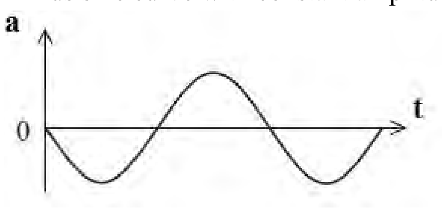
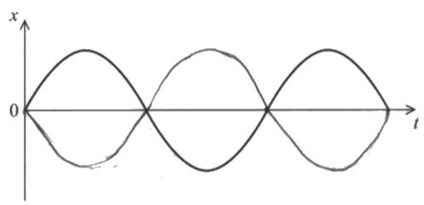
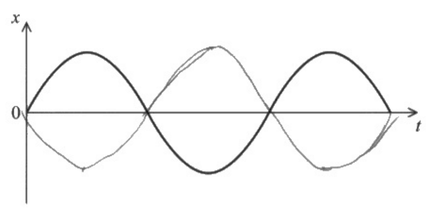
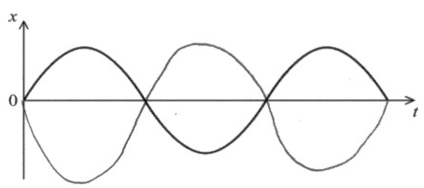
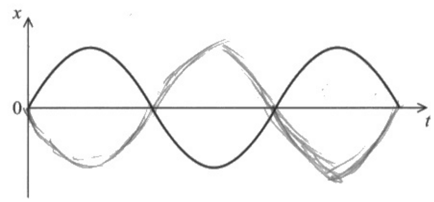
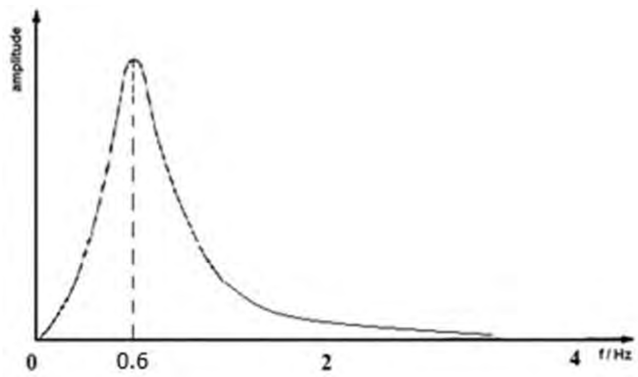
Question Number	Answer	Mark
1(a)	Acceleration is: • (directly) proportional to displacement from equilibrium position **(1)** • (always) acting towards the equilibrium position **Or** idea that acceleration is in the opposite direction (to displacement) **(1)** **Or** Force is: • (directly) proportional to displacement from equilibrium position **(1)** • (always) acting towards the equilibrium position **Or** idea that force is a restoring force e.g. "in the opposite direction" **(1)** [accept towards undisplaced point/fixed point/central point for equilibrium position] [An equation with symbols defined correctly is a valid response for both marks. e.g $a \propto -x$ or $F \propto -x$]	**2**
1(b)	Use of $\omega = \frac{2\pi}{T}$ **(1)** Identifies amplitude of barrier (1.15 m) **(1)** Identifies maximum displacement of barrier from equilibrium position (0.55 m) **(1)** Use of $x = A\cos\omega t$ **(1)** Time available = 3.0 s **(1)** <u>Example of calculation</u> $\omega = \frac{2\pi}{T} = \frac{2\pi}{4.5} = 1.40\,\text{rad}\,\text{s}^{-1}$ $0.55\,\text{m} = 1.15\,\text{m}\cos 1.40\,\text{s}^{-1}t$ $\therefore t = 0.766\ s$ Time available = 4.5 s – (2 ×0.766 s) = 2.97 s	**5**
	Total for Question	**7**

Question Number	Answer	Mark
***2(a)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Current carrying conductor in a magnetic field **(1)** Coil experiences a force **(1)** Current is alternating, so force changes direction with current (same frequency) **(1)** **Or** Current in coil causes a magnetic field **(1)** Current is alternating so field changes direction with current (same frequency) **(1)** Field interacts with permanent magnet's field so coil experiences oscillating force **(1)**	**3**
2(b)(i)	Acceleration is: • proportional to displacement from equilibrium position **(1)** • (always) acting towards the equilibrium position **Or** idea that acceleration is in the opposite direction to displacement **(1)** **Or** Force is: • proportional to displacement from equilibrium position **(1)** • (always) acting towards the equilibrium position **Or** idea that force is a restoring force e.g. "in the opposite direction" **(1)** [accept undisplaced point/fixed point/central point for equilibrium position] [An equation with symbols defined correctly is a valid response for both marks. e.g. $a \propto -x$ **or** $F \propto -x$]	**2**
2(b)(ii)	Minus sine curve with constant amplitude **(1)**  Examples of acceptable graphs:   Examples of unacceptable graphs:  	**1**

2(c)(i)	Identification of weight and force from cone, F_c, as the two forces acting on the sand **(1)** Weight − $F_c = m\omega^2 x$ **(1)** So as x increases, F_c decreases, sand loses contact with cone when $F_c = 0$ **(1)**		**3**
2(c)(ii)	Resultant force equated to weight **Or** acceleration equated to g **(1)** Use of $\omega = 2\pi f$ **(1)** f = 32 Hz **(1)** <u>Example of calculation:</u> $mg = m\omega^2 x_0$ $\omega = \sqrt{\frac{g}{x_0}} = \sqrt{\frac{9.81\,\mathrm{m\,s^{-2}}}{0.25\times10^{-3}\,\mathrm{m}}} = 198\,\mathrm{rad\,s^{-1}}$ $f = \frac{\omega}{2\pi} = \frac{198}{2\pi} = 31.5\,\mathrm{Hz}$		**3**
	Total for Question		**12**

Question Number	Answer		Mark
3(a)(i)	Use of Newton's 2nd law (F = ma) with F = –kx Acceleration/force is in opposite direction to the displacement from the equilibrium position **Or** acceleration/force is (always) towards the equilibrium/undisplaced/rest position <u>Example of calculation:</u> m a = **-** k x $a = -\frac{k}{m}x$	**(1)** **(1)**	**2**
3(a)(ii)	See a = -$\omega^2 x$ Compare with $a = -\frac{k}{m}x$ to give $\omega^2 = \frac{k}{m}$ Substitute for ω using $\omega = \frac{2\pi}{T}$ <u>Example of calculation:</u> $a = -\omega^2 x$ and $a = -\frac{k}{m}x$ $\omega^2 = \frac{k}{m}$ and $\omega = \frac{2\pi}{T}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{k}{m} \quad \therefore T = 2\pi\sqrt{\frac{m}{k}}$	**(1)** **(1)** **(1)**	**3**
3(b)(i)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ Use of $f = \frac{1}{T}$ f = 0.59 Hz <u>Example of calculation:</u> $T = 2\pi\sqrt{\frac{3.5\times10^5\ \text{kg}}{4.8\times16^6\ \text{N m}^{-1}}} = 1.7\,\text{s}$ $f = \frac{1}{T} = \frac{1}{1.7\,\text{s}} = 0.588\,\text{Hz}$	**(1)** **(1)** **(1)**	**3**

3(b)(ii)	Correct shape **(1)** Single sharp peak **(1)** With the peak labelled at 0.6 Hz **(1)** 		**3**
3(b)(iii)	(Max) amplitude of oscillation is reduced **(1)** as energy is transferred from the mass-spring system **(1)** and then dissipated (in the surroundings) **(1)**		**3**
	Total for question		**14**

Question Number	Answer	Mark
4(a)	Force (or acceleration): • (directly) proportional to displacement **(1)** • always acting towards the equilibrium position **(1)**	**2**
4(b)	Use of $\omega = 2\pi f$ OR $\omega = 2\pi/T$ **(1)** Use of $v = A\omega\sin\omega t$ OR $v = A\omega$ **(1)** $v = 0.35 \text{ m s}^{-1}$ **(1)** [If 5 cm or 10 cm is substituted instead of 2.5 cm then still award second mark] <u>Example of calculation</u> $\omega = 2\pi \text{ rad} \times \left(\frac{10}{4.5 \text{ s}}\right) = 14.0 \text{ rad s}^{-1}$ $v = 2.5 \times 10^{-2} \text{ m} \times 14.0 \text{ s}^{-1} = 0.35 \text{ m s}^{-1}$	**3**
4(c)	Any **THREE** from • Node at fixed end or antinode at free end **(1)** • Distance from node to antinode = λ/4 **(1)** • As (vibrating) length increases, wavelength increases **(1)** • Reference to v = f λ **(1)** • The shorter the ruler the higher the frequency **(1)**	**Max 3**
	Total for question	**8**

Question Number	Answer	Mark
5(a)	(Net force) $(\Delta)F=-k(\Delta)x$ (1) Used with $F=ma$ (1)	**(2)**
5(b)	Use of $F=(-)kx$ (1) Correct answer for k OR substitution of expression for k into formula below (1) Use of $\omega^2=k/m$ OR $T=2\pi\sqrt{\frac{m}{k}}$ OR $a_{max}=-\omega^2 A$, with $a_{max}=9.81\ \text{N kg}^{-1}$ (1) Use of $\omega=2\pi f$ OR $f=1/T$ (1) Correct answer for f (1) Example of calculation: $k=\frac{0.15\,\text{kg}\times 9.81\,\text{N kg}^{-1}}{0.2\,\text{m}}=7.4\,\text{N m}^{-1}$ $\omega=\sqrt{\frac{7.4\,\text{N m}^{-1}}{0.15\,\text{kg}}}=7.0\left(\text{rad s}^{-1}\right)$ $f=\frac{\omega}{2\pi}=\frac{7\,\text{s}^{-1}}{2\pi}=1.1\,\text{Hz}$	**(5)**
	Total for question	**(7)**