A rocket of mass 0.50 kg is set on the ground, pointing **vertically** up, as shown in Figure 3. When ignited, the gunpowder burns for a period of 1.5 s, and provides a constant force of 22 N. The mass of the gunpowder is very small compared to the mass of the rocket, and can be ignored. The effects of air resistance can also be ignored.

Figure 3

Question 6

What is the magnitude of the resultant force on the rocket?

$$F_{net} = 22 - mg$$
$$= 22 - 0.5 \times 10$$

17	N

2 marks

Question 7

After 1.5 s, what is the height of the rocket above the ground?

$$a = \frac{F_{net}}{m} \quad a = \frac{17}{0.5} = 34\ ms^{-2} \quad h = \frac{at^2}{2}$$
$$h = \frac{34 \times 1.5^2}{2}$$

38.25	m

2 marks

2006/1

A second **identical** rocket, that again provides a constant force of 22 N for 1.5 s, is now launched **horizontally** from the top of a 50 m tall building. Assume that in its subsequent motion the rocket always points horizontally.

Question 8 17% Average 1.3

After 1.5 s, what is the **speed** of the rocket, and at what **angle** is the rocket moving relative to the ground?

$V_x = a_x t$ $\quad a_x = \frac{F}{m} = \frac{22}{0.5} = 44\ ms^{-2}$

$= 44 \times 1.5$

$= 66\ ms^{-1}$

$\theta = \tan^{-1}\left(\frac{V_y}{V_x}\right)$

$V_y = gt = 10 \times 1.5 = 15\ ms^{-1}$

$V = \sqrt{V_x^2 + V_y^2} = \sqrt{66^2 + 15^2}$

$\theta = \tan^{-1}\left(\frac{15}{66}\right)$

speed = 67.7 m s^{-1}	angle = 12.8 °

4 marks

John is standing on a railway station and drops a ball from a height of 1.25 m (Figure 4). Mary is in a train that is passing **through** the station at a constant speed, and observes the falling ball.

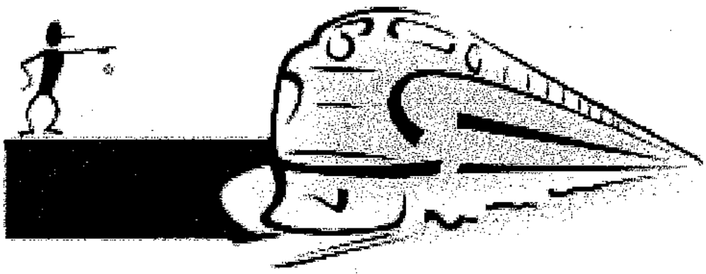
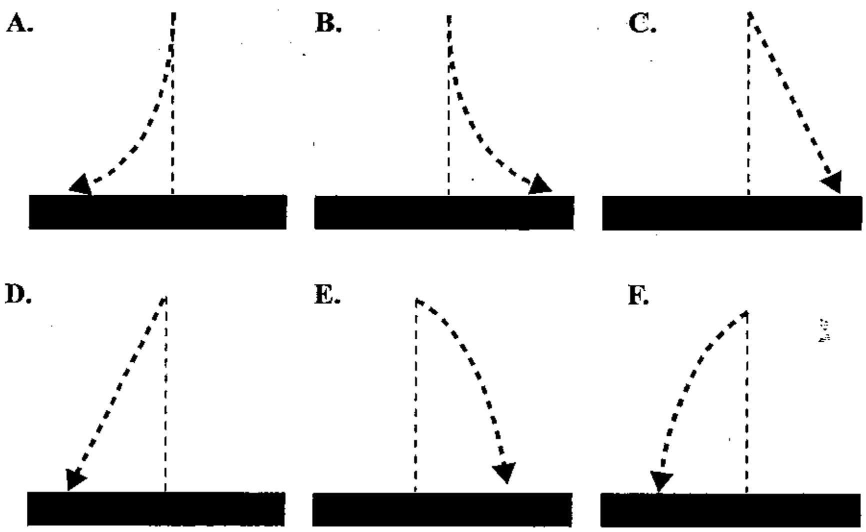


Figure 4

Question 9 33 %

Which of the diagrams (**A–F**) below best represents the path of the ball as seen by Mary?



E

2 marks

Figure 5 shows a space shuttle docking with the international space station.

Imagine that you are an astronaut floating in space **at rest relative to the international space station**. You watch the space shuttle, of mass 6000 kg, dock. You observe the shuttle approaching the space station with a speed of 5.00 m s^{-1}.

After docking, the space station's speed has increased by 0.098 m s^{-1}.

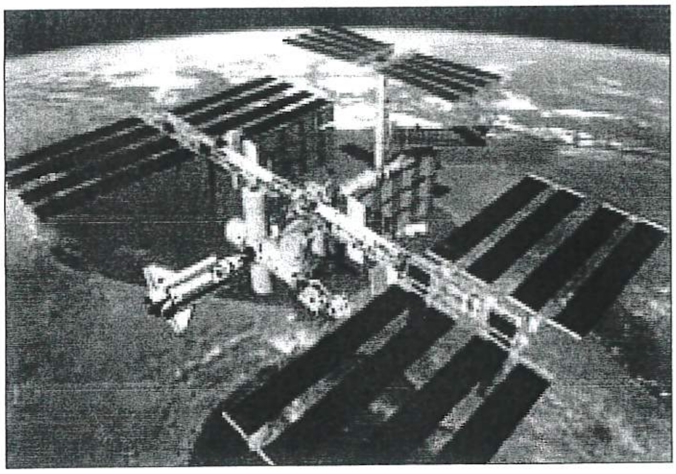


Figure 5

Question 10

Show that the mass of the space station is 3×10^5 kg.

$p_0 = 6000 \times 5 = 30000$ Ns

$p = (6000 + M)\,0.098$

$p_0 = p$

$30000 = 588 + 0.098M$

$M = \frac{29412}{0.098} = 3 \times 10^5$ kg

3 marks

After first making contact, it takes 20 s for the shuttle to come to rest with the space station.

Question 11

Calculate the average force exerted on the shuttle by the space station.

p_0 of shuttle $= 30000$ Ns

p final of shuttle $= 6000 \times 0.098 = 588$

$\Delta p = 29412$

$Ft = \Delta p$

$F = \frac{29412}{20} =$

1470 N

1471

3 marks

A student, Sam, of mass 70 kg, is bungee jumping from a platform at the top of a tower (Figure 6). He reaches the top of the tower by being towed up a slide of length L. The friction between Sam and the slide provides a constant force of 300 N that opposes the motion. The **total work** done in dragging Sam up the slide to the top of the tower is 22 720 J. At the top of the tower Sam's **potential energy** was greater by 13 720 J than it was on the ground.

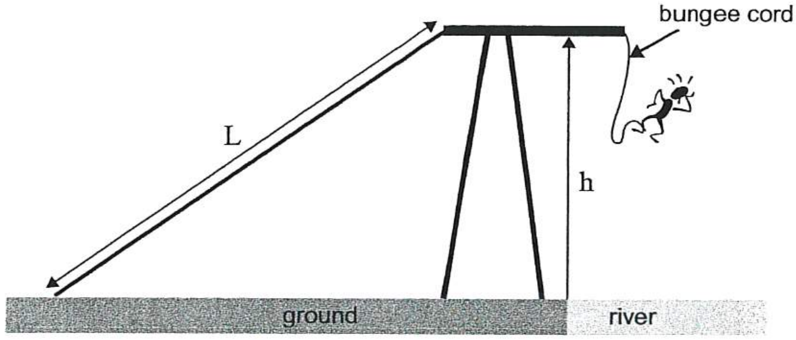


Figure 6

Question 12

Show that the length of the slide, L, is 30 m.

Total work = change in E_{gp} + work against friction

$22720 = 13720 + 300L$

$300L = 9000 \quad L = 30\text{ m}$

3 marks

Question 13

What is the height, h, of the tower?

$mgh = 13720$

$700h = 13720$

19.6 m

2 marks

The natural length of the bungee cord is 10 m.

Sam stops falling and first comes to rest momentarily when the length of the bungee cord is 18 m.

Question 14

What is the spring constant of the bungee cord?

$mg \times 18 = \frac{k \times 8^2}{2} \qquad k = \frac{2 \times 70 \times 10 \times 18}{\cancel{100}\ 64}$

394 N m^{-1}

3 marks

The planet Mars has a mass of 6.4×10^{23} kg, which is approximately $\frac{1}{10}$ that of Earth, and its radius is approximately half that of Earth.

Question 15 63 %

Which of the following (**A–D**) gives the best value for the acceleration due to gravity at the surface of Mars?

A. 1 m s^{-2}

B. 2.5 m s^{-2}

C. 4 m s^{-2}

D. 5 m s^{-2}

C

2 marks

The Mars probe that was launched in August 2005 is now orbiting Mars in an orbit with an average radius of 3.00×10^{7} m (Figure 7).

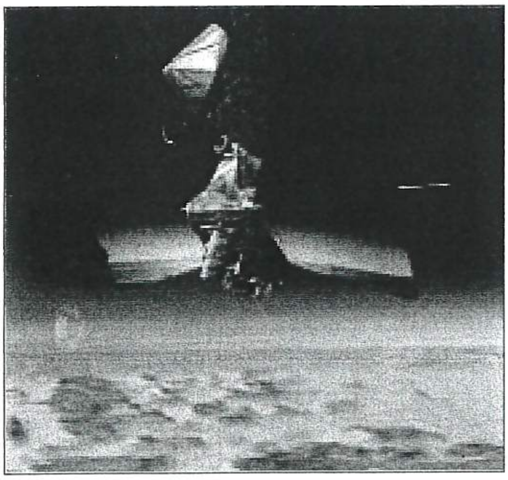


Figure 7

Question 16 30 %. Average 1.3

What is the period of the orbit in seconds?

$$\frac{R^3}{T^2} = \frac{GM}{4\pi^2} \qquad T = \sqrt{\frac{4\pi^2 R^3}{GM}}$$

$$T = \sqrt{\frac{4\pi^2 \times (3\times10^7)^3}{6.67\times10^{-11} \times 6.4\times10^{23}}}$$

1.58×10^5 s

3 marks

END OF AREA OF STUDY 1

The dwarf planet Pluto was discovered in 1930, and was thought to be the outermost member of our solar system. It can be considered to orbit the Sun in a circle of radius 6 billion kilometres (6.0×10^{12} m). In 2003 a new dwarf planet, Eris, was discovered. It has approximately the same mass as Pluto, but the average radius of its orbit around the Sun is 10.5 billion kilometres (10.5×10^{12} m).

Question 12

Which of the choices **(A–D)** below gives the best estimate of the ratio

$$\frac{\text{gravitational attraction of the Sun on Eris}}{\text{gravitational attraction of the Sun on Pluto}}?$$

A. 0.33
B. 0.57
C. 1.75
D. 3.06

A

2 marks

The period of Pluto around the Sun is 248 Earth-years.

Question 13

How many Earth-years does Eris take to orbit the Sun?

574 years

2 marks

In a laboratory class at school, Lee is given a spring with a stiffness of 20 N m^{-1} and unstretched length of 0.40 m. He hangs it vertically, and attaches a mass to it, so that the new length of the spring is 0.60 m.

Question 9

Assuming the spring has no mass, what was the value of the mass he attached?

0.4	kg

$Mg = Kx \qquad x = 0.2$ m

$M \times 10 = 20 \times 0.2$

3 marks

Lee pulls the mass down a further distance of 0.10 m.

Question 10

By how much has the potential energy stored in the spring changed?

$$\Delta E = \frac{Kx_2^2}{2} - \frac{Kx_1^2}{2} = \frac{20 \times 0.3^2}{2} - \frac{20 \times 0.2^2}{2}$$

0.5	J

9+10 together 16% Average 2.5

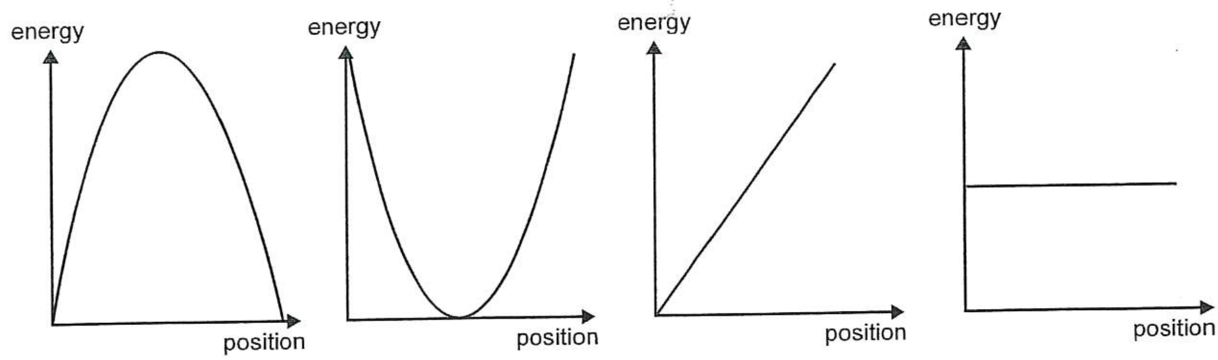
3 marks

He now releases the mass, so that the mass-spring system oscillates. Ignore air resistance.

Question 11

Which one of the curves (**A–D**) below could best represent the variation of the **total energy** of the oscillating mass-spring system as a function of position?

A. **B.** **C.** **D.**



D

2 marks

Use the following information to answer Questions 12–14.

A novelty toy consists of a metal ball of mass 0.20 kg hanging from a spring of spring constant $k = 10\ N\ m^{-1}$. The spring is attached to the ceiling of a room as shown in Figure 7. Ignore the mass of the spring.

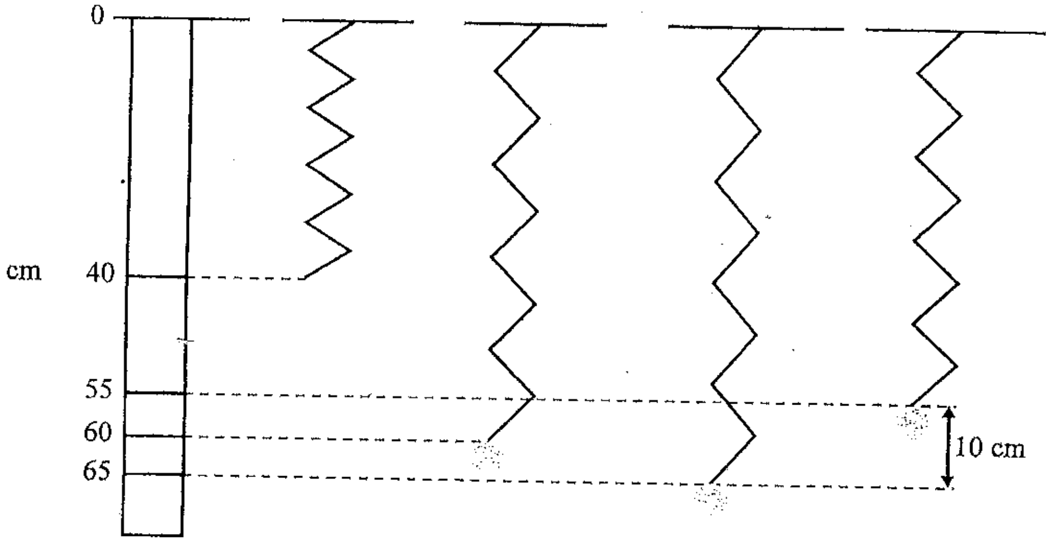


Figure 7

Without the ball attached, the spring has an unstretched length of 40 cm. When the ball is attached, but not oscillating, the spring stretches to 60 cm.

Question 12 40%

How much energy is stored in the spring when the ball is hanging stationary on it?

You must show your working.

$x = 0.6 - 0.4 = 0.2\ m$

$E = \frac{kx^2}{2} = \frac{10 \times 0.2^2}{2}$

0.2 J

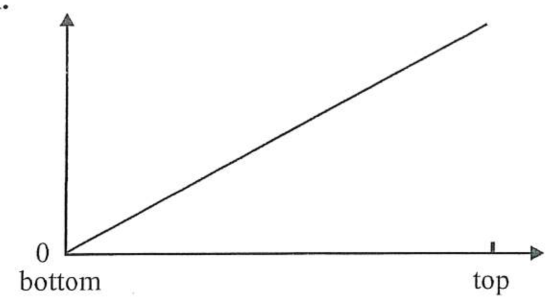
2 marks

The ball is now pulled down a further 5 cm and released so that it oscillates vertically over a range of approximately 10 cm.

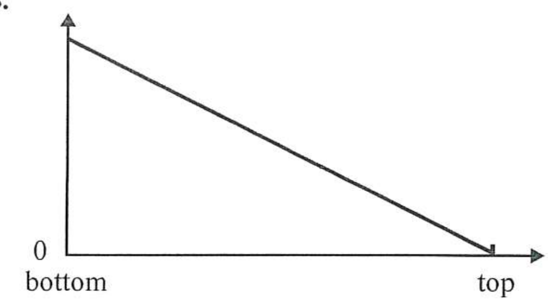
Gravitational potential energy is measured from the level at which the ball is released. Ignore air resistance.

Use Graphs A–E in answering Questions 13 and 14.

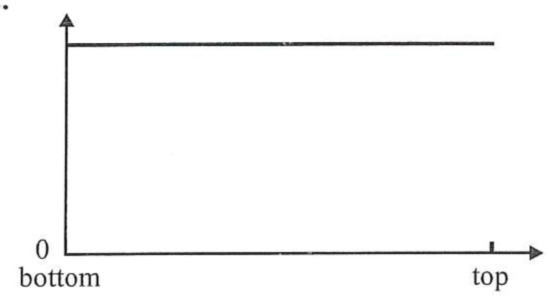
A.



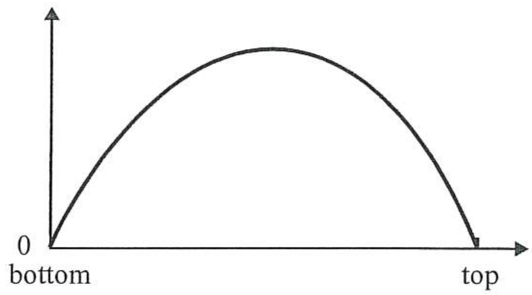
B.



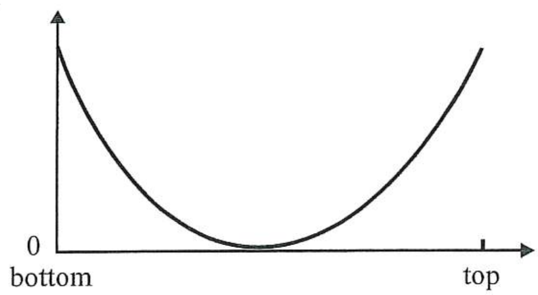
C.



D.



E.



Question 13 38%

Which of the graphs best represents the shape of the graph of **kinetic** energy of the system as a function of height?

D

2 marks

Question 14 50%

Which of the graphs best represents the **gravitational potential** energy of the system as a function of height?

A

2 marks

The following information relates to Questions 7–9.

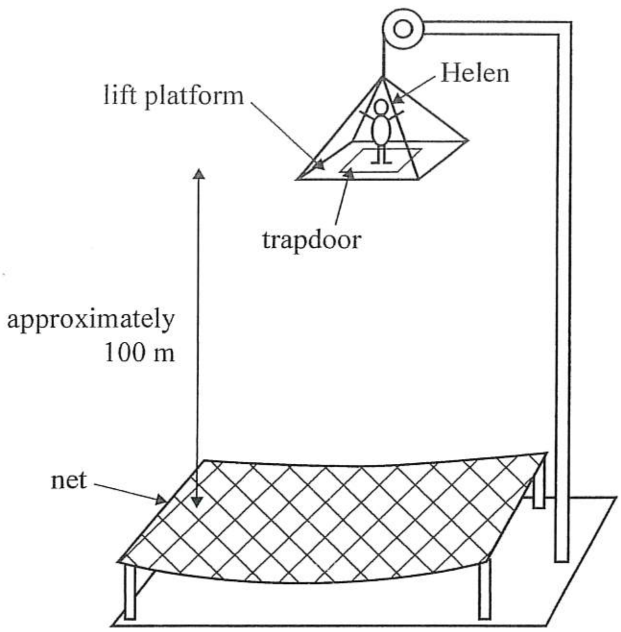


Figure 3

A ride in an amusement park allows a person to free fall without any form of attachment. A person on this ride is carried up on a platform to the top. At the top, a trapdoor in the platform opens and the person free falls. Approximately 100 m below the release point, a net catches the person.

A diagram of the ride is shown in Figure 3.

Helen, who has a mass of 60 kg, decides to take the ride and takes the platform to the top.

The platform travels vertically upward at a constant speed of 5.0 m s^{-1}.

Question 7 64%

What is Helen's apparent weight as she travels up?

$v = \text{const}$ N is apparent weight

$N = mg$

600	N

2 marks

As the platform approaches the top, it slows to a stop at a uniform rate of 2.0 m s^{-2}.

Question 8 43%

What is Helen's apparent weight as the platform slows to a stop?

$$mg - N = ma$$
$$N = m(g - a)$$
$$N = 60(10 - 2)$$

480 N

3 marks

Helen next drops through the trapdoor and free falls. Ignore air resistance.

During her fall, Helen experiences 'apparent weightlessness'.

Question 9 26% Average 2.2

In the space below explain what is meant by apparent weightlessness. You should make mention of gravitational weight force and normal or reaction force.

Apparent weight is normal reaction force N.

Apparent weightlessness – $N = 0$

During the fall Helen is in free fall, her acceleration $= g$

It is not true weightlessness as gravity acting on her

4 marks

Question 12 62 %

On a loop-the-loop roller coaster, a loop in the track has a radius of 7.0 m as shown in Figure 5.
On a particular occasion, the mass of the trolley and riders is 600 kg.

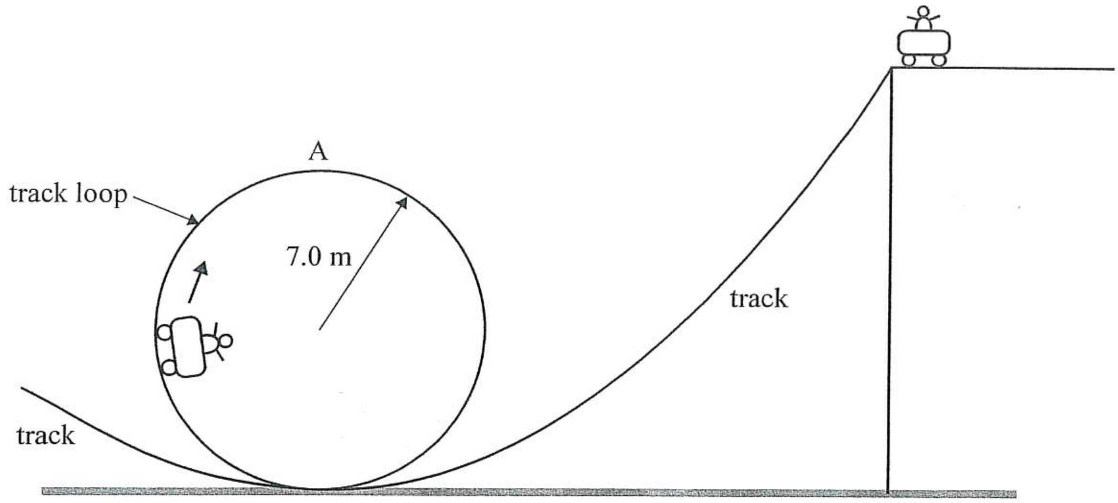


Figure 5

To go safely around the loop, the trolley wheels must not leave the rails at point A.
What is the minimum speed that the trolley must have at point A so that it does not leave the rails?

At A: $N = 0$

$$mg = \frac{mv^2}{r}$$

$$v = \sqrt{gr}$$

8.4	m s^{-1}

3 marks

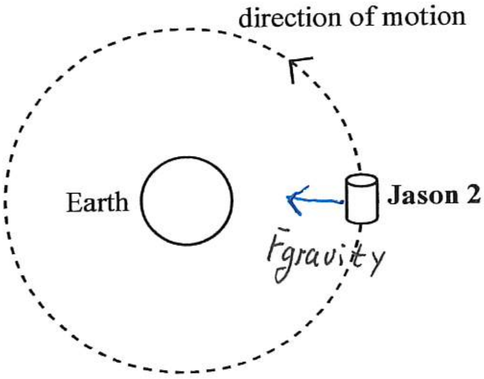
The following information relates to Questions 13 and 14.

The **Jason 2** satellite reached its operational circular orbit of radius 1.33×10^7 m on 4 July 2008 and then began mapping the Earth's oceans.

mass of the Earth = 5.98×10^{24} kg
mass of **Jason 2** = 525 kg
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

Question 13 26%

On the figure below, draw one or more labelled arrows to show the direction of any force(s) acting on **Jason 2** as it orbits Earth. You can ignore the effect of any astronomical bodies other than the Earth.



2 marks

Question 14 51%

What is the period of orbit of the **Jason 2** satellite?

$$\frac{T^2}{r^3} = \frac{4\pi^2}{GM} \qquad T = \sqrt{\frac{4\pi^2 r^3}{GM}}$$

$$T = \sqrt{\frac{4\pi^2 \times (1.33 \times 10^7)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}}$$

1.53×10^4	s

3 marks

END OF AREA OF STUDY 1

The following information relates to Questions 3 and 4.

Two physics students are conducting an experiment in which a block, m_1, of mass 0.40 kg is being pulled by a string across a frictionless surface. The string is attached over a frictionless pulley to another mass, m_2, of 0.10 kg. The second mass, m_2, is free to fall vertically. This is shown in Figure 1.

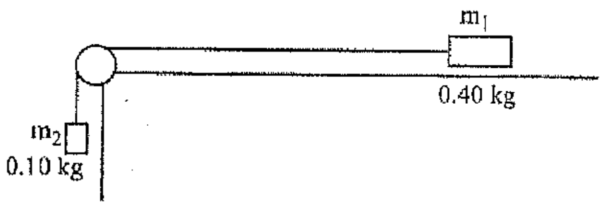


Figure 1

The block is released from rest.

Question 3 10%

What is the acceleration of the block m_1?

$$T = M_1 a \qquad T = 0.4a$$
$$M_2 g - T = M_2 a \quad + \quad 0.1 \times 10 - T = 0.1a$$
$$1 = 0.5a$$

2 m s^{-2}

2 marks

Question 4 51%

What is the kinetic energy of the block m_1, after it has travelled 1.0 m?

$$a = 2\,ms^{-2}$$
$$v^2 = 2aS$$
$$E_K = \frac{mv^2}{2} = maS = 0.4 \times 2 \times 1$$

0.8 J

2 marks

The following information relates to Questions 5 and 6.

In designing a bicycle track at a racing track, the designer wants to bank the track on a particular corner so that the bicycles will go around the corner with no sideways frictional force required between the tyres and the track at 10 m s^{-1}.

Figures 2a and 2b below show the banked track and the bicycle.

Question 5 43 %

On **Figure 2b** draw two arrows to show the two forces acting on the bicycle and rider (treated as a single object).

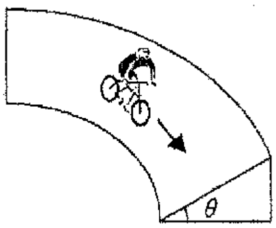


Figure 2a

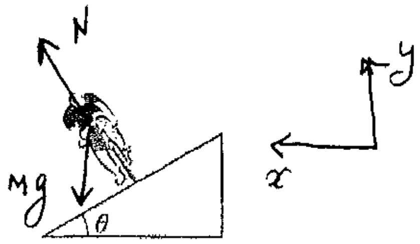


Figure 2b

2 marks

Question 6 48 %.

The circular path of the bicycle has a constant radius of 100 m, and the bicycle will be travelling at a constant 10 m s^{-1}.

What should be the value of the angle of the bank, θ, so that the bicycle travels around the corner with no sideways frictional force between the tyres and the track?

$$x: \quad N\sin\theta = \frac{Mv^2}{r}$$

$$y: \quad N\cos\theta - mg = 0$$

$$\tan\theta = \frac{v^2}{gr}$$

$$\theta = \tan^{-1}\left(\frac{10^2}{10 \times 100}\right)$$

$\boxed{5.7°}$

3 marks

The following information relates to Questions 13 and 14.

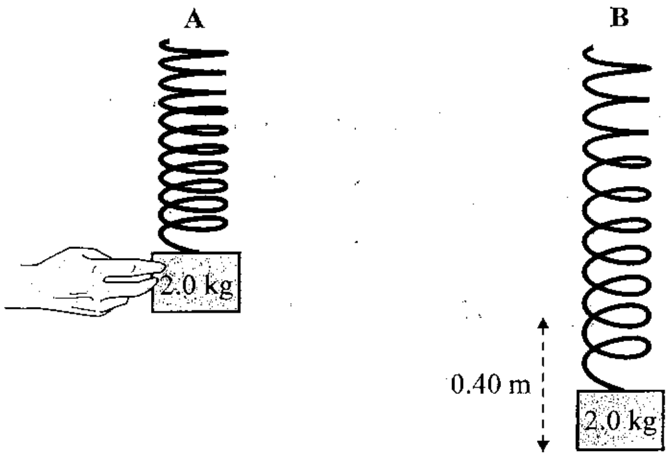


Figure 5a **Figure 5b**

Figure 5a shows an ideal spring with a 2.0 kg mass attached. The spring-mass system is held so that the spring is not extended. The mass is **gently** lowered and the spring stretches until, in Figure 5b, the spring-mass system is at rest. The spring has extended by 0.40 m.

Question 13 52 % average 1.1

What is the value of the spring constant, k, of the spring?

Initial energy mgh = 2×10×0.4 [illegible]

Final energy

$$mg = kx$$

$$2 \times 10 = k \times 0.4$$

$$k = \frac{20}{0.4}$$

50	N m^{-1}

2 marks

Question 14 13 % average 0.7

What is the difference in the magnitude of the total energy of the **spring-mass system** between Figure 5a and Figure 5b?

Write your answer in the box, and show your working in the space provided.

Initial energy $Mgh = 2 \times 10 \times 0.4 = 8J$

Final energy $\frac{kx^2}{2} = \frac{50 \times 0.4^2}{2} = 4J$

$E_0 - E_f = 8 - 4 = 4J$

4J J

2 marks

The following information relates to Questions 15–17.

Physics students are conducting a collision experiment using two trolleys, m_1 of mass 0.40 kg and m_2 of mass 0.20 kg.

- Trolley m_1 has a light spring attached to it. When uncompressed, this spring has a length of 0.20 m.
- Trolley m_1 is initially moving to the right. Trolley m_2 is stationary.
- The trolleys collide, compressing the spring to a length of 0.10 m.
- The trolleys then move apart again, and the spring reverts to its original length (0.20 m), and both trolleys move off to the right.
- The collision is elastic.
- The trolleys do not experience any frictional forces.

The situation is shown in Figure 6.

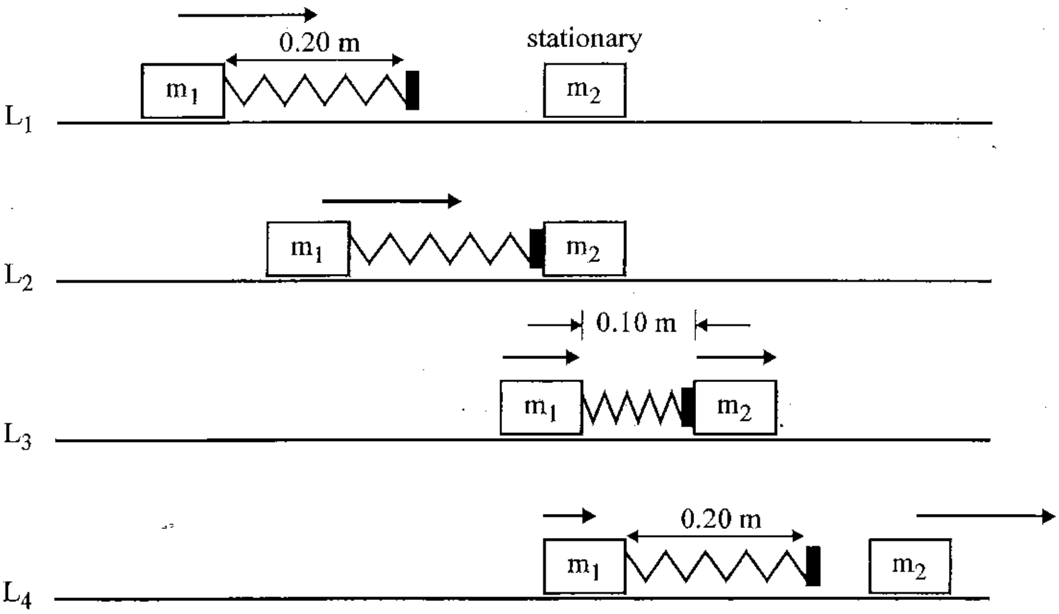
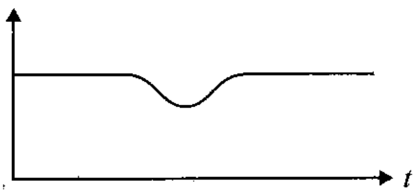


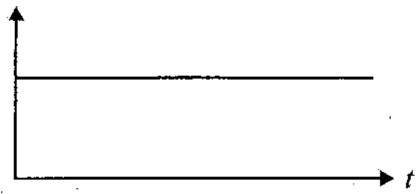
Figure 6

Use the graphs below to answer Questions 15–17.

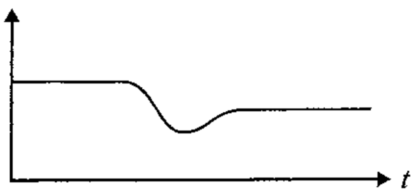
A.



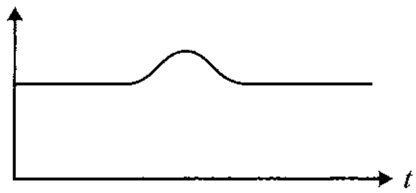
B.



C.



D.



Question 15 36%

Which graph best shows how the total kinetic energy of the system varies with time before, during and after the collision? Explain your answer.

A

In elastic collision kinetic energy after collision equals that before collision. During the collision some of the kinetic energy converted to spring potential energy and then back again

2 marks

Question 16 56%

Which graph best shows how the total momentum of the system varies with time before, during and after the collision? Explain your answer.

B

Momentum always conserved.

2 marks

Question 17 35%

If the collision had been inelastic, which graph would best show how the magnitude of the total momentum of the system varies with time before, during and after the collision? Explain your answer.

B

Momentum alway conserved in elastic or inelastic collision

2 marks

The following information relates to Questions 16–20.

Physics students are conducting an experiment on a spring which is suspended from the ceiling.

Ignore the mass of the spring.

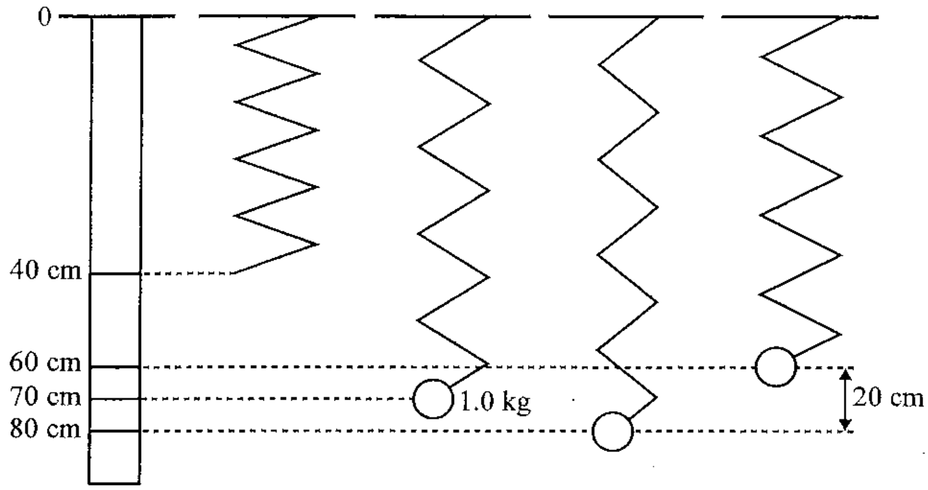


Figure 7

Without the mass attached, the spring has an unstretched length of 40 cm. A mass of 1.0 kg is then attached. When the 1.0 kg mass is attached, with the spring and mass stationary, the spring has a length of 70 cm.

Question 16 48%. average 1.1

What is the spring constant, k, of the spring?

$x = 0.7 - 0.4 = 0.3\,m$

$mg = kx$

$k = \frac{1 \times 10}{0.3}$

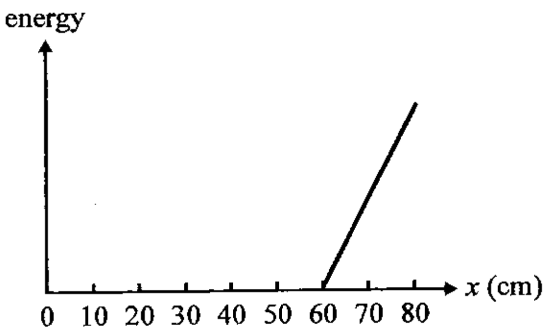
33 N m^{-1}

2 marks

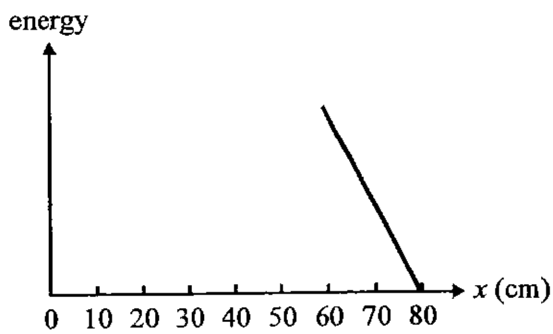
The spring is now pulled down a further 10 cm from 70 cm to 80 cm and released so that it oscillates. Gravitational potential energy is measured from the point at which the spring is released (80 cm on Figure 7).

Use the following graphs (A–H) in answering Questions 17–20.

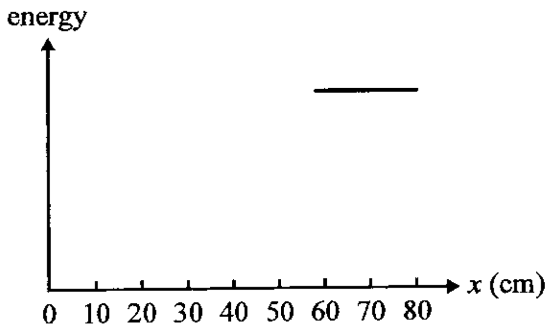
A.



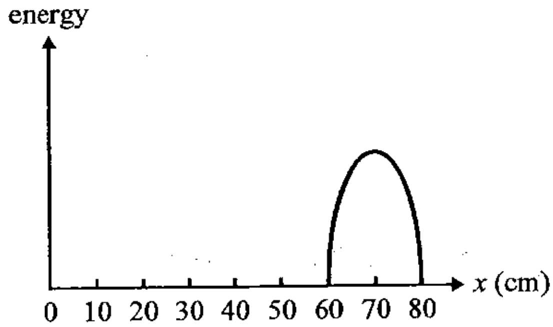
B.



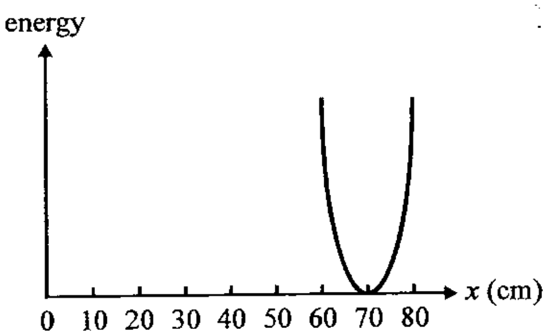
C.



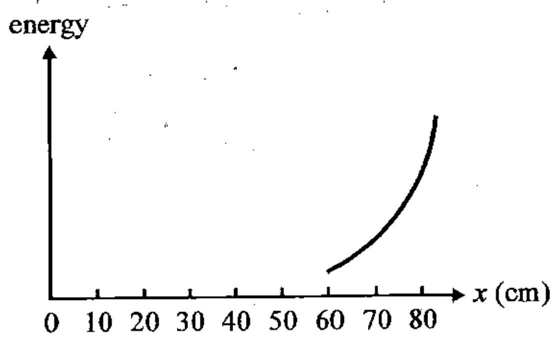
D.



E.



F.



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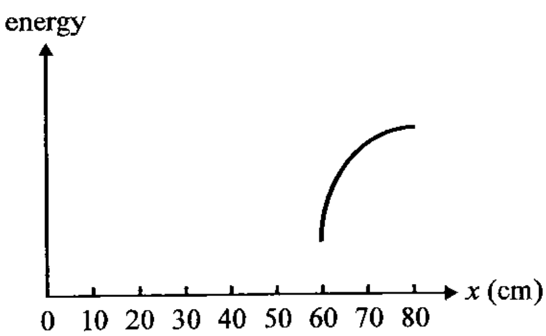
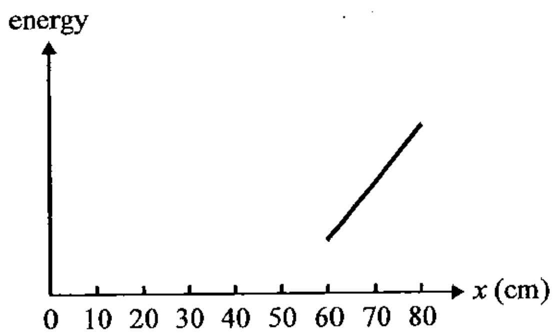


H.



Question 17 42 %

Which of the graphs (A–H) best shows the variation of the kinetic energy of the system plotted against the length of the stretched spring?

D

1 mark

Question 18 65 %

Which of the graphs (A–H) best shows the variation of the total energy of the system of spring and mass plotted against the length of the stretched spring?

C

1 mark

Question 19 46 %

Which of the graphs (A–H) best shows the variation of the gravitational potential energy of the system of spring and mass (measured from the lowest point as zero energy) plotted against the length of the stretched spring?

B

1 mark

Question 20 8 % average 0.8

Which of the graphs (A–H) best shows the variation of the spring (strain) potential energy plotted against the length of the stretched spring?

Give your reasons for choosing this answer for the spring (strain) potential energy.

F

Strain (spring) potential energy proportional to x^2.
Between total lengths 60 and 80 cm it never equal 0.
It will approach 0 when x will approach 40 cm and increasing all the time when length increases from 60 to 80 cm.

3 marks

Question 2 17%

A 1.2 kg block moves to the right along the frictionless surface and collides elastically with a stationary block of mass 2.4 kg as shown in Figure 3.

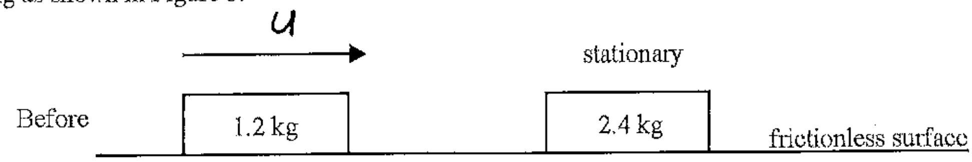


Figure 3

After the elastic collision, the 1.2 kg block moves to the left as shown in Figure 4.

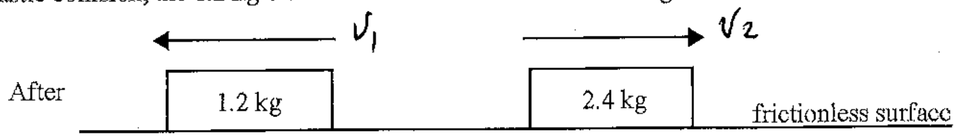


Figure 4

After the collision, the momentum of the 2.4 kg block is **greater** than the momentum that the 1.2 kg block had before the collision.

Explain why the greater momentum of the 2.4 kg block is consistent with the principle of conservation of momentum.

$1.2u = 2.4v_2 - 1.2v_1$ ← law of conservation of momentum

$2.4v_2 = 1.2u + 1.2v_1 > 1.2u$

3 marks

Question 4

Two metal spheres hang from the ceiling as shown in Figure 6. Cable A runs between the ceiling and the upper sphere of mass 2.0 kg. Cable B runs between the 2.0 kg sphere and the 1.0 kg sphere. Assume that the cables have no mass.

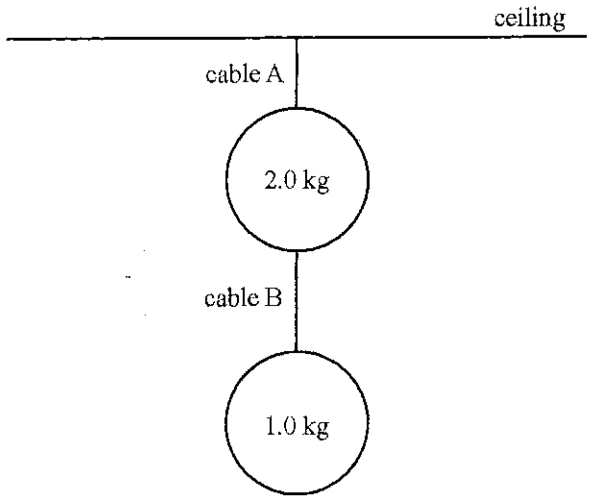


Figure 6

a. State the force (magnitude and direction) that cable A applies to the 2.0 kg sphere. 60 %

Force magnitude	30 N
Force direction	↑

Cable A hold both 2 and 1 kg spheres

2 marks

b. Newton's third law is sometimes stated as 'To every action there is an equal and opposite reaction'. If the weight (the gravitational force by Earth) of the 2.0 kg sphere is taken as the 'action' force, identify the corresponding 'reaction' force and give its direction. 12 % average 0.3

on Earth ↑

2 marks

Question 7

Kim has attached a ball of mass 0.20 kg to a piece of string of length 1.8 m and is making it move in a **horizontal** circle on a frictionless surface. Kim gradually increases the speed, v, of the ball. The situation is shown from above in Figure 9. The string has a breaking force of 4.0 N.

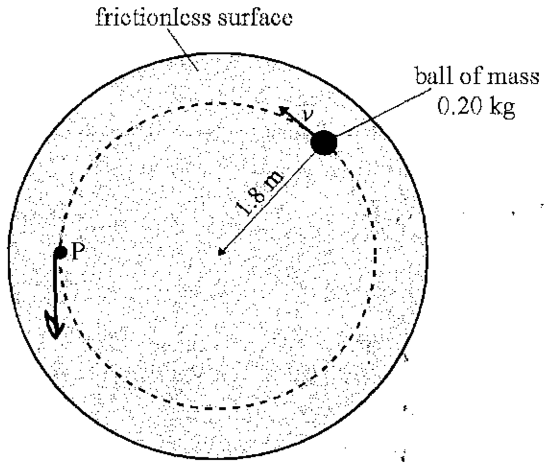


Figure 9

a. Calculate the greatest speed the ball can reach before the string breaks. 77 %

$$F = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{Fr}{m}}$$

$$v = \sqrt{\frac{4 \times 1.8}{0.2}}$$

6 m s^{-1}

2 marks

b. When the ball is at position P, the string breaks. Draw an arrow on Figure 9 from point P, indicating the direction in which the ball travels **immediately after** the string breaks. 75 %

1 mark

c. On another occasion, Kim swings the same ball of mass of 0.20 kg in a **vertical** circle at constant speed. She uses a much stronger string, which does not break.

She notices that the tension in the string is greater at the bottom of the circle than it is at the top of the circle.

Explain why the tension at the bottom is greater than the tension at the top. You may include a diagram as part of your explanation. 13 % average 1.0

Top $T_t + mg = \frac{mv^2}{r}$

Bottom $T_B - mg = \frac{mv^2}{r}$

$T_t > T_B$

3 marks

SECTION A – Core studies

Instructions for Section A

Answer **all** questions in this section in the spaces provided. Write using black or blue pen.
Where an answer box has a unit printed in it, give your answer in that unit.
You should take the value of g to be 10 m s^{-2}.
Where answer boxes are provided, write your final answer in the box.
In questions worth more than 1 mark, appropriate working should be shown.
Unless otherwise indicated, diagrams are not to scale.

Area of study – Motion in one and two dimensions

Question 1 (5 marks)

Students set up an inclined plane surface, as shown in Figure 1a. It is angled at 10° to the horizontal. They place a frictionless trolley of mass 0.50 kg at the top of the incline, so that the distance from the front of the trolley to the stopper at the bottom is 3.5 m.

They release the trolley from rest and find that it takes 2.0 s to reach the stopper at the bottom.

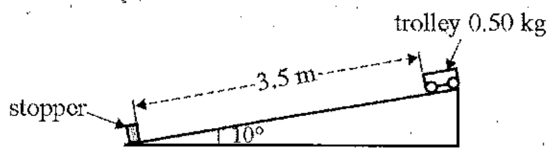


Figure 1a

a. Calculate the acceleration of the trolley. 75 % 2 marks

$a = g \sin 10^0$

$a = 10 \sin 10^\circ$

1.74 m s^{-2}

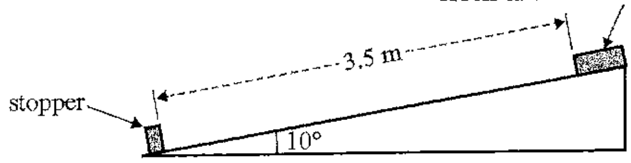


Figure 1b

b. The students replace the frictionless trolley with a block of wood of the same mass. They release the block of wood at a distance of 3.5 m from the stopper, the same as they did with the trolley. When the block is sliding down the incline, there is a constant frictional force between it and the surface. They find that it takes 6.0 s to reach the stopper at the bottom.

Calculate the magnitude of the frictional force of the plane surface acting on the block. 32% 3 marks

average 1.2

$S = \frac{at^2}{2}$ $a = \frac{2S}{t^2}$ $a = \frac{2 \times 3.5}{6^2} = 0.19 \, ms^{-2}$

$mg \sin\theta - F_{fr} = ma$

$F_{fr} = 0.5 \times 10 \sin 10° - 0.5 \times 0.19$

0.77	N

Question 2 (4 marks)

Students set up an experiment that consists of two masses, m_1, of 2.0 kg, and m_2, of 6.0 kg, connected by a string, as shown in Figure 2. The mass of the string can be ignored. The surface is frictionless. The pulley is frictionless.

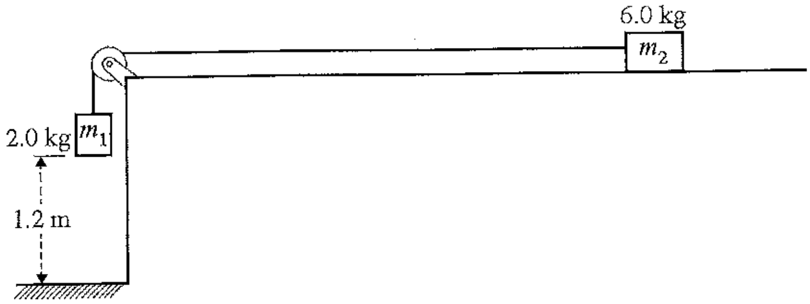


Figure 2

At the start of the experiment, the bottom of mass m_1 is 1.2 m above the floor and both masses are stationary.

a. Calculate the gravitational force on m_1. Include the correct unit in your answer. 66% 1 mark

$F_g = m_1 g$

20 N

b. Calculate the tension in the string as m_1 is falling. 24% average 0.8 3 marks

$m_1 g - T = m_1 a$ $\quad 20 - T = 2a$

$T = m_2 a$ $\quad T = 6a$ +

$20 = 8a \quad a = 2.5\ \text{ms}^{-2}$

$T = 6 \times 2.5 = 15\ \text{N}$

15 N

Question 5 (4 marks)

A mass of 2.0 kg is being swung by a light rod in a vertical circle of radius 1.0 m at a constant speed of 7.0 m s^{-1}, as shown in Figure 5.

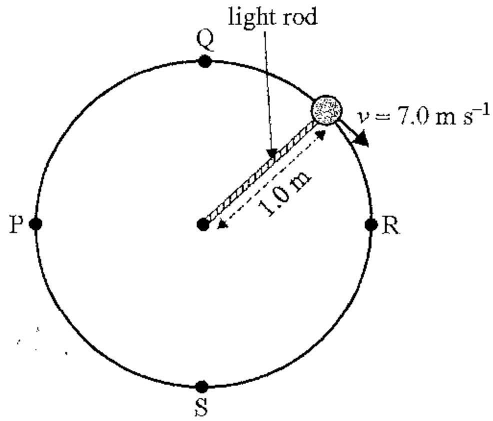
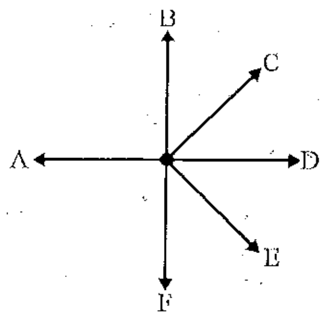


Figure 5

a. Which of the directions (A–F) below shows the direction of the net force on the mass when it is at point P? 68% 1 mark



D

b. Calculate the magnitude of the tension in the light rod at point S. Show the steps of your working. 3 marks

40 %, average 1.3

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

$T = 2 \times 10 + \frac{2 \times 7^2}{1}$

118 N

Question 6 (6 marks)

Students hang a mass of 1.0 kg from a spring that obeys Hooke's law with $k = 10$ N m^{-1}. The spring has an unstretched length of 2.0 m. The mass then hangs stationary at a distance of 1.0 m below the unstretched position (X) of the spring, at Y, as shown at position 6b in Figure 6. The mass is then pulled a further 1.0 m below this position and released so that it oscillates, as shown in position 6c.

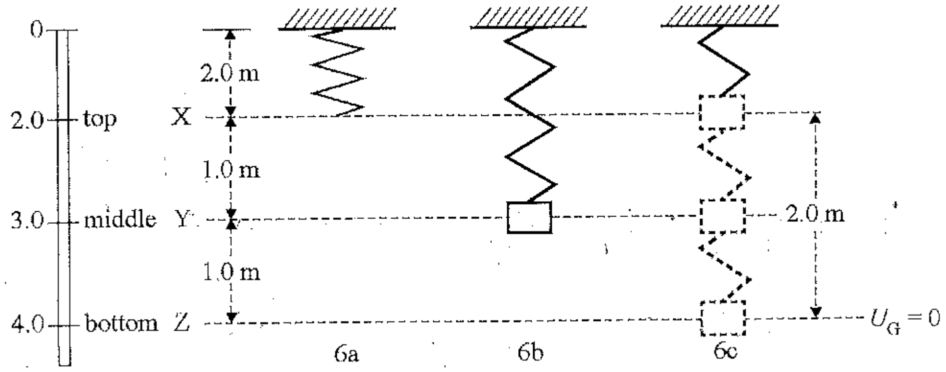


Figure 6
not to scale

The zero of gravitational potential energy is taken to be the bottom point (Z).

The spring potential energy and gravitational potential energy are plotted on a graph, as shown in Figure 7.

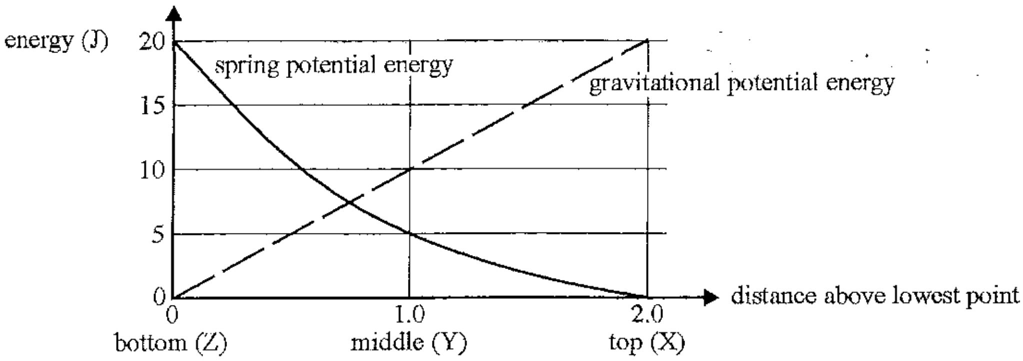


Figure 7

a. Calculate the total energy of the system when the mass is at its lowest point (Z). 81 % 1 mark

20 J

b. From the data in the graph, calculate the speed of the mass at its midpoint (Y). 42 % average 0.9 2 marks

$E_K = E_{total} - E_{gp} - E_{sp} = 20 - 5 - 10 = 5 J$

$\frac{mv^2}{2} = 5 \quad v = \sqrt{\frac{10}{m}} \quad v = \sqrt{\frac{10}{1}}$

3.2 m s^{-1}

Without making any other changes, the students now pull the mass down to point P, 0.50 m below Y. They release the mass and it oscillates about Y, as shown in Figure 8.

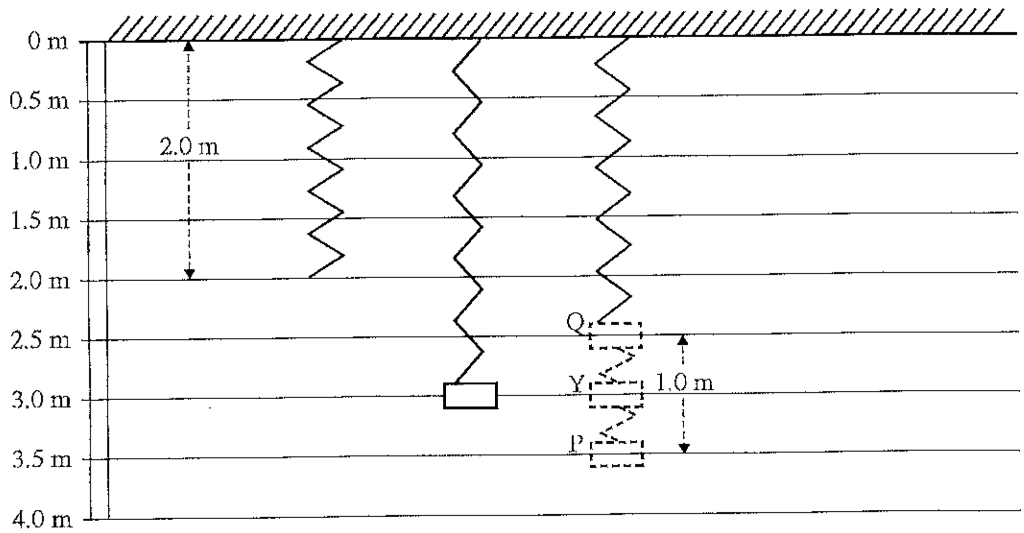


Figure 8

The students now take the zero of gravitational potential energy to be at P and the zero of spring potential energy to be at Q. They expect the total energy at P to be equal to the total energy at Q.

They prepare the following table.

Position	**Gravitational potential energy (GPE)**	**Spring potential energy (SPE)**	**Kinetic energy (KE)**
Q	GPE = mgh $= 1.0 \times 10 \times 1.0 = 10$ J	SPE = 0	KE = 0
P	GPE = 0	SPE = $\frac{1}{2}k(\Delta x)^2$ $= \frac{1}{2} \times 10 \times 1.0^2 = 5.0$ J	KE = 0

However, their calculation of the total energy (GPE + SPE + KE) at Q (10 J) is different from their calculation of the total energy at P (5.0 J).

c. Explain the mistake that the students have made. 7 % average 0.5 — 3 marks

At Q SPE ≠ 0

SPE should be calculated from the unstretched length

At Q SPE = $\frac{K \times 0.5^2}{2} = \frac{10 \times 0.25}{2} = 1.25$ Total energy 11.25 J

At P SPE = $\frac{K \times 1.5^2}{2} = \frac{10 \times 2.25}{2} = 11.25$ J

Total = 11.25 J

Question 7 (6 marks)

A satellite is in a geostationary circular orbit over Earth's equator. It remains vertically above the same point X on the equator, as shown in Figure 9.

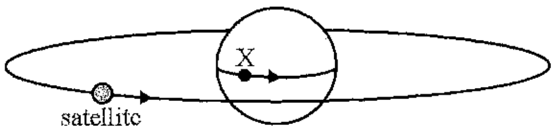


Figure 9

Data

mass of Earth	$M_E = 6.0 \times 10^{24}$ kg
radius of Earth	$R_E = 6.4 \times 10^{6}$ m
mass of satellite	1000 kg
universal gravitational constant	$G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}

a. Calculate the period of the orbit of the satellite. 41% — 1 mark

$24 \times 60 \times 60$

86400 s

b. Calculate the radius of the orbit of the satellite from the centre of Earth. 32% average 0.8 — 2 marks

$\frac{v^2}{r} = g = G\frac{M}{r^2}$

$v^2 = \frac{4\pi r^2}{T^2}$ $\quad \frac{4\pi r^2}{r T^2} = \frac{GM}{r^2}$

$\frac{4\pi^2 r^3}{T^2} = GM$

$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$ $\quad r = \sqrt[3]{\frac{6.67\times10^{-11} \times 6\times10^{24} \times 86400^2}{4\pi^2}}$

4.2×10^{7} m

c. An astronaut of mass 65 kg is on board the satellite. She is interviewed on television and says that she is weightless.

Explain how the terms 'weight', 'weightlessness' and 'apparent weightlessness' either apply or do not apply to the astronaut. 19 % average 1.2 3 marks

Weight = mg yes - apply

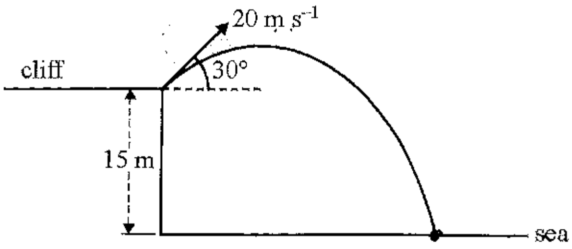
weightlessness mg = 0 no - don't apply

app. weightlessness N = 0 a = g yes - apply

Question 8 (6 marks)

A stone is thrown from the top of a 15 m high cliff above the sea at an angle of 30° to the horizontal. It has an initial speed of 20 m s^{-1}. The situation is shown in Figure 10. Ignore air resistance.

y ↑



$y = 0$

Figure 10
not to scale

a. Calculate the time taken for the stone to reach the sea. 42% average 1.5 — 3 marks

$y = 15 + 20\sin 30° t - \frac{10t^2}{2}$

$5t^2 - 10t - 15 = 0$

$t^2 - 2t - 3 = 0$

$t = 3$

3 s

b. Calculate the magnitude and direction of the velocity of the stone immediately before it reaches the sea. Give the direction as the magnitude of the angle between the velocity and the horizontal. — 3 marks

27% average 1.2

$v_x = 20\cos 30° = 17.3\ \text{m s}^{-1}$

$v_y = 20\sin 30° - g \times 3 = -20\ \text{m s}^{-1}$

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{17.3^2 + 20^2} = 26.4$

$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{20}{17.3}\right)$

26.4 m s^{-1}	49 °

Question 2 (11 marks)

Jo and Sam are conducting an experiment using a mass attached to a spring. The spring has an unstretched length of 40 cm. The situation is shown in Figure 3a.

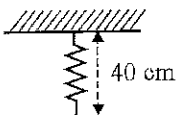


Figure 3a

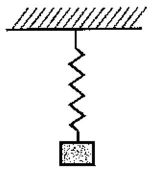


Figure 3b

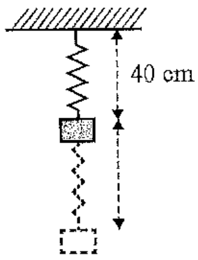


Figure 3c

They begin their experiment by measuring the spring constant of the spring by progressively adding 50 g masses to it, as shown in Figure 3b. They measure the resultant length of the spring with the mass stationary and record the following data.

Number of 50 g masses	0	1	2	3
Length of spring	40 cm	50 cm	60 cm	70 cm

a. Show that the spring constant is equal to 5.0 N m^{-1}. 6% average 1.2 — 2 marks

$mg = kx$

$0.1 \times 10 = k(0.6 - 0.4)$

$k = 5.0 \text{ N m}^{-1}$

Jo and Sam now attach four 50 g masses to the spring and release it from its unstretched position, which is a length of 40 cm. They allow the masses to oscillate freely, as shown in Figure 3c.

b. Find the **extension** of the spring at the lowest point of its oscillation (when it is momentarily stationary). Ignore frictional losses. Show your reasoning. 14% average 0.6 — 3 marks

$mgx = \frac{kx^2}{2}$

Energy at the top Energy at the bottom $x = \frac{2mg}{k} = \frac{2 \times 0.2 \times 10}{5}$

0.8	m

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Jo and Sam measure the position of the four masses as they oscillate freely up and down, as described previously. From this data, they plot graphs of the gravitational potential energy and spring potential energy. Their results are shown in Figure 4.

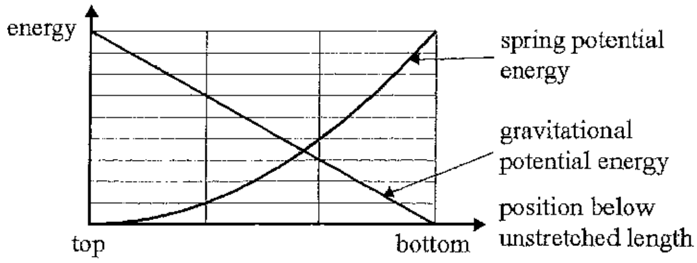

Figure 4

Jo says their calculation must be wrong because the graphs should add to a constant amount, the total energy of the system. However, Sam says that the graphs are correct.

27%

c. Explain why Jo is incorrect. Your explanation should include the reason that the spring potential energy and the gravitational potential energy do not add to a constant amount at each point. 2 marks

Kinetic missing. If it will be added they will add to the same value

average 0.7

d. Calculate the maximum speed of the masses during the oscillation. Show your working. 7% 4 marks

average 0.5

$mg\times 0.4 + \frac{K\,0.4^2}{2} + \frac{mv^2}{2} = Mg\times 0.8$

$0.8 + 0.4 + 0.1v^2 = 1.6$

$0.1v^2 = 0.4$

$v^2 = 4$

$v = 2\ m\,s^{-1}$

2 $m\,s^{-1}$

Question 4 (8 marks)

Mary and Bob are riding in a car on a roller-coaster. The roller-coaster is designed so that the riders will feel 'weightless' at the top of the ride (point A).

It can be assumed that the track is circular in shape at and near the points A and B. The radius of these circular paths at A and B is 20 m. This is shown in Figure 7. Ignore air resistance and frictional forces.

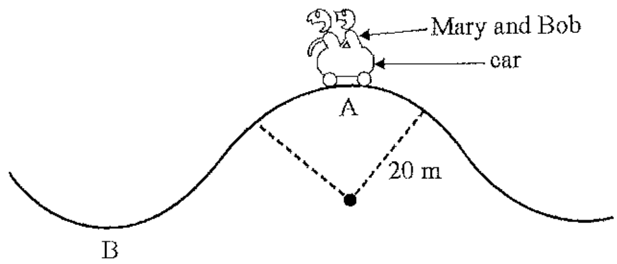

Figure 7

a. Calculate the minimum speed at which Mary and Bob must be moving at point A for them to feel weightless. 69% — 2 marks

$v = \sqrt{gr}$

14.1 m s^{-1}

b. Explain why Mary and Bob feel weightless at point A at this speed. — 3 marks

$N = 0$ $a = g$ app. weightlessness, not true weightlessness, Free fall. as gravity still acting

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SECTION A – Core studies

Instructions for Section A

Answer **all** questions in this section in the spaces provided. Write using black or blue pen.
Where an answer box has a unit printed in it, give your answer in that unit.
You should take the value of g to be 10 m s^{-2}.
Where answer boxes are provided, write your final answer in the box.
In questions worth more than 1 mark, appropriate working should be shown.
Unless otherwise indicated, diagrams are not to scale.

Area of study – Motion in one and two dimensions

Question 1 (7 marks)

Block A, of mass 4.0 kg, is moving to the right at a speed of 8.0 m s^{-1}, as shown in Figure 1. It collides with a stationary block, B, of mass 8.0 kg, and rebounds to the left. Its speed after the collision is 2.0 m s^{-1}.

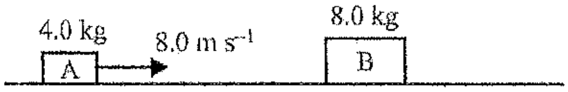

Figure 1

a. Calculate the speed of block B after the collision. 42 % average 0.9 — 2 marks

$4 \times 8 = 4 \times (-2) + 8 v_f$

$p_0 = p$

| 5.0 m s^{-1} |

b. Explain whether the collision is elastic or inelastic. Include some calculations in your answer. 55% average 1.3 — 2 marks

$E_{K_0} = 128\ J$

$E_{K_f} = 108\ J$

$E_{K_f} < E_{K_0}$

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Question 3 (3 marks)

A model car of mass 2.0 kg is on a track that is part of a vertical circle of radius 4.0 m, as shown in *Figure 3*. At the lowest point, L, the car is moving at 6.0 m s^{-1}. Ignore friction.

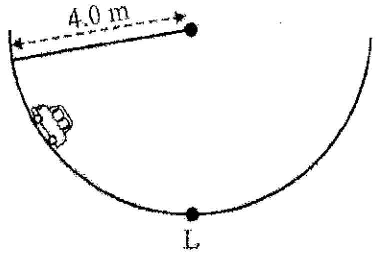
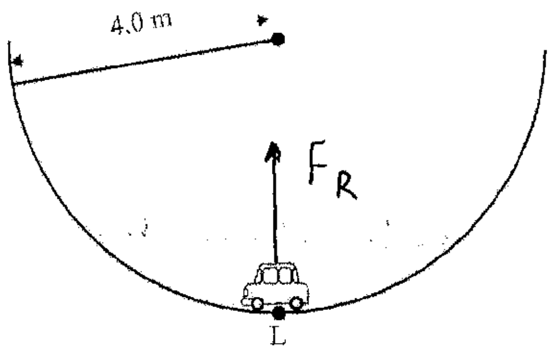


Figure 3

a. At the lowest point (L), draw the resultant force acting on the car as an arrow attached to the car, labelled F_R. 75% — 1 mark



b. Calculate the magnitude of the force exerted by the track on the car at its lowest point (L). Show your working. — 2 marks

47%

$$F = \frac{mv^2}{r} + mg$$

$$F = \frac{2 \times 6^2}{4} + 2 \times 10$$

38 N

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Question 5 (5 marks)

A golfer hits a ball on a part of a golf course that is sloping downwards away from him, as shown in Figure 5.

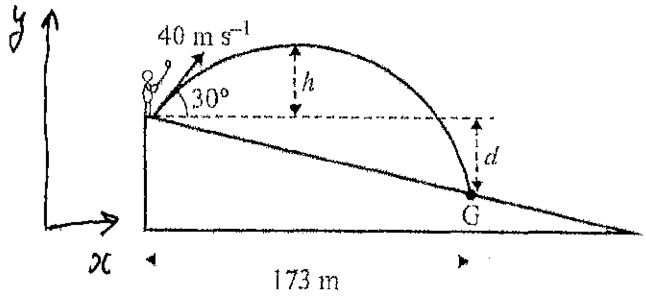

Figure 5
not to scale

The golfer hits the ball at a speed of 40 m s^{-1} and at an angle of 30° to the horizontal. Ignore air resistance.

a. Calculate the maximum height, h, that the ball rises above its initial position. 76% 2 marks

$u_y = 40 \sin 30° = 20 \text{ m s}^{-1}$

$v_y^2 = u^2 + 2gh$

$0 = 20^2 - 2 \times 10 h$

$h = 20$ m

20 m

b. The ball lands at a point at a horizontal distance of 173 m from the hitting-off point, as shown above.

Calculate the vertical drop, d, from the hitting-off point to the landing point, G. 41% 3 marks

average 1.5

$x = u \cos 30° t$

$173 = 40 \cos 30° t$

$t = 5$ s

$y = 40 \sin 30° t - \frac{gt^2}{2}$

$y = 20 \times 5 - \frac{10 \times 5^2}{2} = -25$

−25 m

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DO NOT WRITE IN THIS AREA

Question 6 (8 marks)

A mass of 2.0 kg is suspended from a spring, with spring constant $k = 50 \text{ N m}^{-1}$, as shown in Figure 6.

It is released from the unstretched position of the spring and falls a distance of 0.80 m. Take the zero of gravitational potential energy at its lowest point.

Figure 6

a. Calculate the change in gravitational potential energy as the mass moves from the top position to the lowest position. 87% — 1 mark

$E = mgh$

16 J — J

b. Calculate the spring potential energy at its lowest point. 81% — 2 marks

$E = \frac{1}{2} k x^2$

16 J — J

c. Calculate the speed of the mass at its midpoint (maximum speed). 36% average 1.2 — 3 marks

$E = mgx + \frac{1}{2}kx^2 + \frac{1}{2}mv^2$

$16 = 8 + 4 + \frac{1}{2} \times 2 v^2$

$v^2 = 4$

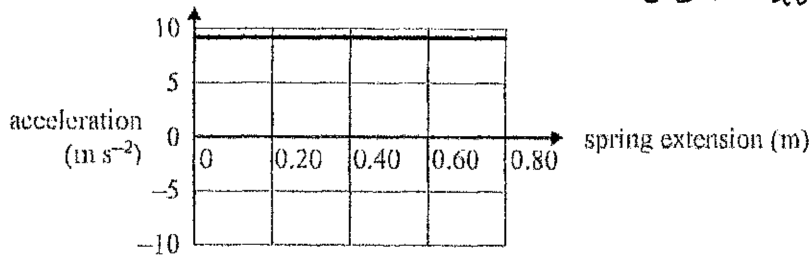
$v = 2 \text{ m s}^{-1}$

2 — m s^{-1}

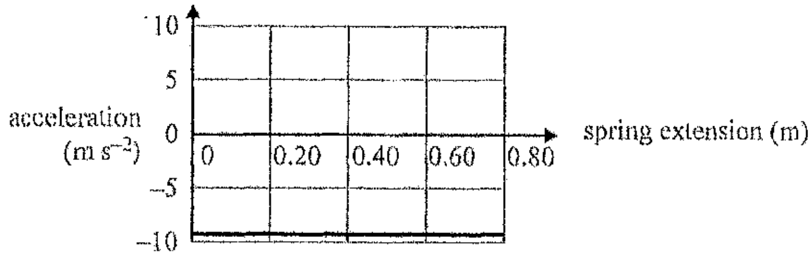
d. Which one of the following graphs (**A.**–**D.**) best shows the acceleration of the mass as it goes from the highest point to the lowest point? Take upwards as positive. Give a reason for your choice. 2 marks

25% average 0.7

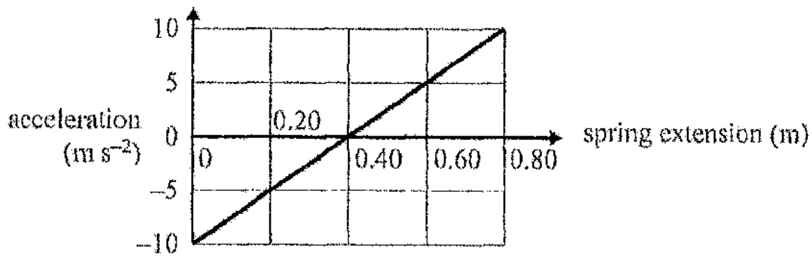
A.



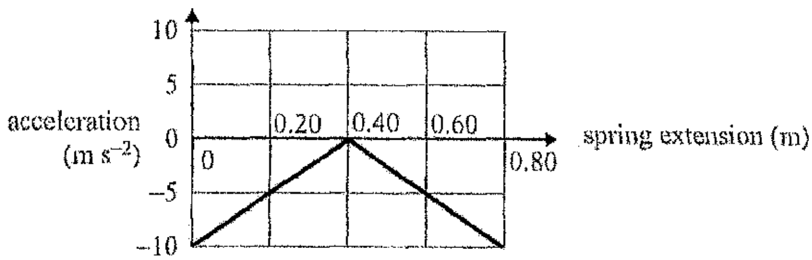
B.



C.



D.



$\boxed{C}$

In the middle $F_{net} = 0$, at the top $mg > kx$, at the bottom $kx > mg$, so acceleration should change direction

SECTION A – Core studies

Instructions for Section A

Answer **all** questions in this section in the spaces provided. Write using blue or black pen.
Where an answer box has a unit printed in it, give your answer in that unit.
You should take the value of g to be 10 m s^{-2}.
Where answer boxes are provided, write your final answer in the box.
In questions worth more than 1 mark, appropriate working should be shown.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Area of study – Motion in one and two dimensions

Question 1 (11 marks)

a. A train consists of an engine of mass 20 tonnes (20 000 kg) towing one wagon of mass 10 tonnes (10 000 kg), as shown in Figure 1.

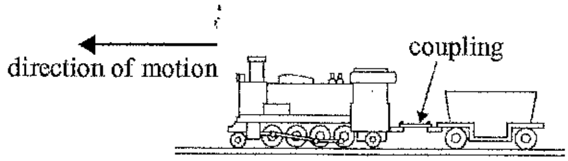


Figure 1

The train accelerates from rest with a constant acceleration of 0.10 m s^{-2}.

Calculate the speed of the train after it has moved 20 m. Show your working. 8 5⁻ⁱ 2 marks

$v^2 = u^2 + 2as$

$v^2 = 0 + 2 \times 0.1 \times 20$

$v = 2$

2 m s^{-1}

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b. The wagon has a frictional resistance of 2000 N.

Calculate the tension in the coupling between the engine and the wagon. 46 % average 1.0 2 marks

$T - F_{fr} = ma$

$T - 2000 = 10\,000 \times 0.1$

3000 N

c. In another situation, the engine, of mass 20 tonnes and moving at 3.0 m s^{-1}, collides with a stationary wagon of mass 10 tonnes and couples with it, as shown in Figure 2.

Figure 2

Calculate the speed of the train (engine and wagon) after the collision. 87 % 2 marks

$m_1 u_1 + \cancel{m_2 u_2} = (m_1 + m_2) V$

$20\,000 \times 3 = 30\,000\,V$

2 m s^{-1}

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Question 6 (6 marks)

a. Explain the conditions for a satellite to be in a geostationary orbit (that is, stationary over a fixed point on Earth's surface). There is no need to calculate the actual radius of the orbit. 2 % 3 marks

Orbit over equator average 0.8

Period 24h

$\cancel{\frac{mv^2}{r} = \frac{GM}{r^2}}$ $v^2 = \frac{GM}{r}$ or moves in a same direction as rotation of Earth

b. Roger states that there are a number of situations on or near Earth's surface where a person may 'feel weightless'.

Emily states that this is impossible. It is only possible to feel weightless in deep space where there is no, or very little, gravitational force on a person.

Is Emily correct or incorrect? Explain your answer. 36 % 3 marks

Emily incorrect

$N = 0$

$mg \neq 0$ $a = g$ free fall - apparent weightlessness, can occur on or near Earth