

M1.D

[1]

M2.D

[1]

M3.B

[1]

M4.D

[1]

M5.D

[1]

M6.C

[1]

M7.(a) (i) elastic potential energy **and** gravitational potential energy ✓

*For elastic pe allow "pe due to tension", or "strain energy"
etc.*

1

- (ii) elastic pe \rightarrow kinetic energy \rightarrow gravitational pe
 \rightarrow kinetic energy \rightarrow elastic pe ✓✓
 [or pe \rightarrow ke \rightarrow pe \rightarrow ke \rightarrow pe is ✓ only]
 [or elastic pe \rightarrow kinetic energy \rightarrow gravitational pe is ✓ only]
If kinetic energy is not mentioned, no marks.
Types of potential energy must be identified for full credit.

2

- (b) (i) period = 0.80 s ✓
 during one oscillation there are two energy transfer cycles
 (or elastic pe \rightarrow ke \rightarrow gravitational pe \rightarrow ke \rightarrow elastic pe in 1 cycle)
 or there are two potential energy maxima per complete oscillation ✓
Mark sequentially.

2

- (ii) sinusoidal curve of period 0.80 s ✓
 – cosine curve starting at $t = 0$ continuing to $t = 1.2\text{s}$ ✓
For 1st mark allow ECF from T value given in (i).

2

(c) (i) use of $T = 2\pi\sqrt{\frac{m}{k}}$ gives $0.80 = 2\pi\sqrt{\frac{0.35}{k}}$ ✓
 $\therefore k \left(= \frac{4\pi^2 \times 0.35}{0.80^2} \right) = 22 \text{ (21.6)} \text{ ✓ } \text{ N m}^{-1} \text{ ✓}$

Unit mark is independent: insist on N m^{-1} .
Allow ECF from wrong T value from (i): use of 0.40s gives 86.4 (N m^{-1}).

3

- (ii) maximum ke = $(\frac{1}{2} m v_{\text{max}}^2) = 2.0 \times 10^{-2}$ gives

$$v_{\text{max}}^2 = \frac{2.0 \times 10^{-2}}{0.5 \times 0.35} \text{ ✓ } (= 0.114 \text{ m}^2\text{s}^{-2}) \text{ and } v_{\text{max}} = 0.338 \text{ (m s}^{-1}\text{)} \text{ ✓}$$

$$v_{\text{max}} = 2\pi f A \text{ gives } A = \frac{0.338}{2\pi \times 1.25} \text{ ✓}$$

and $A = 4.3(0) \times 10^{-2} \text{ m} \text{ ✓}$ i.e. about 40 mm

[or maximum ke = $(\frac{1}{2} m v_{\text{max}}^2) = \frac{1}{2} m (2\pi f A)^2 \text{ ✓}$

$$\frac{1}{2} \times 0.35 \times 4\pi^2 \times 1.25^2 \times A^2 = 2.0 \times 10^{-2} \quad \checkmark$$

$$\therefore A^2 = \frac{2 \times 2.0 \times 10^{-2}}{4\pi^2 \times 0.35 \times 1.25^2} \quad \checkmark \quad (= 1.85 \times 10^{-3})$$

and $A = 4.3(0) \times 10^{-2} \text{ m} \quad \checkmark$ i.e. about 40 mm]

[or maximum ke = maximum pe = $2.0 \times 10^{-2} \text{ (J)}$

maximum pe = $\frac{1}{2} k A^2 \quad \checkmark$

$$\therefore 2.0 \times 10^{-2} = \frac{1}{2} \times 21.6 \times A^2 \quad \checkmark$$

$$\text{from which } A^2 = \frac{2 \times 2.0 \times 10^{-2}}{21.6} \quad \checkmark \quad (= 1.85 \times 10^{-3})$$

and $A = 4.3(0) \times 10^{-2} \text{ m} \quad \checkmark$ i.e. about 40 mm]

First two schemes include recognition that $f = 1 / T$ i.e. $f = 1 / 0.80 = 1.25 \text{ (Hz)}$.

Allow ECF from wrong T value from (i) – 0.40s gives $A = 2.15 \times 10^{-2} \text{ m}$ but mark to max 3.

Allow ECF from wrong k value from (i) – 86.4 Nm^{-1} gives $A = 2.15 \times 10^{-2} \text{ m}$ but mark to max 3.

4
[14]

M8.D

[1]

M9.(a) acceleration is proportional to displacement (from equilibrium) \checkmark

Acceleration proportional to negative displacement is 1st mark only.

acceleration is in opposite direction to displacement

or towards a fixed point / equilibrium

Don't accept "restoring force" for accln.

position \checkmark

2

$$(b) \quad (i) \quad f \left(= \frac{1}{2\pi} \sqrt{\frac{g}{l}} \right) = \frac{1}{2\pi} \sqrt{\frac{9.81}{0.984}} \quad \checkmark \quad = 0.503 \text{ (0.5025) (Hz)} \quad \checkmark$$

3SF is an independent mark.

$$[\text{ or } T \left(= 2\pi \sqrt{\frac{l}{g}} \right) = 2\pi \sqrt{\frac{0.984}{9.81}} \quad \checkmark \quad (= 1.9(90) \text{ (s)})$$

When $g = 9.81$ is used, allow either 0.502 or 0.503 for 2nd and 3rd marks.

$$f \left(= \frac{1}{T} \right) = \frac{1}{1.990} = 0.503 \text{ (0.5025) (Hz)} \quad \checkmark]$$

Use of $g = 9.8$ gives 0.502 Hz: award only 1 of first 2 marks if quoted as 0.502, 0.503 0.50 or 0.5 Hz.

answer to **3SF** ✓

3

$$(ii) \quad a \left(= -(2\pi f)^2 x \right) = (-)(2\pi \times 0.5025)^2 \times 42 \times 10^{-3} \quad \checkmark$$

Allow ECF from **any** incorrect f from (b)(i).

$$= 0.42 \text{ (0.419) (m s}^{-2}\text{)} \quad \checkmark$$

2

(c) recognition of 20 oscillations of (shorter) pendulum

and / or 19 oscillations of (longer) pendulum ✓

Explanation: difference of 1 oscillation or phase change of 2π

or $\Delta t = 0.1$ so $n = 2 / 0.1 = 20$, **or** other acceptable point ✓

time to next in phase condition = 38 (s) ✓

Allow "back in phase (for the first time)" as a valid explanation.

$$[\text{ or } (T = 1.90 \text{ s so}) (n + 1) \times 1.90 = n \times 2.00 \quad \checkmark$$

gives $n = 19$ (oscillations of longer pendulum) ✓

$$\text{minimum time between in phase condition} = 19 \times 2.00 = 38 \text{ (s)} \quad \checkmark]$$

3

[10]

M10.(a) (i) correct period read from graph or use of $f=1/T$ 0.84 ± 0.01

C1

2.4 Hz gets C1

correct frequency 1.2 (1.18 – 1.25 to 3 sf)

A1

(ii) correct shape (inverse)

B1

Crossover PE = KE

B1

(b) (i) Use of $T = 2\pi\sqrt{\frac{l}{g}}$

C1

48.7 (49) m

A1

(ii) $v = 120\,000 / 3600 = 33(.3) \text{ m s}^{-1}$

B1

Use of $F = m v^2/r$ (allow v in km h^{-1})

B1

Total tension = $6337 + (280 \times 9.81) = 9.083 \times 10^3 \text{ N}$
Allow their central force

B1

Divide by 4 $2.27 \times 10^3 \text{ N}$
Allow their central force

B1

(iii) $mgh = \frac{1}{2} mv^2$

B1

Condone: Use of $v = 2\pi fA$ (max2)

$9.8 \times 44 = 0.5 v^2$ Allow 45 in substitution

B1

Condone 22 m s^{-1}

29.4 m s^{-1} (Use of 45 gives 29.7)

B1

106 km h⁻¹ (their m s⁻¹ correctly converted)
Or compares with 33 m s⁻¹

B1

(iv) 1/16th(0.625) % of KE left if correct

M1

Allow 1/8 (0.125) or 1/32(0.313)

KE at start = 5.6×10^4 J or states energy \propto speed² so speed is $\frac{1}{4}$

M1

Allow for correct subⁿ $E = \frac{1}{2} 280 \times 20^2$ x factor from incorrect number of swings calculated correctly

Final speed calculated = 5 m s⁻¹

A1

Must be from correct working

[17]

M11.D

[1]

M12.B

[1]

M13. D

[1]

M14. A

[1]

