SIMPLE HARMONIC MOTION

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 Simple harmonic motion is defined as the motion of a particle such that

A its displacement x from the equilibrium position is always given by the expression $x = x_o sin\omega t$

B its displacement x from the equilibrium position is related to its velocity by the expression $v = \omega x$

C its acceleration is proportional to, and in the opposite direction to, the displacement from the equilibrium position.

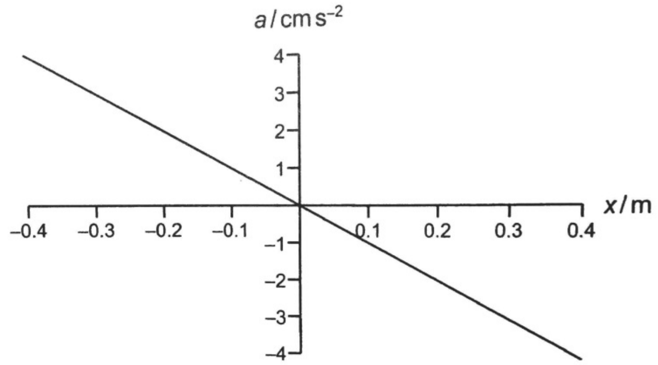
D Its acceleration is always $\omega^2 x_o$ and is directed at right angles to its motion.

2 A particle is in simple harmonic motion.

What is the magnitude of the phase difference between the velocity and displacement of particle?

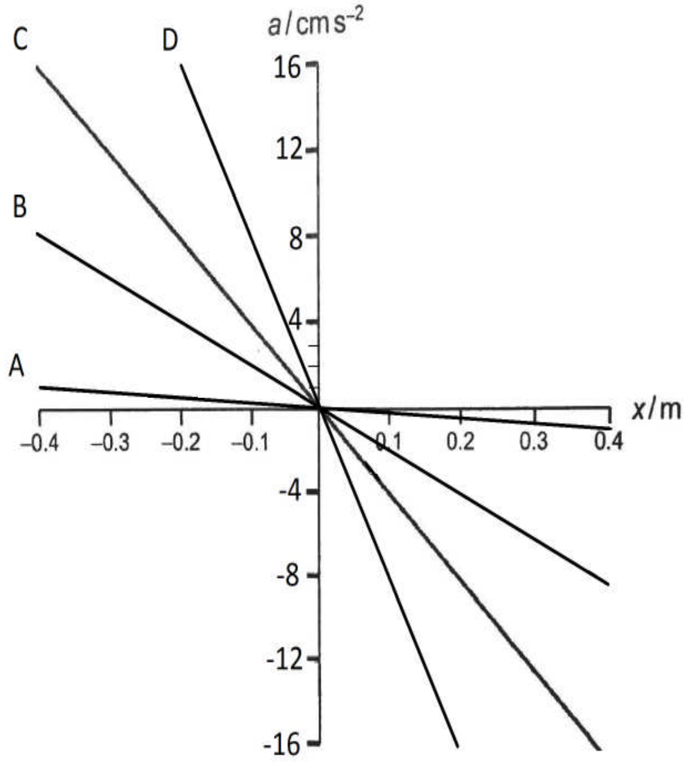
A $\frac{\pi}{4} rad$ **B** $\frac{\pi}{2} rad$ **C** $\pi\ rad$ **D** $\frac{3\pi}{2} rad$

3 The graph shows the variation of acceleration *a* with displacement *x* for an object undergoing simple harmonic motion.

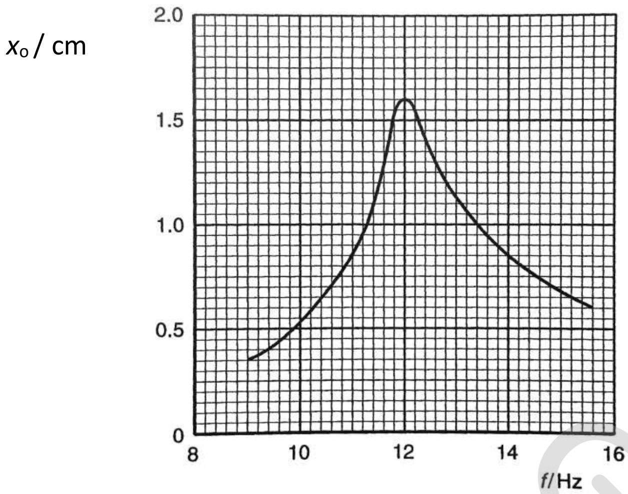


The simple harmonic motion system is altered so that it has a period half of that before.

Which line shows the new variation of acceleration *a* with displacement *x* for the object?



4 The variation with frequency f of the amplitude x_o of the forced oscillations of a machine is as shown.



Which of the following statement is false?

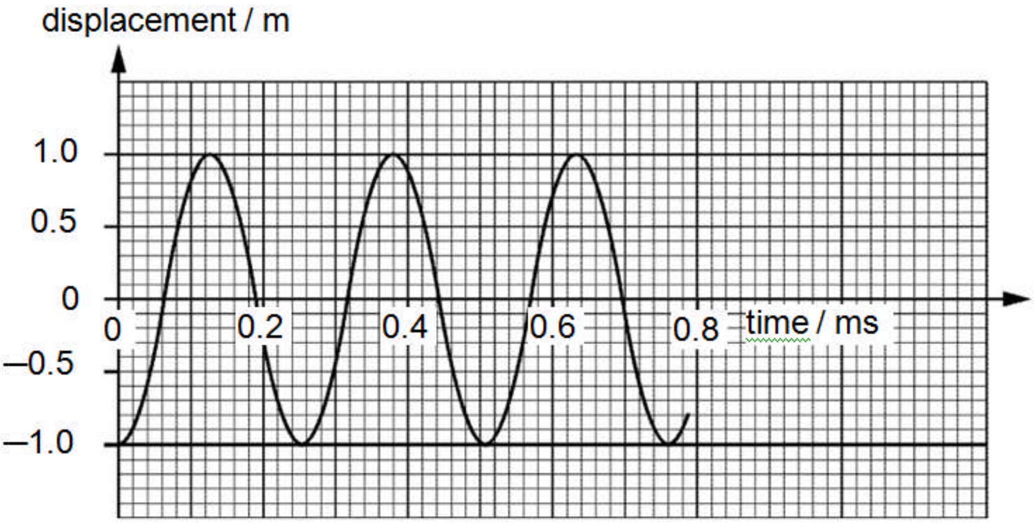
A Resonance frequency of the above system is 12 Hz

B For no damping, the maximum amplitude is 1.6 cm.

C Increased damping reduces the sharpness of the resonance peak

D Damping decreases the maximum amplitude of the oscillations

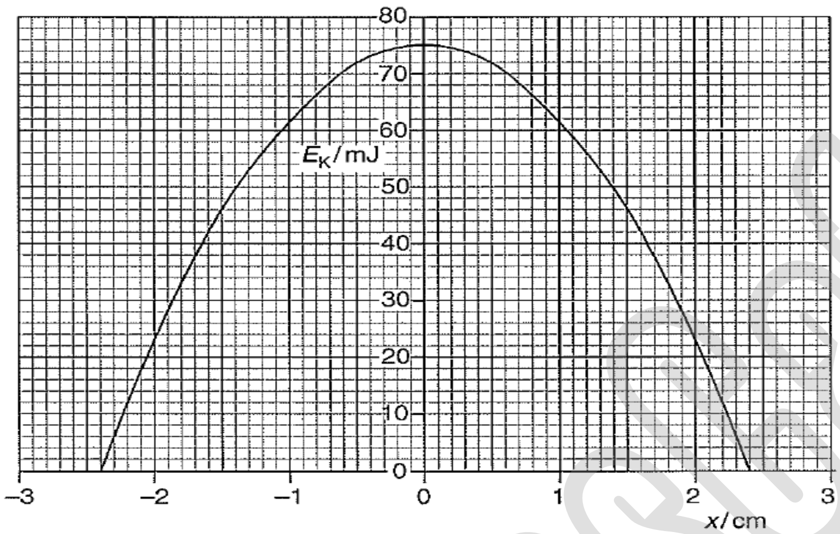
5 A body moves with simple harmonic motion about a point *P*. The graph shows the variation with time of its displacement from *P*.



What is its angular frequency?

A 1.6×10^{-3} rad s^{-1} **B** 4.0×10^{-3} rad s^{-1} **C** 4.0×10^{3} rad s^{-1} **D** 2.5×10^{4} rad s^{-1}

6 Two horizontal springs are attached to a trolley. The trolley is then displaced along the axis of the springs and then released. The trolley undergoes simple harmonic motion. The variation of the kinetic energy E_K of the trolley with horizontal displacement x from its equilibrium position is shown in the figure below.



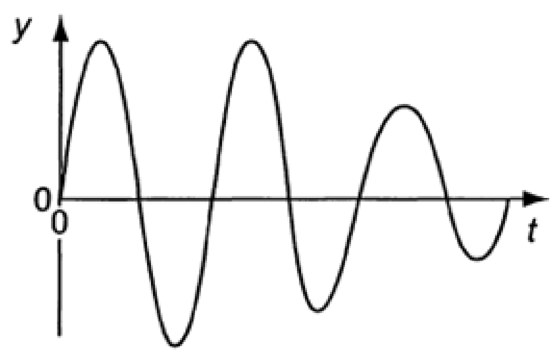
The trolley loses energy so that its maximum kinetic energy is reduced by 50 mJ. What is the amplitude of the oscillations?

A 2.4 cm **B** 1.9 cm **C** 1.4 cm **D** 0.95 cm

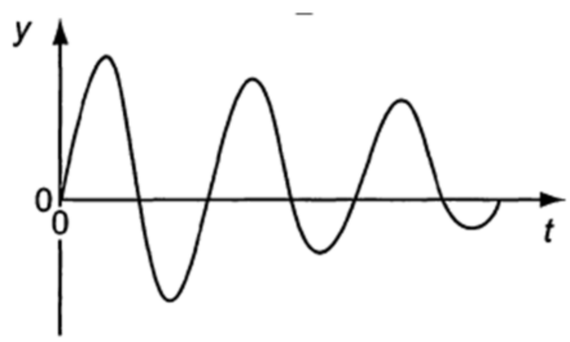
7 A mass-spring system is placed in water and allowed to oscillate with decreasing amplitude until it comes to a complete stop.

Which diagram shows the variation of the displacement *y* with time *t* of the system?

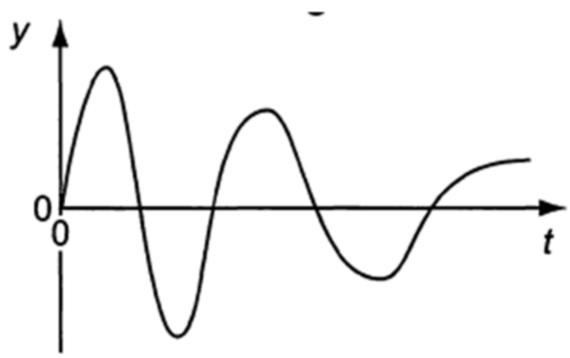
A



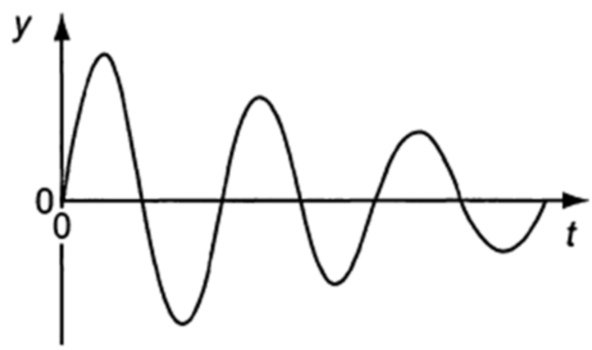
B



C



D



8 A block P, of mass *m,* attached to a spring with spring constant *k,* oscillates in simple harmonic motion on a frictionless horizontal surface. A block Q, of the same mass as P, is attached to a similar spring and oscillates vertically in simple harmonic motion. The angular frequency ω of the oscillation is determined by $\omega = \sqrt{\frac{k}{m}}$.

Given that both blocks oscillate with the same amplitude, which of the following statements is true?

A The maximum kinetic energy of P is smaller than the maximum kinetic energy of Q.

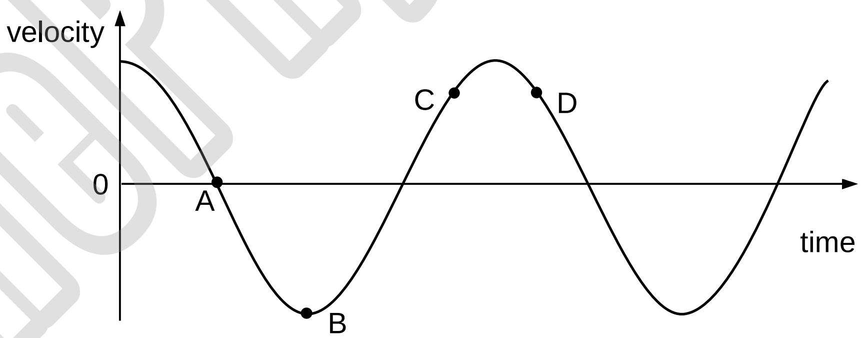
B The maximum kinetic energy of P is larger than the maximum kinetic energy of Q.

C The maximum elastic potential energy of P is smaller than the maximum elastic potential energy of Q.

D The maximum elastic potential energy of P is larger than the maximum elastic potential energy of Q.

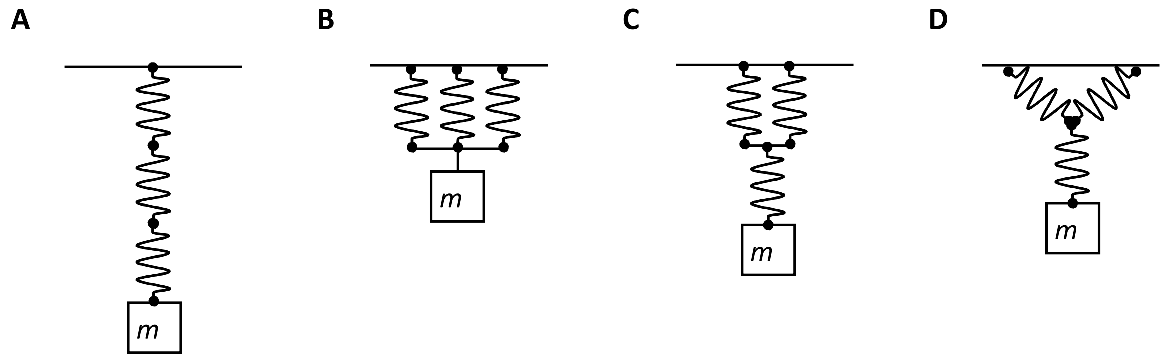
9 The diagram shows the graph of velocity against time for a body performing simple harmonic motion.

At which point are the velocity and acceleration in opposite directions?

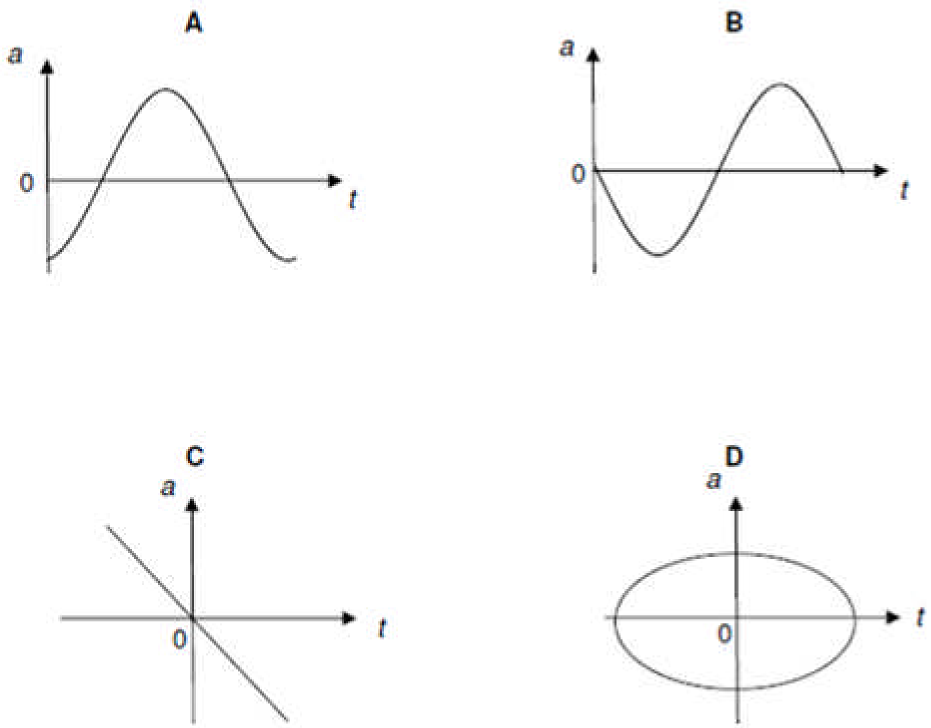


10 The diagram below shows 3 identical springs arranged in different manners.

Which arrangement will result in vertical oscillations of the highest frequency?



11 A pendulum moving with simple harmonic motion has maximum potential at time t = 0 s. Which of the following graphs best describes the variation of the acceleration a of the pendulum with time t?



12 When an object is displaced from its equilibrium position, the oscillating system undergoes critical damping.

Which of the following is true about a critically damped system?

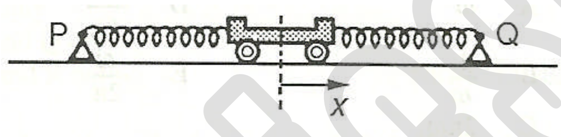
A The object oscillates with its amplitude varying linearly with time.

B The object does not return to its equilibrium position for a very long time.

C The object returns to its equilibrium position in the shortest possible time.

D The object oscillates with its amplitude decreasing exponentially with time.

13 A trolley of mass 2.0 kg with free-running wheels is attached to two fixed points P and Q by two springs under tension as shown.

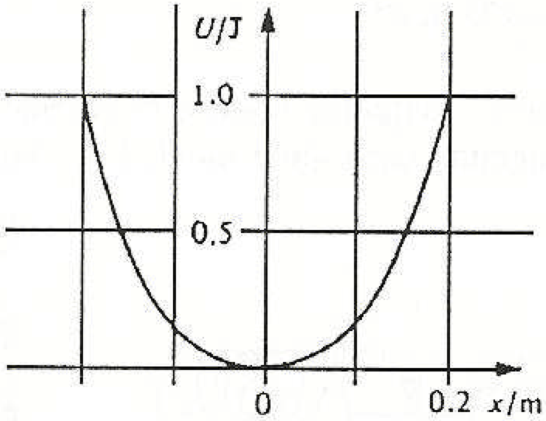


The trolley is displaced a small distance of 5.0 cm towards Q by a resultant force of 10 N and is then released. The equation of the subsequent motion is $a = -\omega^2 x$, where x is the displacement from the equilibrium position.

What is the constant ω^2?

A - 10 rad^2 s^{-2} **B** - 100 rad^2 s^{-2} **C** 10 rad^2 s^{-2} **D** 100 rad^2 s^{-2}

14 A particle of mass 4.0 kg moves with a simple harmonic motion and its potential energy *U* varies with position *x* as shown.



What is the period of oscillation of the mass?

A $\dfrac{\pi\sqrt{2}}{5}$ s **B** $\dfrac{8\pi}{25}$ s **C** $\dfrac{4\pi}{5}$ s **D** $\dfrac{2\pi\sqrt{2}}{5}$ s

15 A housewife notices that her washing machine vibrates most vigorously whenever the r.p.m. (revolutions per minute) of the spinning drum reaches a certain value. She sends it for repair and the repairman merely attached a heavy mass to the drum of the washing machine.

Which of the following outcomes is most likely to happen to the washing machine?

A It does not vibrate vigorously anymore at all r.p.m. values.

B It vibrates most vigorously at the same r.p.m. value.

C It vibrates most vigorously at a higher r.p.m. value.

D It vibrates most vigorously at a lower r.p.m. value.

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WORKED SOLUTIONS

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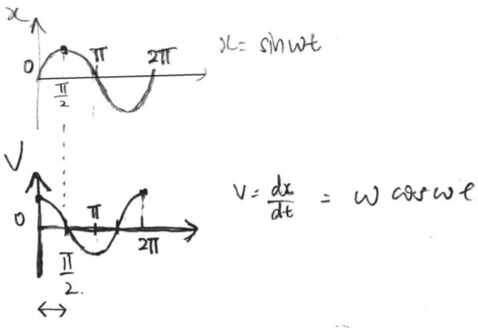
1 Ans: **C**

Definition of SHM

2 Ans: **C**

Use $a_{max} = \omega^2 x_o$

3 Ans: **B**



4 Ans: **B**

For no damping, the maximum amplitude is infinity.

5 Ans: **D**

angular frequency, $\omega = 2\pi f = 2\pi\left(\dfrac{3}{0.76\times10^{-3}}\right) = 24800$ rads^{-1}

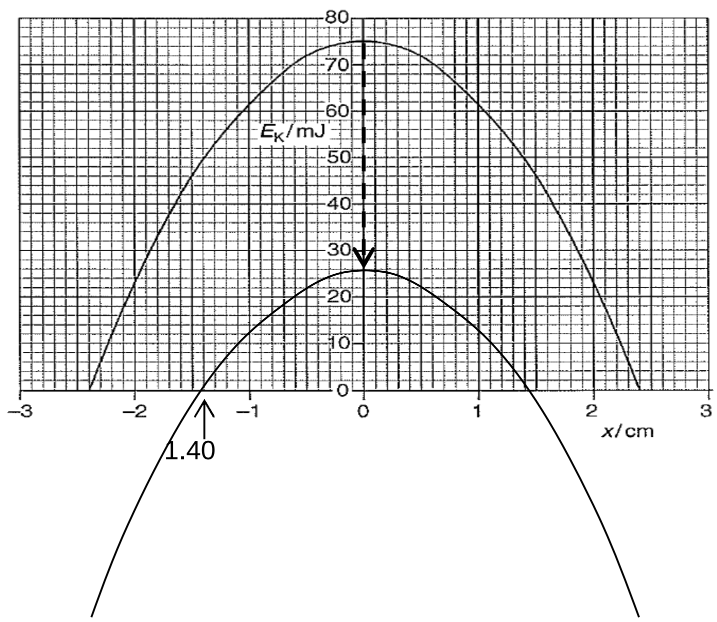
6 Ans: **C**

First method

Shift the graph down by 50 mJ.

Read off the x-intercept value.

$x_0 = 1.40$ cm



Second method

$$KE_{max} = \frac{1}{2} m\omega^2 {x_0}^2$$

$$KE_{max} \propto {x_0}^2$$

$$\frac{75}{75-50} = \left(\frac{2.4}{x_0}\right)^2$$

$$x_0 = 1.39 \text{ cm}$$

7 Ans: **D**

With light damping, there should be a progressive decrease in the amplitude of oscillation.

Option A is wrong because the first two peaks are of the same height.
Option B is wrong because the amplitude is not continuously decreasing.
Option C is wrong because the graph is not sinusoidal.
Option D is true as the amplitude decreases progressively.

8 Ans: **C**

Option A and B are wrong because based on the equation, $KE_{max} = ½m\omega^2 x_0^2$ the maximum *KE* for both horizontal and vertical systems are equal since *k* is the same, mass of P and Q are equal and the amplitude is the same.

Option C is true since for block P, the spring is not stretched at equilibrium before it is allowed to oscillate whereas for block Q, the spring is stretched at equilibrium before it oscillates with the same amplitude as block P. Hence EPE_{max} for block P < EPE_{max} for block Q.

Based on the reasoning for option C, option D is wrong.

9 Ans: **D**

10 Ans: **B**

11 Ans: **A**
Object has maximum PE at t = 0 means that object starts at either extreme positions at t = 0.
Since acceleration is proportional to displacement, the acceleration should be either a positive maximum or negative maximum at t = 0.

12 Ans: **C**

13 Ans: **D**

At the amplitude position,

$a_o = -\omega^2 x_o$

$\left|\frac{F_{max}}{m}\right| = \omega^2 x_o$

$\frac{10}{2.0} = \omega^2 (0.05)$

$\omega^2 = 100$

14 Ans: **D**

From graph, PE_{max} at amplitude position = 1.0 J
By conservation of energy, KE_{max} at equilibrium position is also 1.0 J.

$KE_{max} = ½ \, m \, v_o^2 = ½ \, (4.0) \, v_o^2 = 1.0$

$v_o = \frac{1}{\sqrt{2}}$ m s^{-1}

For SHM, $v_o = x_o \, \omega$

$$\frac{1}{\sqrt{2}} = (0.2)\frac{2\pi}{T}$$

$$\frac{1}{\sqrt{2}} = \frac{2\pi}{5T}$$

$$T = \frac{2\pi\sqrt{2}}{5} \text{ s}$$

15 Ans: **D**

By attaching a heavy mass, the natural frequency of the drum will be lowered. Hence resonance will now occur at a lower driving frequency.
Note that attaching a heavy mass does not change the damping.