Topic Test: OxfordAQA International A level Physics

Circular and Periodic Motion

Name: ____________________

Class: ____________________

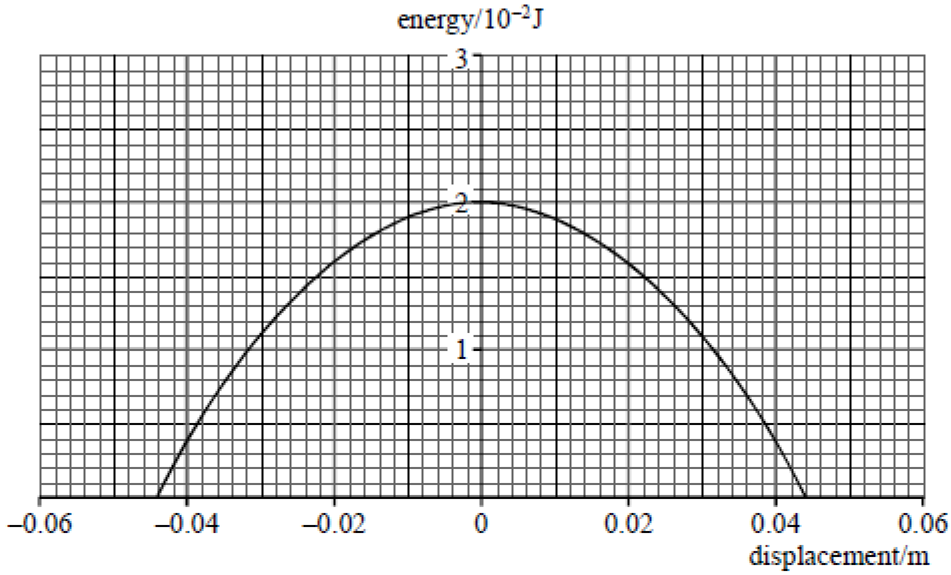
Date: ____________________

Time: **47 minutes**

Marks: **44 marks**

Comments:

1 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)

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

___

___

(2)

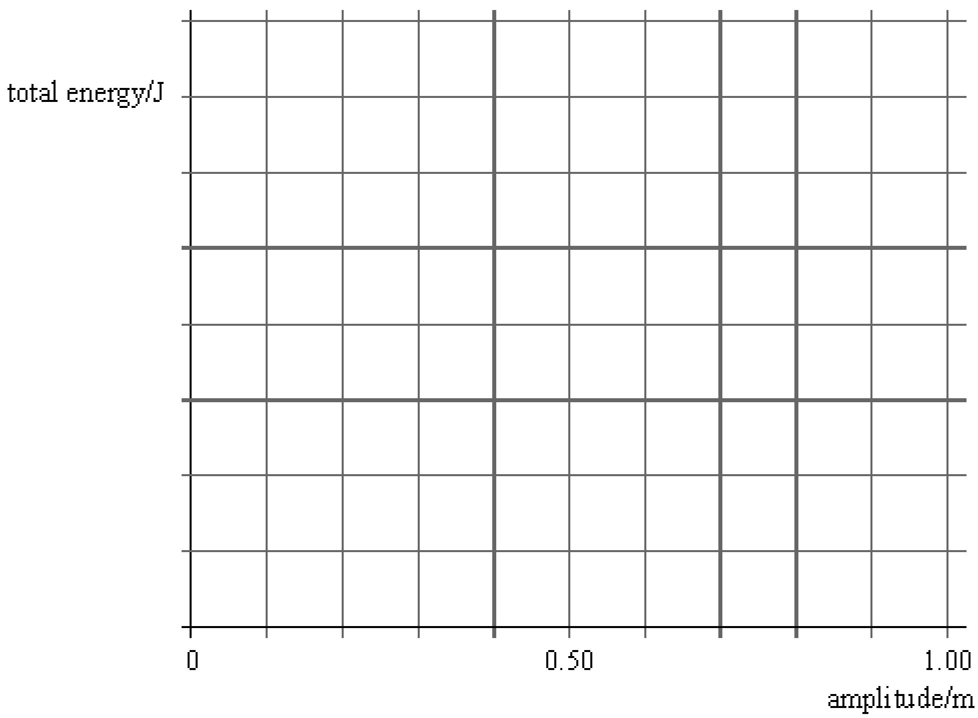
(b) A child on a swing oscillates with simple harmonic motion of period 3.2 s.

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.

(2)

(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)

3 The Hubble space telescope was launched in 1990 into a circular orbit near to the Earth. It travels around the Earth once every 97 minutes.

(a) Calculate the angular speed of the Hubble telescope, stating an appropriate unit.

answer = ______________________

(3)

(b) (i) Calculate the radius of the orbit of the Hubble telescope.

answer = ______________________ m

(3)

(ii) The mass of the Hubble telescope is 1.1×10^4 kg. Calculate the magnitude of the centripetal force that acts on it.

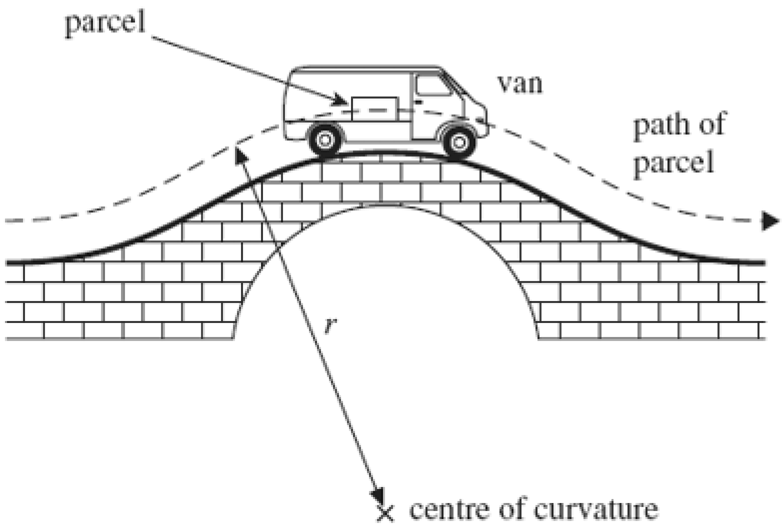
answer = ______________________ N

(2)

(Total 8 marks)

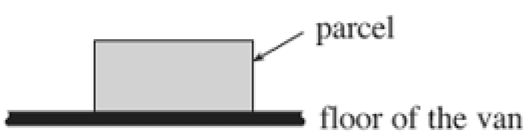
4 **Figure 1** shows a parcel on the floor of a delivery van that is passing over a hump-backed bridge on a straight section of road. The radius of curvature of the path of the parcel is r and the van is travelling at a constant speed v. The mass of the parcel is m.

Figure 1



(a) (i) Draw arrows on **Figure 2** below to show the forces that act on the parcel as it passes over the highest point of the bridge. Label these forces.

Figure 2



(1)

(ii) Write down an equation that relates the contact force, R, between the parcel and the floor of the van to m, v, r and the gravitational field strength, g.

____

____

(1)

(iii) Calculate R if m = 12 kg, r = 23 m, and v = 11ms^{-1}.

answer = ____________________ N

(2)

(b) Explain what would happen to the magnitude of *R* if the van passed over the bridge at a higher speed. What would be the significance of any van speed greater than 15ms^{-1}? Support your answer with a calculation.

____

____

____

____

____

____

____

(3)

(Total 7 marks)

5 (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)

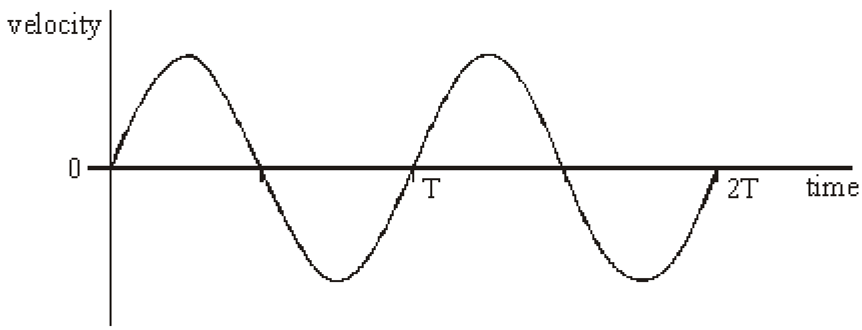


Figure 1

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.

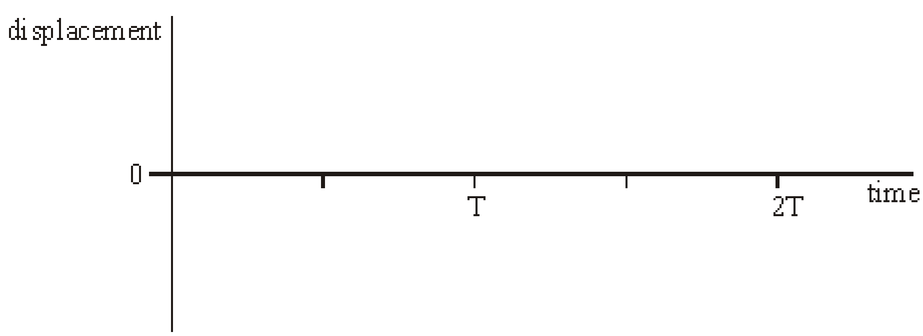


Figure 2

(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.

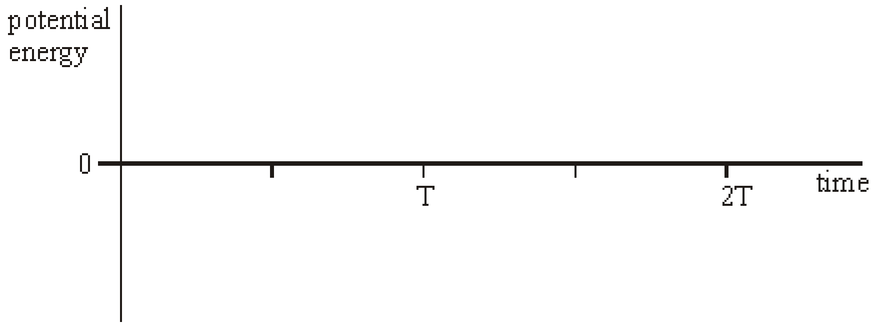
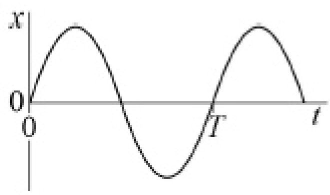


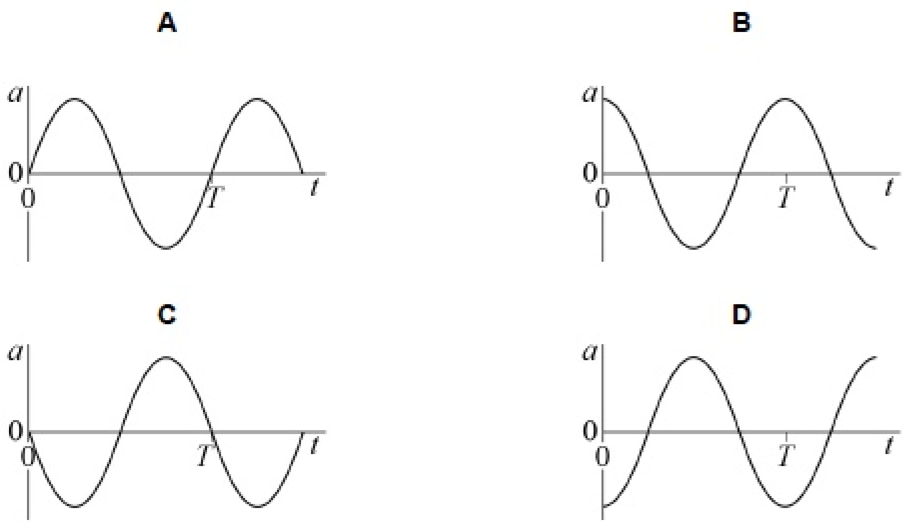
Figure 3

(4)
(Total 12 marks)

6 The graph shows the variation of displacement x with time t for an object performing simple harmonic motion. T is the period of the oscillation.



Which graph shows the variation of acceleration a with time t for the same object?



A ⬭

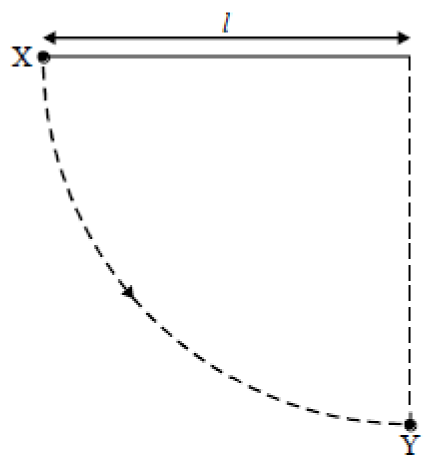
B ⬭

C ⬭

D ⬭

(Total 1 mark)

7



A simple pendulum consists of a bob of mass m on the end of a light string of length l.
The bob is released from rest at X when the string is horizontal. When the bob passes through Y its velocity is v and the tension in the string is T. Which one of the following equations gives the correct value of T?

A $T = mg$

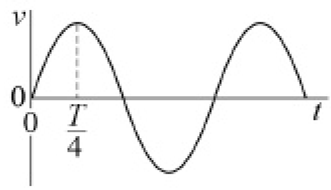
B $T = \frac{mv^2}{l}$

C $T + mg = \frac{mv^2}{l}$

D $T - mg = \frac{mv^2}{l}$

(Total 1 mark)

8 The graph shows the variation of the velocity v with time t for an object performing simple harmonic motion. The period of the oscillation is T.



The maximum acceleration of the object is equivalent to the:

A gradient of the graph when $t = 0$ ⬭

B gradient of the graph when $t = \frac{T}{4}$ ⬭

C area between the graph and the t axis between $t = 0$ and $t = \frac{T}{4}$ ⬭

D area between the graph and the t axis between $t = 0$ and $t = \frac{T}{2}$ ⬭

(Total 1 mark)

9 A girl of mass 40 kg stands on a roundabout 2.0 m from the vertical axis as the roundabout rotates uniformly with a period of 3.0 s. The horizontal force acting on the girl is approximately

A zero.

B 3.5×10^2 N.

C 7.2×10^2 N.

D 2.8×10^4 N.

(Total 1 mark)

10 The total energy of an object that is performing simple harmonic motion is:

A always zero. ⬭

B a maximum when the object is at maximum speed. ⬭

C a maximum when the object is at maximum displacement from the equilibrium position. ⬭

D constant throughout a complete cycle. ⬭

(Total 1 mark)

Mark schemes

1 (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) $\alpha_{max} = (2\pi 3.5)^2\ 0.044$

C1

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)

A1

(2)

[6]

2 (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) $3.2 = 2\pi\sqrt{l/9.8}$ (condone use of g = 10 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]

3 (a) $\omega \left(= \frac{2\pi}{T}\right) = \frac{2\pi}{97 \times 60}$ [or $\omega \left(= \frac{360}{T}\right) = \frac{360}{97 \times 60}$]

$= 1.1 \times 10^{-3}$ (1.08×10^{-3}) **(1)** [$= 6.2$ (6.19) $\times 10^{-2}$]

rad s^{-1} [accept s^{-1}] **(1)** [degree s^{-1}]

3

(b) (i) $\frac{GMm}{r^2} = m\omega^2 r$ **or** $r^3 = \frac{GM}{\omega^2}$ **(1)**

gives $r^3 = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(1.08 \times 10^{-3})^2}$ **(1)**

$\therefore r = 6.99 \times 10^6$ (m) **(1)**

3

(ii) F ($= m\omega^2 r$) $= 1.1 \times 10^4 \times (1.08 \times 10^{-3})^2 \times 6.99 \times 10^6$ **(1)**

$= 9.0 \times 10^4$ (8.97×10^4) (N) **(1)**

[**or** $F\left(= \frac{GMm}{r^2}\right) = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 1.1 \times 10^4}{(6.99 \times 10^6)^2}$ **(1)**

$= 9.0 \times 10^4$ (8.98×10^4) (N) **(1)**]

2

[8]

4 (a) (i) arrows to show R (or N) vertically up and mg (or W) vertically down and along the same line (within ± 2 mm) ✓

1

(ii) $mg - R = \frac{mv^2}{r} \therefore R = mg - \frac{mv^2}{r}$ ✓ $\left[= m\left(g - \frac{v^2}{r}\right)\right]$

1

(iii) **use** of $R = m\left(g - \frac{v^2}{r}\right)$ gives $R = 12(9.81 - \frac{11^2}{23})$ ✓

= 55 (54.6) (N) ✓

2

(b) R decreases (as v increases) ✓

because mg is unchanged but $\frac{mv^2}{r}$ is larger ✓

at higher speeds **R** becomes = 0 [**or** package is not in contact with the floor] ✓

supported by calculation eg when $v = 15\ \text{m s}^{-1}$,
R = 0.33 N (or ≈ 0) ✓

max 3

[7]

5 (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 Hz (or s^{-1}) **(1)** (1.09 Hz)

(ii) (use of $a = (2\pi f)^2 A$ gives)
$a = (2\pi \times 1.09)^2 \times 76 \times 10^{-3}$ **(1)**
= $3.6\ \text{m s}^{-2}$ **(1)** ($3.56\ \text{m s}^{-2}$)
(use of f = 1.1 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)
$x = 76 \times 10^{-3}\cos(2\pi \times 1.09 \times 0.60)$ **(1)**
= $(-)4.3(1) \times 10^{-2}$m **(1)** (43 mm)
(use of f = 1.1 Hz gives
$x = (-)4.0(7) \times 10^{-2}$ 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]

6 C

[1]

7 D

[1]

8 A

[1]

9 B

[1]

10 D

[1]