right and then returns to equilibrium at point **A**
- At point **B**, the bob has returned to the maximum displacement on the left and its velocity is 0
- At point **C**, the bob is in equilibrium but heading towards the right
  - This is also the direction of its velocity
  - Therefore, **C** is correct
- At point **D,** the bob is at maximum displacement on the right and its velocity is 0



7

The correct answer is **D** because:

- The total energy, E_T is equal to the sum of the kinetic and potential energy of the oscillating system
  - This means that when the potential energy = 0, then the kinetic energy is at a **maximum**
- This means total energy is $E_T = \frac{1}{2}mv^2$
- Therefore:
  - Energy during first oscillation, $E_1 = \frac{1}{2}mv^2$
  - Energy during second oscillation, $E_2 = \frac{1}{2}m(2v)^2$
- Comparing E_2 to E_1:
  - $E_2 = 4 \times \left(\frac{1}{2}mv^2\right)$
  - Therefore, $E_2 = 4E_1$
- The period of the oscillation is **independent** of the energy
  - Hence, period T does not change
- Hence, option **D** is correct

Remember to always check the relation between two variables with equations where you can. Especially look out for when variables are **squared**.

Remember that all oscillations in SHM are **isochronous**, meaning that the period and the amplitude are independent of one another, so changing either one won't affect the other. In fact, it is the initial displacement, or amplitude, that affects the total energy in the oscillating system and the energy determines the speed of the oscillation

8

The correct answer is **B** because:

- For an object in SHM, when its displacement, x is 0 (at equilibrium), the object travels at its faster speed v
- When its displacement is at a maximum (at its amplitude), the object has a speed $v = 0$
  - The only graph that matches this pattern is graph **B**

A is incorrect as	in this graph, when x is 0 then v is also 0. This is the opposite way around
C & **D** are incorrect as	the question mentions that v is the speed, which is a scalar quantity and cannot be negative

9

The correct answer is **A** because:

- The defining equation of SHM states that $a = -\omega^2 x$
  - The negative sign shows that the vectors on each side of the equation are pointing in opposite directions
- Angular frequency is constant for a given set of oscillations
- We are looking for a graph which shows **direct** proportionality, which means a straight line through the origin, and has negative gradient

B & **D** are incorrect as	they are not directly proportional (not straight lines through the origin)

C is incorrect as	the line has a positive gradient instead of negative

10

The correct answer is **C** because:

- The time period, *T* is given by the equation:
  - $T = \frac{1}{f}$ where *f* is the frequency
- *T* is the time for 1 complete oscillation
- From the graph, this is around 7.5 s
- Therefore, the frequency is:
  - $f = \frac{1}{7.5}$ Hz

A is incorrect as	this is only considered half the oscillation, instead of one full oscillation
B is incorrect as	this is the time period, not the frequency
D is incorrect as	this is the time period of only half of an oscillation, not the frequency