A-Level Physics

Simple Harmonic Motion

Mark Scheme

Time available: 58 minutes
Marks available: 42 marks

Mark schemes

1. (a) Use of time = angle / angular speed ✓

To get 3.5 s ✓

2

(b) Arrow towards centre of turntable starting at the block. ✓

1

(c) Use of $F = mrw^2$ ✓

To give 0.10 N ✓

2

(d) Block constantly changing direction (at constant speed) ✓

Ref to N1 and therefore force must apply ✓

OR

Changing direction shows (centripetal) acceleration ✓

Reference to N2 and therefore force must apply ✓

2

(e) Use of pendulum equation ✓

To give 1.55 m ✓

2

(f) Amplitude – the pendulum shadow amplitude becomes less than the block shadow amplitude ✓

Phase – time period decreases/changes as pendulum amplitude gets less/closer to zero so shadow of bob will move ahead of block/phase changes ✓

condone the two shadows remain in phase (as pendulum motion isochronous for small angles)

2

[11]

2. (a) (use of $v = 2\pi f\sqrt{a^2 - x^2}$)

v_{max}=2π × 2.0 × 2.5 × 10^{-2}

v_{max}= 0.314 m s^{-1} ✓

(use of E_k = ½mv^2)

54 × 10^{-3} = ½m × $(0.314)^2$

m = 1.1 (kg) ✓

$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

2.0 × 2π=√(k/1.1) ✓

(*k* = $(4\pi)^2$ × 1.1)

k = 173 (172.8) ✓(N m^{-1})

Can

OR

5.4 × 10^{-3} = ½ *k* $(2.5 \times 10^{-2})^2$ ✓

k = 173 (172.8) N m^{-1} ✓

If either of these methods used can then find mass from frequency formula or from kinetic energy

OR

54 × 10^{-3} = ½ *F* × 2.5 × 10^{-2}

F = 4.32

4.32 = *k* × 2.5 × 10^{-2}

k = 173 (N m^{-1})

Accept 170 and 172.8 to 174

1
1
1
1

(b) (use of $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$))

same mass so $f \propto \sqrt{k}$

thus frequency = $2.0 \times \sqrt{3}$

frequency = 3.5 (3.46) (Hz) ✓

Allow CE from (a) for k or m

1
1

(c) Two from:

(resonance) peak / maximum amplitude is at a higher frequency ✓
due to higher spring constant ✓

(resonant) peak would be broader ✓
due to damping ✓

amplitude would be lower (at all frequencies) ✓
due to energy losses from the system ✓

First mark in each case for effect

Second mark for reason

2 marks max for effects

2 marks max for reason

Cannot award from sketch graph unless explained

First mark in each pair stand alone

Second mark conditional on first in each pair

1
1
1
1

[10]

3. (a) SHM is when

The acceleration is proportional to the displacement ✓

the acceleration is in opposite direction to displacement✓

2

(b) f = 1/T =1/0.05=20 Hz ✓

($(v_{max} = 2\pi f A)$

$A = \frac{0.044}{2\pi \times 20}$ ✓ (=3.5 × 10^{-4} m)

2

(c) Cosine shape drawn, maximum at *t*= 0, amplitude 3.5 × 10^{-4} m ✓

1

(d) (any of the following when the velocity is zero) 0.00s, 0.025s,0.050s or 0.075s ✓

1

(e) when the vibrating surface accelerates down with an acceleration less than the acceleration of free fall the sand stays in contact. ✓

above a particular frequency, the acceleration is greater than g ✓

there is no contact force on the sand ***OR***

sand no longer in contact when downwards acceleration of plate is greater than acceleration of sand due to gravity ✓

3

(f) (when the surface acceleration is the same as free fall)

$g = r\,\varpi^2 = A\,(2\,\pi f)^2$ ✓

$f = \sqrt{(g / A 4 \pi^2)} = (9.81/(3.5 \times 10^{-4} \times 4\,\pi^2))^{1/2} = 26.6(7)$ Hz ✓

2

[11]

4. (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) $f\left(=\frac{1}{2\pi}\sqrt{\frac{g}{l}}\right)=\frac{1}{2\pi}\sqrt{\frac{9.81}{0.984}}$ ✓ $= 0.503\ (0.5025)$ (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) $a\left(=-(2\pi f)^2 x\right) = (-)(2\pi \times 0.5025)^2 \times 42 \times 10^{-3}$ ✓

*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 2 π

or Δ*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.

[**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]