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 → kinetic energy → gravitational pe
→ kinetic energy → elastic pe ✓✓
[**or** pe→ke→pe→ke→pe is ✓ only]
[**or** elastic pe → kinetic energy → 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→ke→gravitational pe→ke→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 = 1.2s ✓

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 (21.6) ✓ N m^{-1} ✓

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 = (½ mv_{max}^2) = 2.0 × 10^{-2} gives

$v_{max}^2 = \frac{2.0\times10^{-2}}{0.5\times0.35}$ ✓ (= 0.114 m^2s^{-2}) and v_{max} = 0.338 (m s^{-1}) ✓

$v_{max} = 2\pi fA$ gives $A = \frac{0.338}{2\pi\times1.25}$ ✓

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

[**or** maximum ke = (½ mv_{max}^2) = ½ $m\,(2\pi fA)^2$ ✓

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

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

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

[**or** maximum ke = maximum pe = 2.0×10^{-2} (J)

maximum pe = $\frac{1}{2} k A^2$ ✓

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

from which $A^2 = \dfrac{2 \times 2.0 \times 10^{-2}}{21.6}$ ✓ ($= 1.85 \times 10^{-3}$)

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

First two schemes include recognition that f = 1 / T i.e. f = 1 / 0.80 = 1.25 (Hz).

Allow ECF from wrong T value from (i) – 0.40sgives A = 2.15 × 10^{-2}m but mark to max 3.

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

4

[14]

M8.D

[1]

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

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 ✓

2

(b) (i) $f\left(=\dfrac{1}{2\pi}\sqrt{\dfrac{g}{l}}\right)=\dfrac{1}{2\pi}\sqrt{\dfrac{9.81}{0.984}}$ ✓ = 0.503 (0.5025) (Hz) ✓

3SF is an independent mark.

[**or** $T\left(=2\pi\sqrt{\frac{l}{g}}\right)=2\pi\sqrt{\frac{0.984}{9.81}}$ ✓ (= 1.9(90) (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 (0.5025) (Hz) ✓]

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

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

= 0.42 (0.419) (m s^{-2}) ✓

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 Δt = 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.

[**or** (*T* = 1.90 s so) (*n* + 1) × 1.90 = *n* × 2.00 ✓

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

minimum time between in phase condition = 19 × 2.00 = 38 (s) ✓]

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) m s^{-1}

B1

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

B1

Total tension = 6337 + (280 × 9.81) = 9.083 × 10^3 N
Allow their central force

B1

Divide by 4 2.27 × 10^3 N
Allow their central force

B1

(iii) $mgh = ½\,mv^2$

B1

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

9.8×44 = 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 ∝ speed^2 so speed is ¼

M1

Allow for correct sub^n E =½ 280 × 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]