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) π radians or 180° (**or** ½ 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 π / 2 radians or 90° **or** ¼ of a period (or driven lags on driver by π / 2 radians or 90° **or** ¼ of a period).*

[Condone phase difference is π / 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]

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)**

$= 3.8$ 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)**

$= 1.2 \times 10^3$ m s^{-2} **(1)**

[or correct use of $\alpha = \omega^2 r$]

(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]

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]