

1

The frequency of a body moving with simple harmonic motion is doubled. If the amplitude remains the same which of the following is also doubled?

A The time period.

☐

B The total energy.

☐

C The maximum velocity.

☐

D The maximum acceleration.

☐

(Total 1 mark)

2

A particle oscillates with undamped simple harmonic motion.

The acceleration of the particle

A is always in the opposite direction to its velocity.

☐

B decreases as the potential energy increases.

☐

C is proportional to the frequency.

☐

D is least when the speed is greatest.

☐

(Total 1 mark)

3

Which one of the following statements is true when an object performs simple harmonic motion about a central point?

A The acceleration is always directed away from the central point.

B The acceleration and velocity are always 180° out of phase.

C The velocity and displacement are always in the same direction.

D Acceleration and displacement are always 180° out of phase.

(Total 1 mark)

4

For a body performing simple harmonic motion, which one of the following statements is correct?

A The maximum kinetic energy is directly proportional to the frequency.

B The time for one oscillation is directly proportional to the frequency.

C The speed at any instant is directly proportional to the displacement.

D The maximum acceleration is directly proportional to the amplitude.

(Total 1 mark)

5

A particle of mass 5.0×10^{-3} kg, moving with simple harmonic motion of amplitude 0.15 m, takes 47 s to make 50 oscillations.

What is the maximum kinetic energy of the particle?

- A 2.0×10^{-3} J
- B 2.5×10^{-3} J
- C 3.9×10^{-3} J
- D 5.0×10^{-3} J

(Total 1 mark)

6

Which line, **A** to **D**, in the table gives the amplitude and frequency of a body performing simple harmonic motion whose displacement x at time t is given by the equation $x = P \cos Qt$?

	Amplitude	Frequency
A	$\frac{P}{2}$	$\frac{Q}{2\pi}$
B	P	$2\pi Q$
C	P	$\frac{Q}{2\pi}$
D	$2P$	$\frac{Q}{2\pi}$

(Total 1 mark)

7

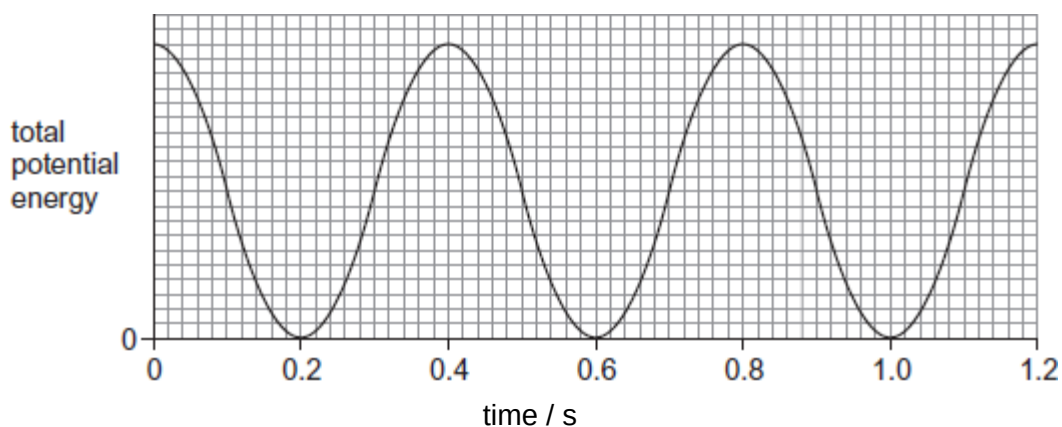
- (a) (i) Name the **two** types of potential energy involved when a mass–spring system performs vertical simple harmonic oscillations.

(1)

- (ii) Describe the energy changes which take place during one complete oscillation of a vertical mass-spring system, starting when the mass is at its lowest point.

- (b) **Figure 1** shows how the **total** potential energy due to the simple harmonic motion varies with time when a mass-spring system oscillates vertically.

Figure 1

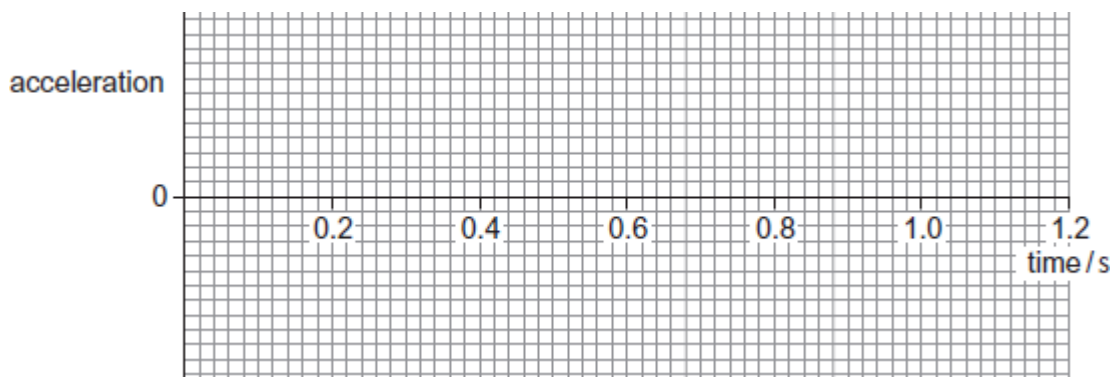


- (i) State the time period of the simple harmonic oscillations that produces the energy–time graph shown in **Figure 1**, explaining how you arrive at your answer.

(2)

- (ii) Sketch a graph on **Figure 2** to show how the acceleration of the mass varies with time over a period of 1.2 s, starting with the mass at the highest point of its oscillations. On your graph, upwards acceleration should be shown as positive and downwards acceleration as negative. Values are not required on the acceleration axis.

Figure 2



(2)

- (c) (i) The mass of the object suspended from the spring in part (b) is 0.35 kg. Calculate the spring constant of the spring used to obtain **Figure 1**. State an appropriate unit for your answer.

spring constant _____ unit _____

(3)

- (ii) The maximum kinetic energy of the oscillating object is 2.0×10^{-2} J. Show that the amplitude of the oscillations of the object is about 40 mm.

(4)

(Total 14 marks)

8

A particle of mass m oscillates in a straight line with simple harmonic motion of constant amplitude. The total energy of the particle is E . What is the total energy of another particle of mass $2m$, oscillating with simple harmonic motion of the same amplitude but double the frequency?

- A E
- B $2E$
- C $4E$
- D $8E$

(Total 1 mark)

9

- (a) A simple pendulum is given a small displacement from its equilibrium position and performs *simple harmonic motion*.

State what is meant by simple harmonic motion.

(2)

- (b) (i) Calculate the frequency of the oscillations of a simple pendulum of length 984 mm. Give your answer to an appropriate number of significant figures.

frequency _____ Hz

(3)

- (ii) Calculate the acceleration of the bob of the simple pendulum when the displacement from the equilibrium position is 42 mm.

acceleration _____ ms^{-2}

(2)

- (c) A simple pendulum of time period 1.90 s is set up alongside another pendulum of time period 2.00 s. The pendulums are displaced in the same direction and released at the same time.

Calculate the time interval until they next move in phase. Explain how you arrive at your answer.

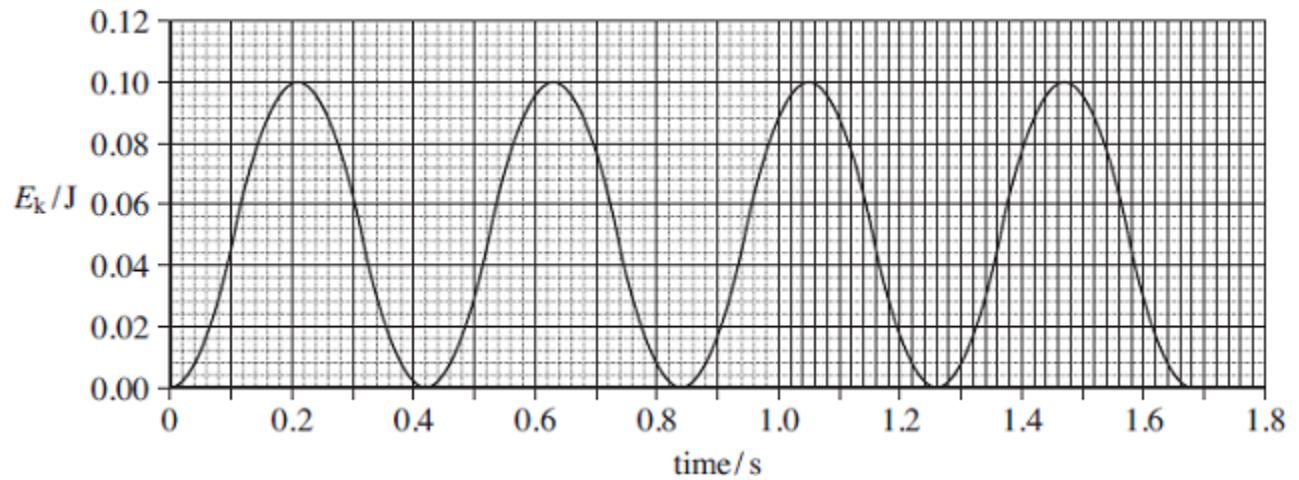
time interval _____ s

(3)

(Total 10 marks)

- (a) **Figure 1** shows how the kinetic energy, E_k , of an oscillating mass varies with time when it moves with simple harmonic motion.

Figure 1



- (i) Determine the frequency of the oscillations of the mass.

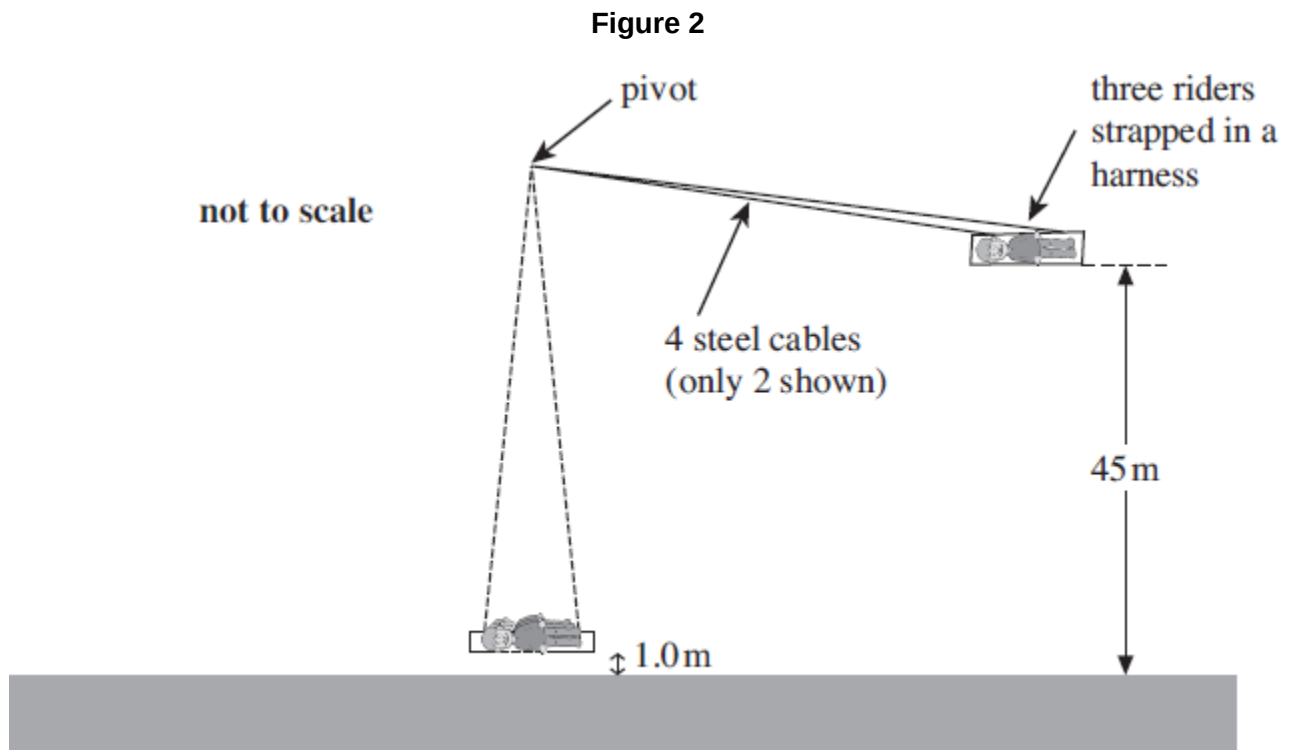
frequency of oscillation _____ Hz

(2)

- (ii) Sketch, on **Figure 1**, a graph showing how the potential energy of the mass varies with time during the first second.

(2)

(b) **Figure 2** shows a ride called a 'jungle swing'.



The harness in which three riders are strapped is supported by 4 steel cables. An advert for the ride states that the riders will be released from a height of 45 m above the ground and will then swing with a period of 14.0 s. It states that they will be 1.0 m above the ground at the lowest point and that they will travel at speeds of 'up to 120 km per hour'.

- (i) Treating the ride as a simple pendulum, show that the distance between the pivot and the centre of mass of the riders is about 49 m.

- (ii) The riders and their harness have a total mass of 280 kg.
Calculate the tension in each cable at the lowest point of the ride, assuming that the riders pass through this point at a speed of 120 km h^{-1} . Assume that the cables have negligible mass and are vertical at this point in the ride.

tension in each cable _____ N

(4)

- (iii) Show that the maximum speed stated in the advert is an exaggerated claim.
Assume that the riders are released from rest and neglect any effects of air resistance.

(4)

- (iv) The riders lose 50% of the energy of the oscillation during each half oscillation. After one swing, the speed of the riders as they pass the lowest point is 20 m s^{-1} .

Calculate the speed of the riders when they pass the lowest point, travelling in the same direction after two further complete oscillations.

speed of riders _____ ms^{-1}

(3)

(Total 17 marks)

11

A particle of mass 0.20 kg moves with simple harmonic motion of amplitude $2.0 \times 10^{-2}\text{ m}$. If the total energy of the particle is $4.0 \times 10^{-5}\text{ J}$, what is the time period of the motion?

- A $\frac{\pi}{4}$ seconds
- B $\frac{\pi}{2}$ seconds
- C π seconds
- D 2π seconds

(Total 1 mark)

12

Which one of the following statements is true when an object performs simple harmonic motion about a central point O?

- A The acceleration is always directed away from O.
- B The acceleration and velocity are always in opposite directions.
- C The acceleration and the displacement from O are always in the same direction.
- D The graph of acceleration against displacement is a straight line.

(Total 1 mark)

13

The frequency of a body moving with simple harmonic motion is doubled. If the amplitude remains the same, which one of the following is also doubled?

- A the time period
- B the total energy
- C the maximum velocity
- D the maximum acceleration

(Total 1 mark)

14

Which one of the following gives the phase difference between the particle velocity and the particle displacement in simple harmonic motion?

- A $\frac{\pi}{4}$ rad
- B $\frac{\pi}{2}$ rad
- C $\frac{3\pi}{4}$ rad
- D 2π rad

(Total 1 mark)

15

A body moves with simple harmonic motion of amplitude A and frequency $\frac{b}{2\pi}$.

What is the magnitude of the acceleration when the body is at maximum displacement?

- A zero
- B $4\pi^2 Ab^2$
- C Ab^2
- D $\frac{4\pi^2 A}{b^2}$

(Total 1 mark)

16

- (a) A body is moving with simple harmonic motion. State **two** conditions that must be satisfied concerning the *acceleration* of the body.

condition 1 _____

condition 2 _____

(2)

- (b) A mass is suspended from a vertical spring and the system is allowed to come to rest. When the mass is now pulled down a distance of 76 mm and released, the time taken for 25 oscillations is 23 s.

Calculate

- (i) the frequency of the oscillations,

- (ii) the maximum acceleration of the mass,

- (iii) the displacement of the mass from its rest position 0.60 s after being released. State the direction of this displacement.

(6)

(c)

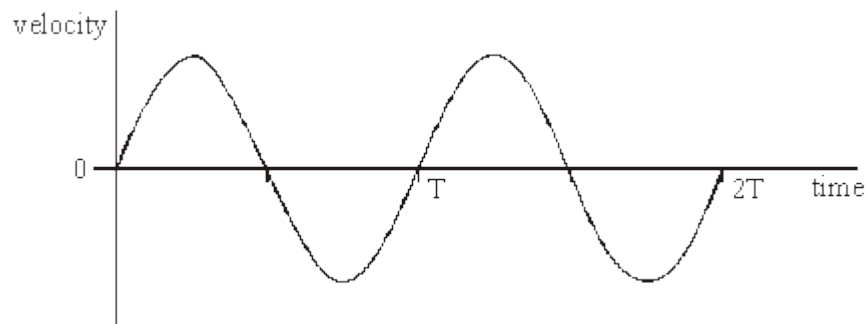


Figure 1

Figure 1 shows qualitatively how the velocity of the mass varies with time over the first two cycles after release.

- (i) Using the axes in **Figure 2**, sketch a graph to show qualitatively how the displacement of the mass varies with time during the same time interval.

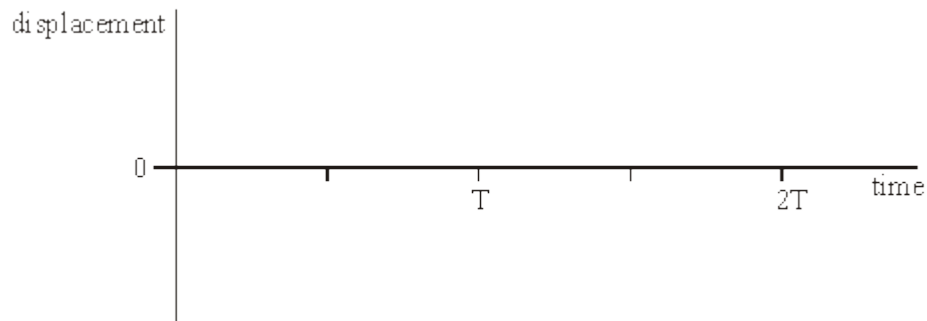


Figure 2

- (ii) Using the axes in **Figure 3**, sketch a graph to show qualitatively how the potential energy of the mass-spring system varies with time during the same time interval.

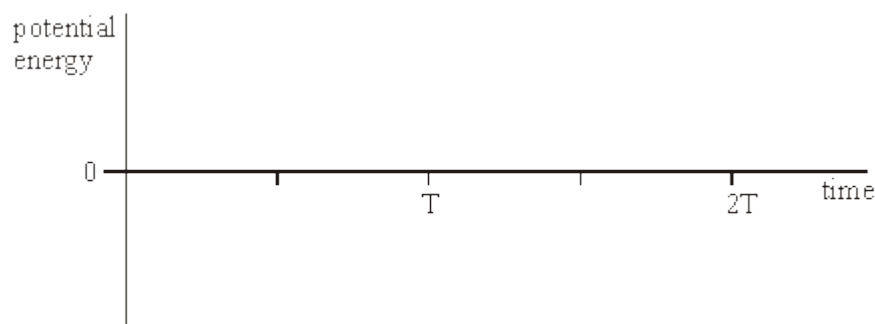


Figure 3

(4)

(Total 12 marks)

17

A body is in simple harmonic motion of amplitude 0.50 m and period 4π seconds. What is the speed of the body when the displacement of the body is 0.30 m?

- A 0.10 m s⁻¹
- B 0.15 m s⁻¹
- C 0.20 m s⁻¹
- D 0.40 m s⁻¹

(Total 1 mark)

18

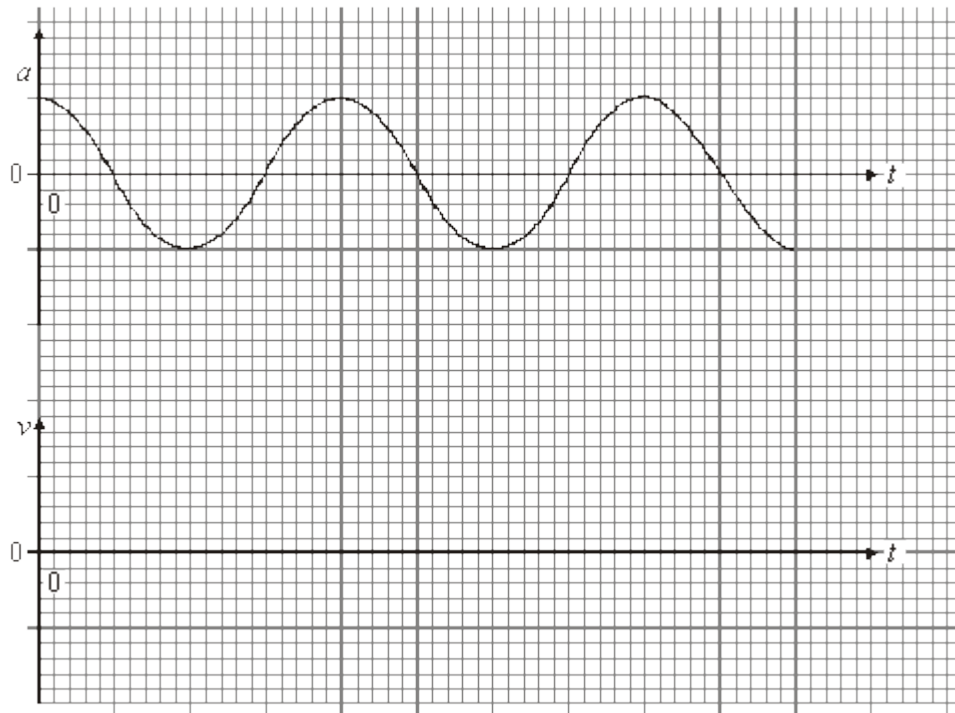
(a) Simple harmonic motion may be represented by the equation

$$a = -(2\pi f)^2 x$$

- (i) Explain the significance of the minus sign in this equation.

(1)

- (ii) In **Figure 1** sketch the corresponding v - t graph to show how the **phase** of velocity v relates to that of the acceleration a .

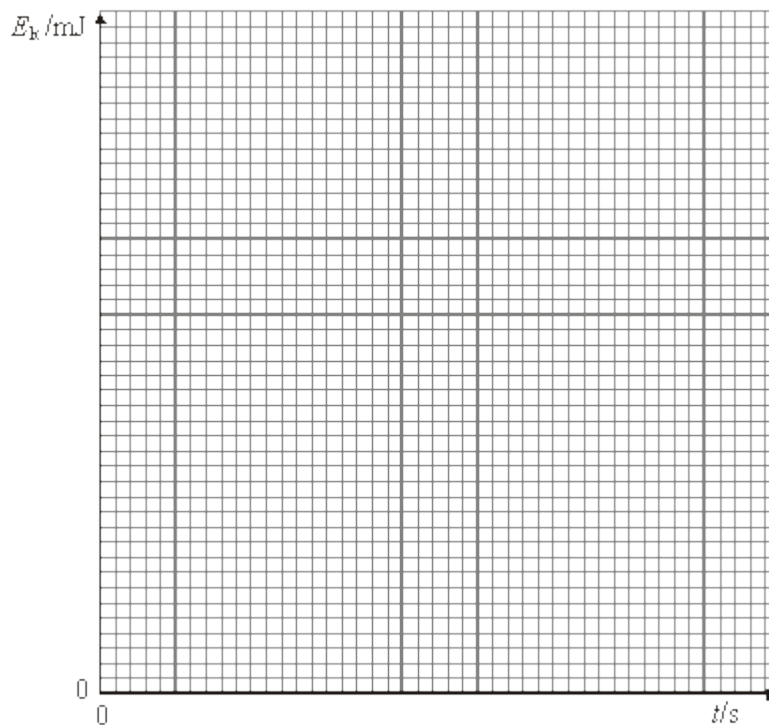


(1)

- (b) (i) A mass of 24 kg is attached to the end of a spring of spring constant 60 N m^{-1} . The mass is displaced 0.035 m vertically from its equilibrium position and released. Show that the maximum kinetic energy of the mass is about 40 mJ.

(5)

- (ii) When the mass on the spring is quite heavily damped its amplitude halves by the end of each complete cycle. On the grid of **Figure 2** sketch a graph to show how the kinetic energy, E_k , of the mass on the spring varies with time over a single period. Start at time, $t = 0$, with your maximum kinetic energy. You should include suitable values on each of your scales.



(3)

(Total 10 marks)

19

- (a) State the conditions necessary for a mass to undergo simple harmonic motion.

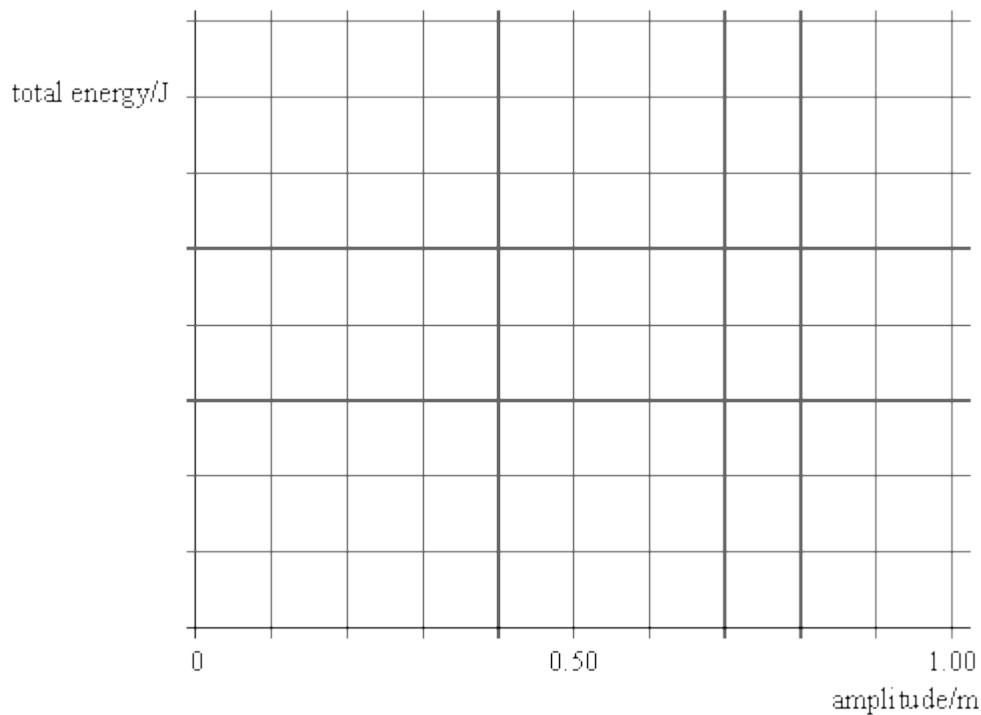
(2)

- (b) A child on a swing oscillates with simple harmonic motion of period 3.2 s.

acceleration of free fall = 9.8 m s^{-2}

- (i) Calculate the distance between the point of support and the centre of mass of the system.

- (ii) The total energy of the oscillations is 40 J when the amplitude of the oscillations is 0.50 m. Sketch a graph showing how the total energy of the child varies with the amplitude of the oscillations for amplitudes between 0 and 1.00 m. Include a suitable scale on the total energy axis.

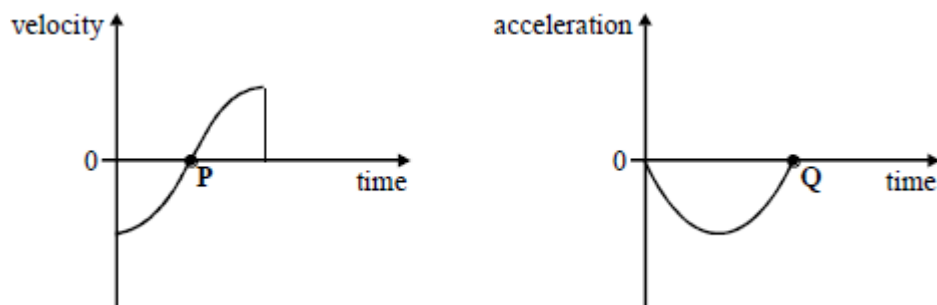


(2)

(Total 6 marks)

20

The diagrams show the variation of velocity and acceleration with time for a body undergoing simple harmonic motion.



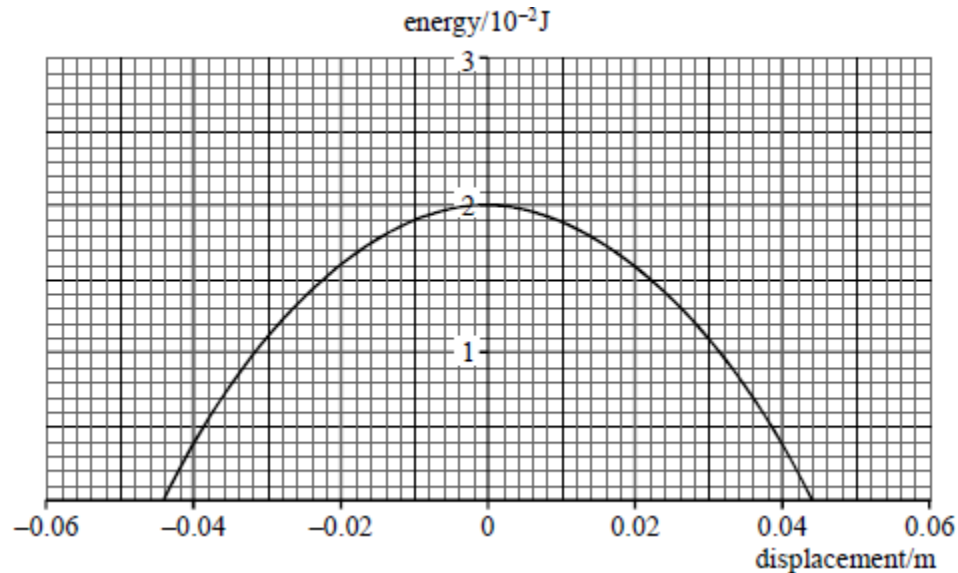
Which one of the following is proportional to the change in momentum of the body during the time covered by the graphs?

- A The area enclosed by the velocity-time graph and the time axis
- B The gradient of the velocity-time graph at the point P
- C The area enclosed by the acceleration-time graph and the time axis
- D The gradient of the acceleration-time graph at the point Q

(Total 1 mark)

21

The diagram below shows how the kinetic energy of a simple pendulum varies with displacement.



- (a) Sketch on the diagram above a graph to show how the potential energy of the pendulum varies with displacement.

(2)

- (b) (i) State the amplitude of the oscillation.

(1)

- (ii) The frequency of vibration of the pendulum is 3.5 Hz. Write down the equation that models the variation of position with time for the simple harmonic motion of **this** pendulum.

(1)

- (iii) Calculate the maximum acceleration of the simple pendulum.

(2)

(Total 6 marks)

22

A particle of mass m executes simple harmonic motion in a straight line with amplitude A and frequency f . Which one of the following expressions represents the total energy of the particle?

- A $2 \pi^2 m f A^2$
 B $2 \pi^2 m f^2 A^2$
 C $4 \pi^2 m^2 f^2 A$
 D $4 \pi^2 m f^2 A^2$

(Total 1 mark)

23

A body moves with simple harmonic motion of amplitude A and frequency $\frac{b}{2\pi}$.

What is the magnitude of the acceleration when the body is at maximum displacement?

- A zero
- B $4\pi^2 Ab^2$
- C Ab^2
- D $\frac{4\pi^2 A}{b^2}$

(Total 1 mark)

24

Which one of the following statements is true when an object performs simple harmonic motion about a central point O?

- A The acceleration is always away from O.
- B The acceleration and velocity are always in opposite directions.
- C The acceleration and the displacement from O are always in the same direction.
- D The graph of acceleration against displacement is a straight line.

(Total 1 mark)

25

A mass M hangs in equilibrium on a spring. M is made to oscillate about the equilibrium position by pulling it down 10 cm and releasing it. The time for M to travel back to the equilibrium position for the first time is 0.50 s. Which line, **A** to **D**, is correct for these oscillations?

	amplitude/cm	period/s
A	10	1.0
B	10	2.0
C	20	2.0
D	20	1.0

(Total 1 mark)

26

A particle oscillates with undamped simple harmonic motion. Which one of the following statements about the acceleration of the oscillating particle is true?

- A It is least when the speed is greatest.
- B It is always in the opposite direction to its velocity.
- C It is proportional to the frequency.
- D It decreases as the potential energy increases.

(Total 1 mark)

27

Which one of the following gives the phase difference between the particle velocity and the particle displacement in simple harmonic motion?

- A $\frac{\pi}{4}$ rad
- B $\frac{\pi}{2}$ rad
- C $\frac{3\pi}{4}$ rad
- D 2π rad

(Total 1 mark)

28

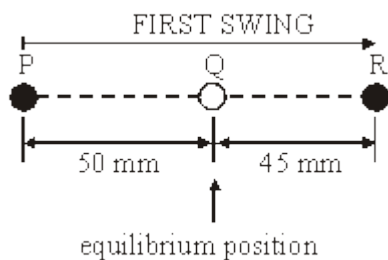
A body is in simple harmonic motion of amplitude 0.50 m and period 4π seconds. What is the speed of the body when the displacement of the body is 0.30 m?

- A 0.10ms^{-1}
- B 0.15ms^{-1}
- C 0.20 m s^{-1}
- D 0.40 m s^{-1}

(Total 1 mark)

29

A particle, whose equilibrium position is at Q, is set into oscillation by being displaced to P, 50 mm from Q, and then released from rest. Its subsequent motion is simple harmonic, but subject to damping. On the first swing, the particle comes to rest momentarily at R, 45 mm from Q.



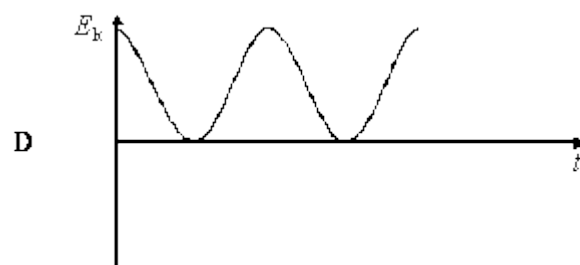
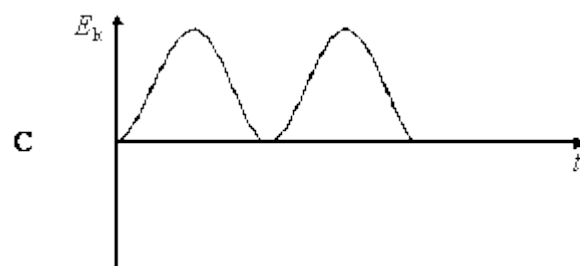
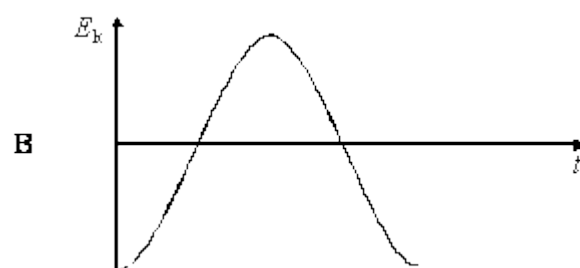
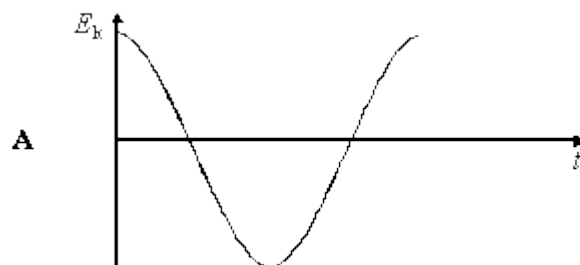
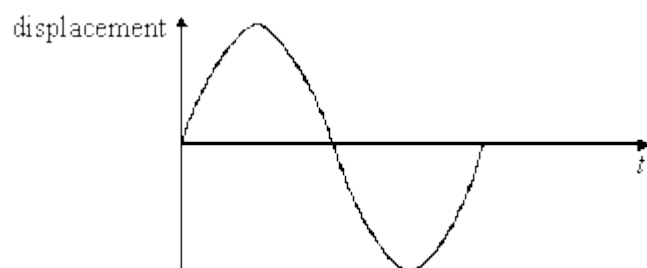
During this first swing, the greatest value of the acceleration of the particle is when it is at

- A P.
- B Q.
- C R.
- D P and R.

(Total 1 mark)

30

The top graph is a displacement/time graph for a particle executing simple harmonic motion. Which one of the other graphs shows correctly how the kinetic energy, E_k , of the particle varies with time?



(Total 1 mark)

31

A body moves in simple harmonic motion of amplitude 0.90 m and period 8.9 s. What is the speed of the body when its displacement is 0.70 m?

- A 0.11 m s⁻¹
- B 0.22 m s⁻¹
- C 0.40 m s⁻¹
- D 0.80 m s⁻¹

(Total 1 mark)

32

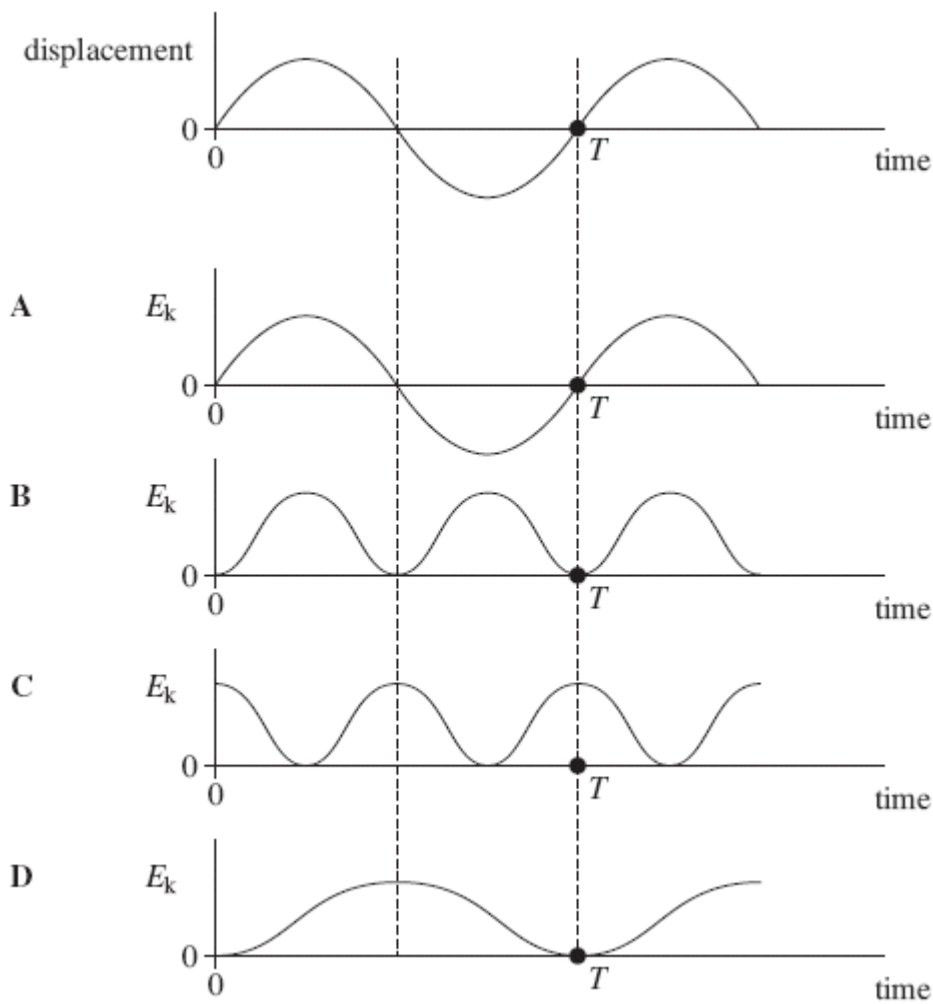
A body moves with simple harmonic motion of amplitude 0.90 m and period 8.9 s. What is the speed of the body when its displacement is 0.70 m?

- A 0.11 m s⁻¹
- B 0.22 m s⁻¹
- C 0.40 m s⁻¹
- D 0.80 m s⁻¹

(Total 1 mark)

33

An object oscillating in simple harmonic motion has a time period T . The first graph shows how its displacement varies with time. Which of the subsequent graphs, **A** to **D**, show how the kinetic energy, E_k , of the object varies with time?



(Total 1 mark)

34

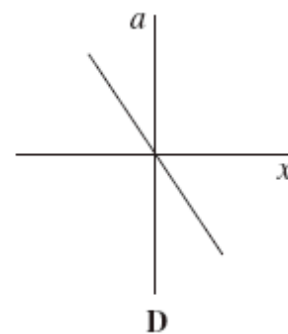
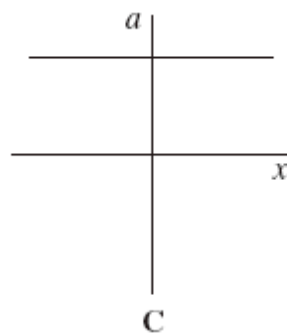
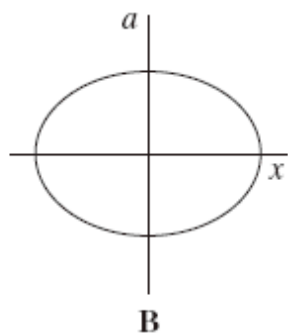
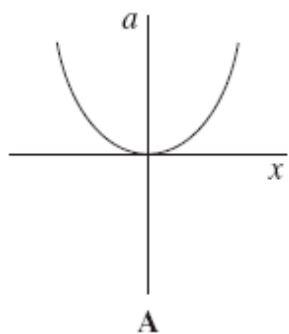
A body moves with simple harmonic motion of amplitude A and frequency $\frac{b}{2\pi}$. What is the magnitude of the acceleration when the body is at maximum displacement?

- A zero
- B $4\pi^2 Ab^2$
- C Ab^2
- D $\frac{4\pi^2 A}{b^2}$

(Total 1 mark)

35

Which one of the following graphs shows how the acceleration, a , of a body moving with simple harmonic motion varies with its displacement, x ?



(Total 1 mark)

Mark schemes

1	C	[1]
2	D	[1]
3	D	[1]
4	D	[1]
5	B	[1]
6	C	[1]
7	(a) (i) elastic potential energy and gravitational potential energy ✓ <i>For elastic pe allow “pe due to tension”, or “strain energy” etc.</i> (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] <i>If kinetic energy is not mentioned, no marks.</i> <i>Types of potential energy must be identified for full credit.</i> (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 ✓ <i>Mark sequentially.</i> (ii) sinusoidal curve of period 0.80 s ✓ – cosine curve starting at $t = 0$ continuing to $t = 1.2\text{s}$ ✓ <i>For 1st mark allow ECF from T value given in (i).</i>	1 2 2

(c) (i) use of $T = 2\pi\sqrt{\frac{m}{k}}$ gives $0.80 = 2\pi\sqrt{\frac{0.35}{k}}$ ✓

$$\therefore k = \left(\frac{4\pi^2 \times 0.35}{0.80^2} \right) = 22 \text{ (21.6) } \checkmark \quad \text{N m}^{-1} \checkmark$$

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 = $(\frac{1}{2}mv_{\max}^2) = 2.0 \times 10^{-2}$ gives

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

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

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

[or maximum ke = $(\frac{1}{2}mv_{\max}^2) = \frac{1}{2}m(2\pi fA)^2 \checkmark$

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

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

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

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

$$\text{maximum pe} = \frac{1}{2}kA^2 \checkmark$$

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

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

and $A = 4.3(0) \times 10^{-2} \text{ m } \checkmark$ 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 N m⁻¹ gives

$A = 2.15 \times 10^{-2} \text{ m}$ but mark to max 3.

4

[14]

9

- (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

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

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

- (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

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

Final speed calculated = 5 m s⁻¹

A1

Must be from correct working

[17]

11

D

[1]

12

D

[1]

13

C

[1]

14

B

[1]

15

C

[1]

16

- (a) acceleration is proportional to displacement **(1)**
 acceleration is in opposite direction to displacement, or
 towards a fixed point, or towards the centre of oscillation **(1)**

2

(b) (i) $f = \frac{25}{23} = 1.1 \text{ Hz (or s}^{-1}\text{) (1)}$ (1.09 Hz)

(ii) (use of $a = (2\pi f)^2 A$ gives)
 $a = (2\pi \times 1.09)^2 \times 76 \times 10^{-3} \text{ (1)}$
 $= 3.6 \text{ m s}^{-2} \text{ (1)}$ (3.56 m s⁻²)
 (use of $f = 1.1 \text{ Hz}$ gives $a = 3.63 \text{ m s}^{-2}$)
 (allow C.E. for incorrect value of f from (i))

(iii) (use of $x = A \cos(2\pi ft)$ gives)
 $x = 76 \times 10^{-3} \cos(2\pi \times 1.09 \times 0.60) \text{ (1)}$
 $= (-)4.3(1) \times 10^{-2} \text{ m (1)}$ (43 mm)
 (use of $f = 1.1 \text{ Hz}$ gives
 $x = (-)4.0(7) \times 10^{-2} \text{ m (41 mm)}$)
 direction: above equilibrium position or upwards **(1)**

6

- (c) (i) graph to show:
 correct shape, i.e. cos curve **(1)**
 correct phase i.e. $-(\cos)$ **(1)**
- (ii) graph to show:
 two cycles per oscillation **(1)**
 correct shape (even if phase is wrong) **(1)**
 correct starting point (i.e. full amplitude) **(1)**

max 4

[12]

17

C

[2]

18

- (a) (i) acceleration (not a) and displacement (not x) are in
 opposite directions OR restoring force/acceleration
 always acts toward rest position

B1

1

- (ii) (+) sine curve consistent with a graph

B1

1

(b) (i) statement that $E_K = E_P$

B1

statement of max values considered

B1

$$E_P = \frac{1}{2} k(\Delta l)^2 \text{ or } E_{P\max} = \frac{1}{2} kA^2$$

B1

correctly substituted values

B1

$$E_K = 3.7 \times 10^{-2} \text{ J}$$

B1

OR

$f = 1/T$ or $T = 3.97 \text{ s}$ or period equation

B1

leading to $f = 0.252 \text{ Hz}$

B1

$$\omega_{\max} = 1.58 \text{ rad s}^{-1} \text{ or } v_{\max} = 0.055 \text{ ms}^{-1} \text{ (seen or used)}$$

B1

substituted values into $E_K = \frac{1}{2} m A^2 \omega^2$ or $E_K = \frac{1}{2} m v^2$

B1

$$E_K = 3.7 \times 10^{-2} \text{ J}$$

B1

(ii) any attenuation from $t = 0$ seen

M1

10 mJ or $E_0/4$ at either 4s or third hump

M1

consistent period values minima at 1 and 3s
maxima at 0 and 4s

A1

3

[10]

19

- (a) acceleration/force is directed toward
a (fixed) point/the centre/the equilibrium position
or
 $a = -kx$ + '−' means that a is opposite direction to x

B1

acceleration/force is proportional to the distance from the
point/displacement

or

$a = -kx$ where a = acceleration; x = displacement and
 k is constant

B1

2

- (b) (i) $3.2 = 2\pi\sqrt{9.8}$ (condone use of $g = 10 \text{ m s}^{-2}$ for C mark)
(use of $a = -\omega^2 x$ is a PE so no marks)

C1

2.5(4) m

A1

2

- (ii) Correct value at 0.5 m and correct curvature

M1

Energy at 1 m = 160 J

A1

2

[6]

20

C

[1]

21	(a) Max to zero to max with zero at 0 displacement and correct amplitude correct shape drawn with reasonable attempt to keep total energy constant, crossing at 1×10^{-2} J	A1 (2)
	(b) (i) 0.044 m	B1 (1)
	(ii) $x = 0.044 \cos 2\pi 3.5t$ (0.044 cos 22t) or $x = 0.044 \sin 2\pi 3.5t$ etc ecf for A	B1 (1)
	(iii) $\alpha_{\max} = (2\pi 3.5)^2 0.044$ 21 (21.3) m s^{-2} ecf for A and incorrect $2\pi f$ from (ii) (0.042 gives 20.3; 0.04 gives 19.4)	C1 A1 (2)
		[6]
22	B	[1]
23	C	[1]
24	D	[1]
25	B	[1]
26	A	[1]
27	B	[1]
28	C	[1]
29	A	[1]
30	D	[1]
31	C	[1]
32	C	[1]

33 C

[1]

34 C

[1]

35 D

[1]