

Mark schemes

1	B		[1]
2	A		[1]
3	A		[1]
4	A		[1]
5	C		[1]
6	C		[1]
7	(a) (i)	free oscillation: there is no force acting other than internal forces or only internal forces are involved or there are no external forces acting or no energy input (following initial displacement) do not allow a free oscillation is not forced to oscillate B1 forced oscillation: oscillator is acted on by a periodic external force (condone acted on by external varying force) or energy is given periodically by an external source or made to oscillate at the frequency of another oscillator B1 (2) (ii) $T = 2\pi\sqrt{l / g}$ or $8 = 2\pi\sqrt{l / 9.8}$ C1 15.9 (16) m A1 (2)	

(iii) $a(\text{max}) = \omega^2 A$ (**not** x , s or r)

C1

$\omega = 2\pi f$ **or** $2\pi / T$ or $\pi / 4$ or 0.785 (0.79) (radian s^{-1})

C1

$3.08 - 3.12 \text{ m s}^{-2}$

A1

(3)

(iv) $F = ma$ or $F = 1.5 \times 10^3 \times (\text{iii})$

C1

4 600 N to 4700 N (but allow e.c.f. for a from (iii))

A1

(2)

- (b) graph showing two cycles of energy change in a time of 8 s;
peak at 12 kJ; shape always positive

M1

approx. $\sin^2$ shape; clearly curved at each zero value

(condone any extension beyond 8 s)

A1

(2)

[11]

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- (a) (i) *free*: system displaced and left to oscillate (1)

- (ii) *forced*: oscillation due to (external) periodic driving force [or oscillation at the frequency of another vibrating system] (1)

2

(b) (i) $k = \frac{3000}{5.0 \times 10^{-2}} = 6.0 \times 10^4 \text{ Nm}^{-1}$ (1)

(ii) $T = 2\pi \sqrt{\frac{m}{k}} = 2\pi \sqrt{\frac{9000}{g \times 6.0 \times 10^4}}$
giving 0.78 s (1)

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(c) (i) $t = \frac{s}{v} = \frac{16}{20} = 0.80 \text{ s}$ (1)

- (ii) time $\cong$ period of free oscillations, resonance (1)
i.e. large amplitude oscillations (1)

3

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- (a) vibrations are forced when periodic force is applied **(1)**
 frequency determined by frequency of driving force **(1)**
 resonance when frequency of applied force = natural frequency **(1)**
 when vibrations of large amplitude produced
 [or maximum energy transferred at resonance] **(1)**
- (b) (i) damping when force opposes motion [or damping removes energy] **(1)**
 (ii) damping reduces sharpness of resonance
 [or reduces amplitude at resonant frequency] **(1)**

(max 3)**(2)****[5]****10**

- (a) forced vibrations or resonance **(1)**
- (b) reference to natural frequency (or frequencies) of structure **(1)**
 driving force is at same frequency as natural frequency of structure **(1)**
 resonance **(1)**
 large amplitude vibrations produced or large energy transfer to structure **(1)**
 could cause damage to structure [or bridge to fail] **(1)**
- (c) stiffen the structure (by reinforcement) **(1)**
 install dampers or shock absorbers **(1)**
 [or other acceptable measure e.g. redesign to change natural frequency
 or increase mass of bridge or restrict number of pedestrians]

1**max 4****2****[7]****11**

- (a) (i) $r = 0.012 \text{ (m)}$ **(1)**
 (use of $v = 2\pi fr$ gives) $v = 2\pi 50 \times 0.012$ **(1)**
 $= 3.8 \text{ m s}^{-1}$ **(1)** (3.77 m s⁻¹)
- (ii) correct use of $a = \frac{v^2}{r}$ or $a = \frac{3.8^2}{0.012}$ **(1)**
 $= 1.2 \times 10^3 \text{ m s}^{-2}$ **(1)**
 [or correct use of $a = \omega^2 r$
 (allow C.E. for value of v from (i))

5

- (b) panel resonates **(1)**
 (because) motor frequency = natural frequency of panel **(1)**

2
QWC 2

[7]

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- (a) *forced vibrations:*
 repeated upwards and downwards movement ✓
 vibrations at frequency of support rod ✓
 amplitude is small at high frequency **or** large at low frequency ✓
 correct reference to phase difference between displacements
 of driving and forced vibrations ✓

Acceptable references to phase differences:

*Forced vibrations – when frequency of driver » frequency of driven, displacements are out of phase by (almost) π radians or 180° (**or** $\frac{1}{2}$ a period) **or** when frequency of driver « frequency of driven, displacements are (almost) in phase. [Accept either].*

[Condone >, < for », «].

resonance:

- frequency of support rod **or** driver is equal to natural frequency
 of (mass-spring) system ✓
 large (or maximum) amplitude vibrations of mass ✓
 maximum energy transfer (rate) (from support rod
 to mass-spring system) ✓
 correct reference to phase difference between displacements
 of driving and driven vibrations at resonance ✓

*Resonance – displacement of driver leads on displacement of driven by $\pi / 2$ radians or 90° **or** $\frac{1}{4}$ of a period (or driven lags on driver by $\pi / 2$ radians or 90° **or** $\frac{1}{4}$ of a period).*

[Condone phase difference is $\pi / 2$ radians or 90°].

max 4

- (b) (i) cone oscillates without ring (ticked)
 Only one box to be ticked.

1

- (ii) damping is caused by air resistance ✓
area is the same whether loaded or not loaded ✓
loaded cone has more kinetic energy **or** potential energy **or**
momentum (at same amplitude) ✓
smaller proportion (or fraction) of (condone less) energy removed
per oscillation from loaded cone (or vice versa) ✓
inertia of loaded cone is greater ✓
Award marks for correct physics even when answer to (b)(i) is incorrect.

max 3

[8]