

**M1.(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)  $\pi$  radians or  $180^\circ$  (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  $90^\circ$  **or**  $\frac{1}{4}$  of a period (or driven lags on driver by  $\pi / 2$  radians or  $90^\circ$  **or**  $\frac{1}{4}$  of a period).*

*[Condone phase difference is  $\pi / 2$  radians or  $90^\circ$ ].*

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]

**M2.A**

**[1]**

**M3. B**

**[1]**

**M4. A**

**[1]**

**M5. C**

**[1]**

**M6. A**

**[1]**

**M7. B**

[1]

**M8.** D

[2]

**M9.** (a) (i)  $r = 0.012$  (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<sup>-1</sup>)

(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)**

QWC 2

[7]

**M10.(a)** forced vibrations or resonance **(1)**

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)**

max 4

- (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]

2

[7]

**M11.C**

[1]

- M12.(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)**

(max 3)

- (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)**

(2)

[5]

