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.

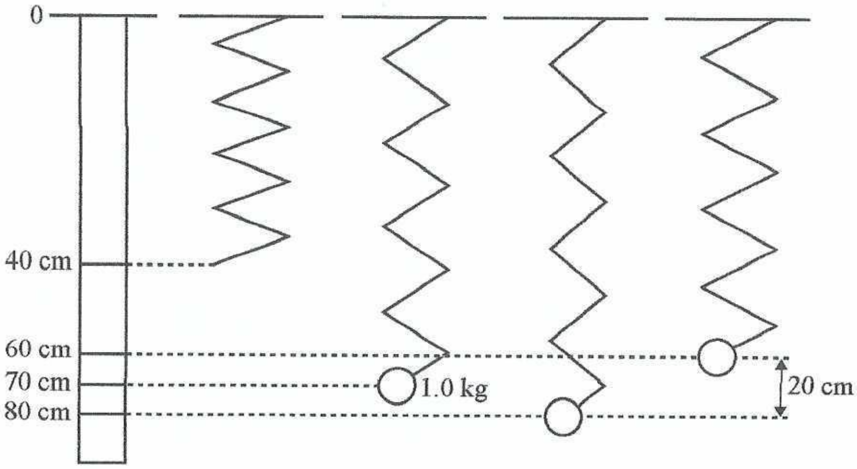


Figure 7

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

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

$mg = K\Delta x$

$K = \frac{mg}{\Delta x}$

$K = \frac{1 \times 10}{0.3} = 33.3 N m^{-1}$

$(K = \frac{1 \times 9.8}{0.3} = 32.7 N m^{-1})$

33.3	N m^{-1}

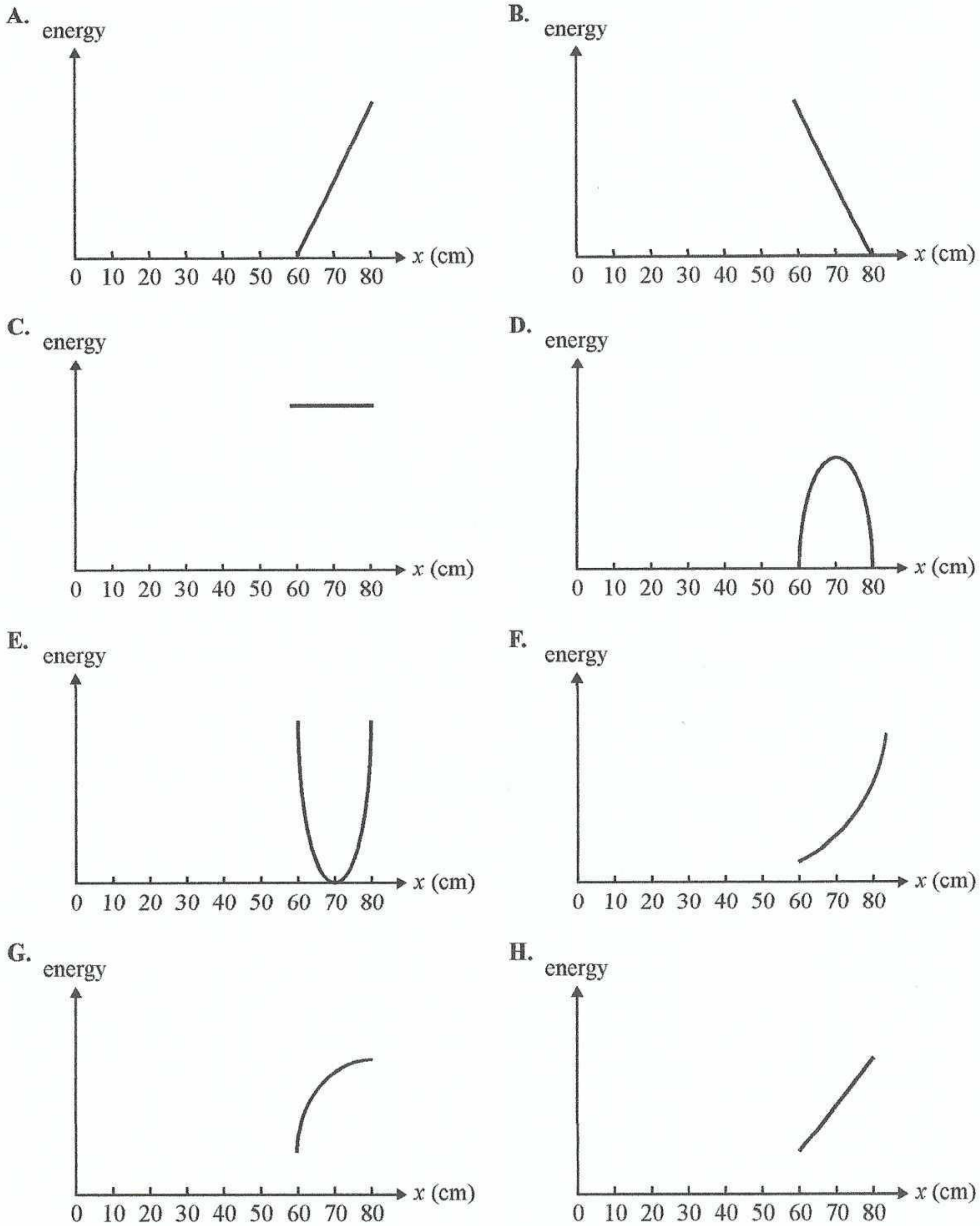
(32.7 $g = 9.8$)

2 marks

48%

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.



NO WRITING ALLOWED IN THIS AREA

Question 17

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

E_K = max at the equilibrium position, 0 at the ends

1 mark

42 %

Question 18

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

E_{total} = const

65%

1 mark

Question 19

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

E_{gp} = 0 at the bottom, max at the top

1 mark

46 %

Question 20

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

$E_{ep} \approx \frac{kx^2}{2}$, so parabolic shape, upright parabola.
E_{ep} max at the bottom as x max.
E_{ep} min at $x = 60$, but not 0 as spring already stretched

3 marks

8%

SECTION A – Core

Instructions for Section A

Answer **all** questions **for both** Areas of study 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}.
In questions where more than one mark is available, appropriate working should be shown.

Area of study 1 – Motion in one and two dimensions

Question 1

A spring is resting against a wall. The spring is compressed by a distance of 8.0 cm from its uncompressed length. Jemima holds a block of mass 1.2 kg stationary against the compressed spring as shown in Figure 1.

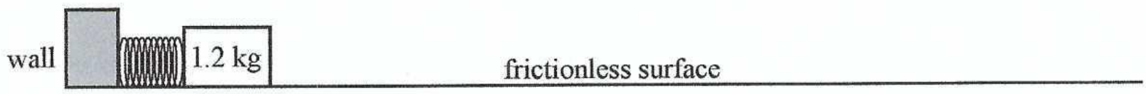


Figure 1

Jemima releases the block and it slides to the right on a frictionless surface. It leaves the spring with a kinetic energy of 5.4 J and slides at constant speed as shown in Figure 2.

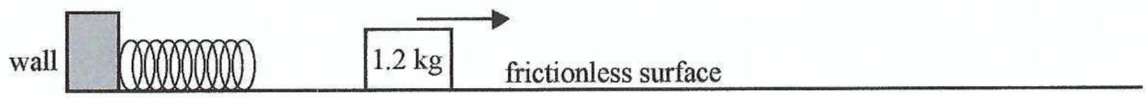


Figure 2

a. Calculate the speed of the block as it leaves the spring.

$$\frac{mv^2}{2} = 5.4$$

$$v = \sqrt{\frac{2 \times 5.4}{1.2}}$$

$\boxed{3 \text{ m s}^{-1}}$

84%

1 mark

b. Calculate the work done by the spring on the block.

$W = E_K$

5.4	J

63%

1 mark

c. Calculate the spring constant, k, of the spring. Assume that the spring obeys Hooke's law.

$E_p = \frac{Kx^2}{2}$ $\quad 5.4 = \frac{K \times 0.08^2}{2}$

$K = \frac{2 \times 5.4}{0.08^2} = 1687.5$

1.7×10^3	N m^{-1}

49%

2 marks

d. Calculate the magnitude of the total impulse that the spring gives to the 1.2 kg block by the time it leaves the spring.

$Ft = \Delta p$

$= 1.2 \times 3$

$= 3.6$

3.6	N s

75%

2 marks

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

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.

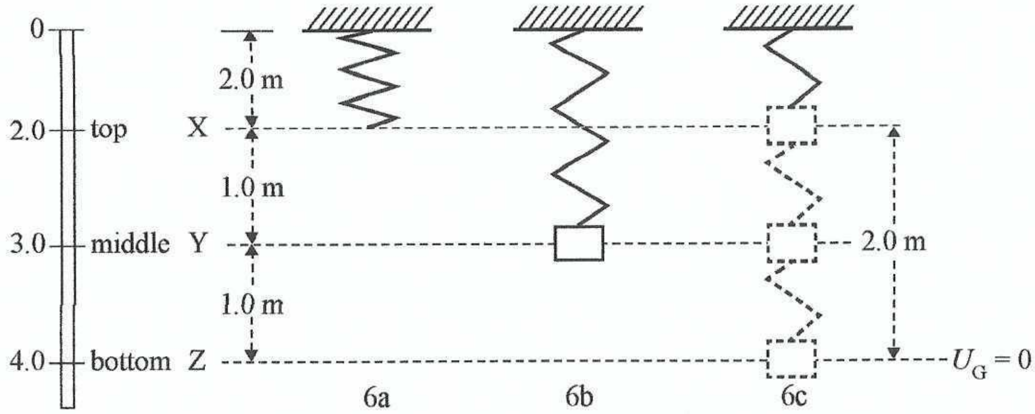


Figure 6
not to scale

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.

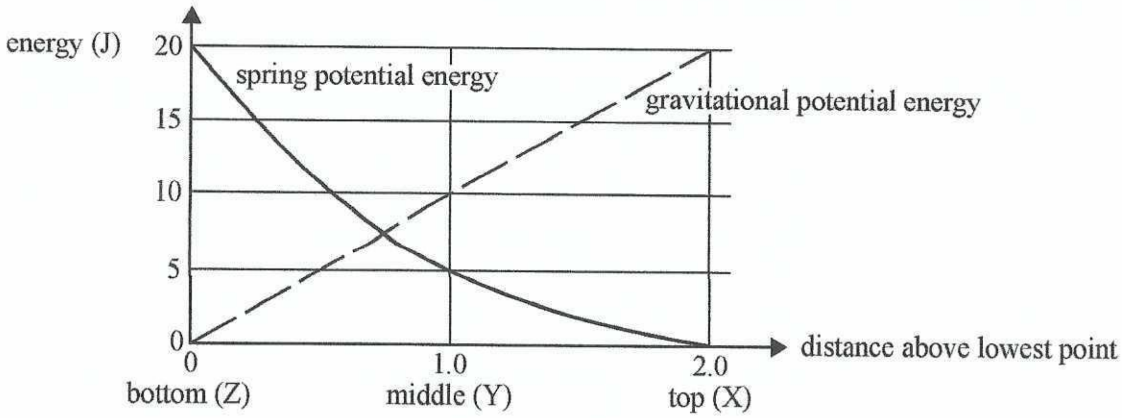


Figure 7

81 %

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

At Z all energy is SPE

20 J

42 %

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

$E_k = E_{total} - GPE - SPE$

$= 20 - 10 - 5 = 5\,J$

$E_k = \frac{mv^2}{2}$

$v = \sqrt{\frac{2 \times 5}{1}}$

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.

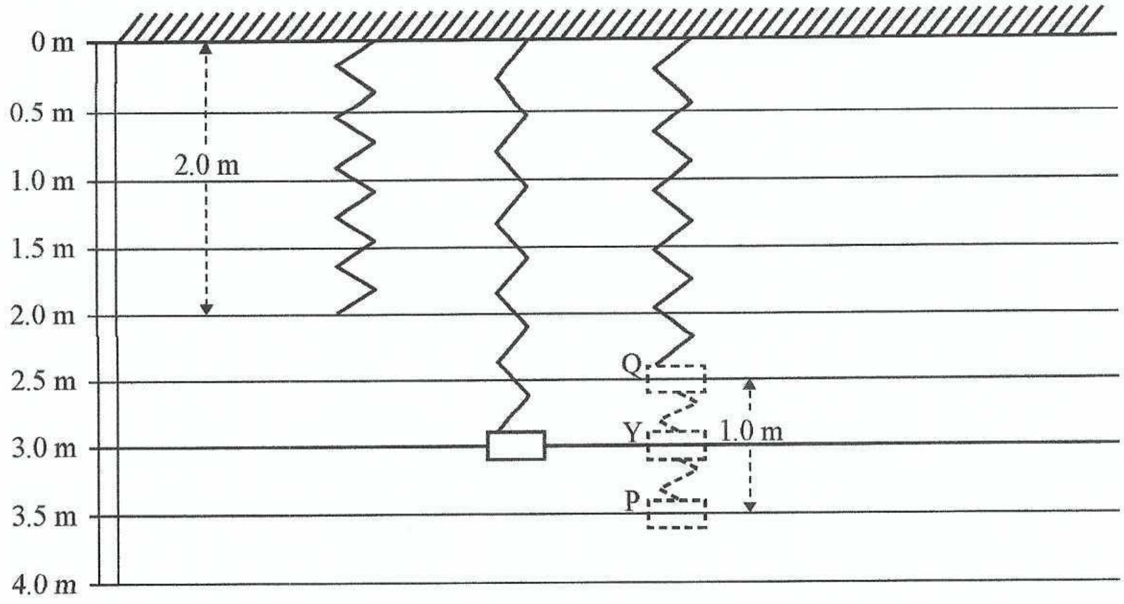


Figure 8

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. 3 marks

At Q SPE ≠ 0 as spring stretched. 7%

At Q SPE = $\frac{k \times 0.5^2}{2} = \frac{10 \times 0.5^2}{2} = 1.25$ J $E_{total} = 10 + 1.25 = 11.25$ J

P SPE = $\frac{k \times 1.5^2}{2} = \frac{10 \times 1.5^2}{2} = 11.25$ J

$E_{Q\,total} = E_{P\,total}$

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.

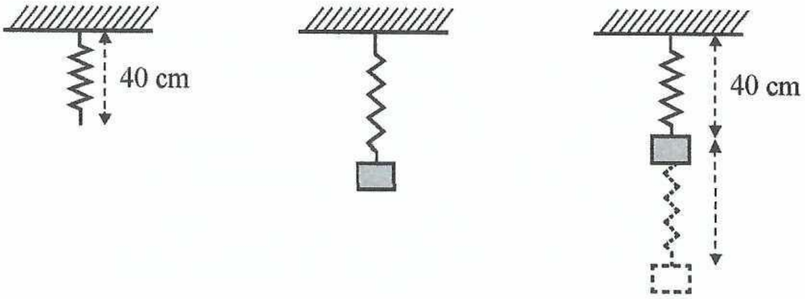


Figure 3a **Figure 3b** **Figure 3c**

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}. 2 marks

At 50 cm $mg = kx$ 61%

$k = \frac{mg}{x}$

$k = \frac{0.05 \times 10}{0.5 - 0.4} = 5 \text{ N m}^{-1}$

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. 3 marks

At the top $E_{total} = E_{gp} = mgx$ 14%

At the bottom $E_{total} = E_{ep} = \frac{kx^2}{2}$

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

$x = \frac{2mg}{k} = \frac{2 \times 0.2 \times 10}{5} = 0.8 \text{ m}$

0.8	m

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.

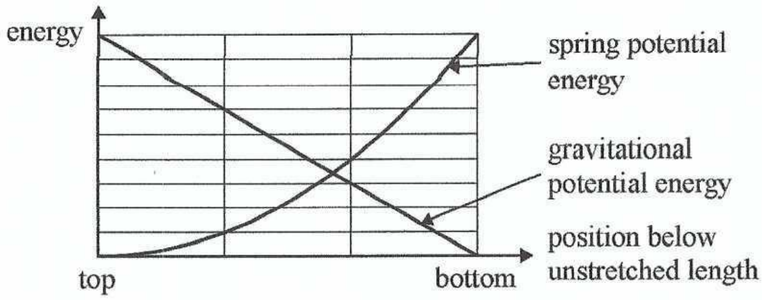


Figure 4

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.

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

27%

Kinetic energy is missing. If kinetic energy will be added graphs will add to a constant amount.

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

7%

$E_{\cancel{total}} = mgh = 0.2 \times 10 \times 0.8 = 1.6\ J$

V_{max} in the middle. $\frac{mV_m^2}{2} + mgh + \frac{Kx^2}{2} = 1.6$

$\frac{0.2V^2}{2} + 0.2 \times 10 \times 0.4 + \frac{5 \times 0.4^2}{2} = 1.6$

$V^2 = \frac{1.6 - 0.8 - 0.4}{0.1} = 4$

$V = 2$

$\boxed{2\ \text{m s}^{-1}}$

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.

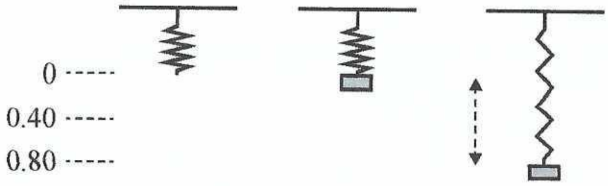


Figure 6

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

$\Delta E = mgh$ 87%

$= 2 \times 10 \times 0.8$

16 J

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

$SPE = \frac{kx^2}{2}$ 81%

$= \frac{50 \times 0.8^2}{2}$

or SPE = GPE from part a = 16 J

16 J

c. Calculate the speed of the mass at its midpoint (maximum speed). 3 marks

$\frac{mv^2}{2} + \frac{kx^2}{2} + mgh = 16$ 36%

$\frac{2v^2}{2} + \frac{50 \times 0.4^2}{2} + 2 \times 10 \times 0.4 = 16$

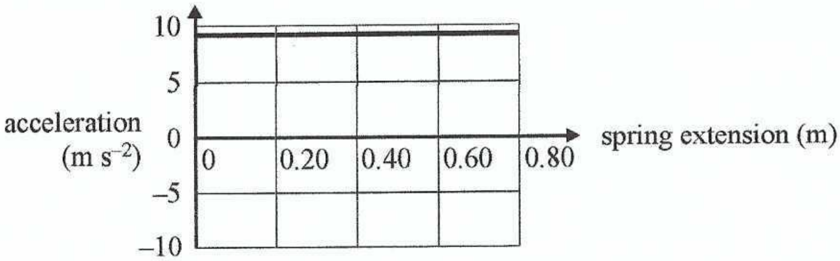
$v^2 = 4$

2 m s^{-1}

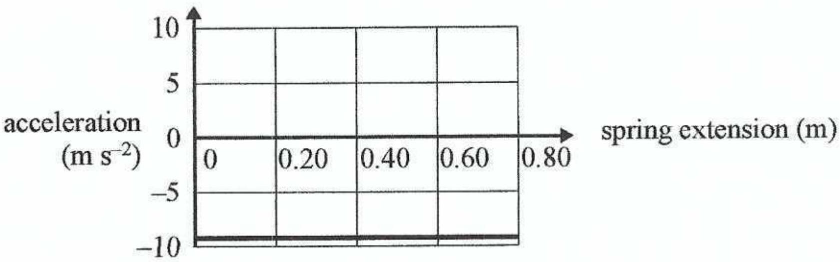
d. Which one of the following graphs (**A.**–**D.**) best shows the acceleration of the mass as it goes from the highest point to the lowest point? Take upwards as positive. Give a reason for your choice. 2 marks

25 %

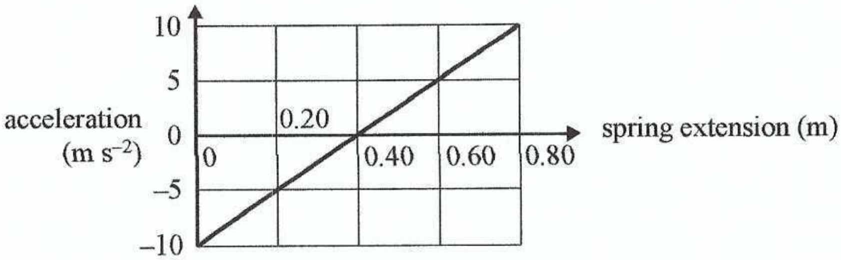
A.



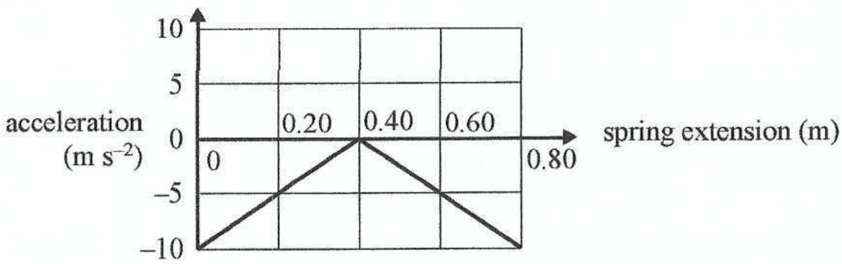
B.



C.



D.



$\boxed{C}$

Acceleration at the middle = 0

From top to the middle ~~[illegible]~~ $mg > kx$

from middle to the bottom $mg < kx$

Question 3 (4 marks)

To determine the spring constant, *k*, of a spring, students attach 50 g masses to it consecutively and measure the extension, Δx. This is shown in Figure 4a.

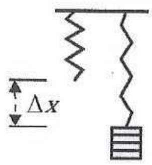


Figure 4a

The students' results are shown in the table below.

Number of masses	Extension from unstretched length, Δx
0	0 cm
1	25 cm
2	50 cm
3	75 cm

a. Calculate the value of the spring constant, *k*. 2 marks

57%

$Mg = k\Delta x$

$k = \frac{mg}{\Delta x}$

$k = \frac{0.1 \times 10}{0.5} = 2$

2 N m^{-1}

b. With four masses on the spring, the students release it from its unstretched length, as shown in Figure 4b.

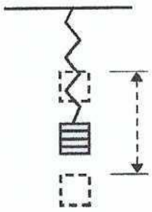


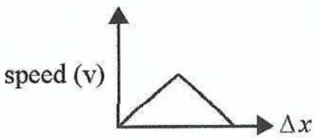
Figure 4b

Which one of the following graphs (**A.–E.**) best shows the speed as a function of extension Δx as the mass moves from top to bottom? Explain your answer.

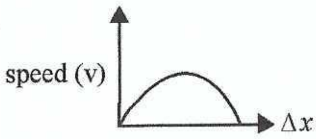
2 marks

48%

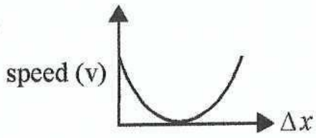
A.



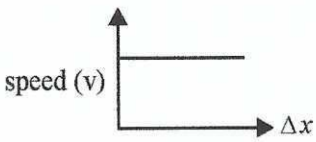
B.



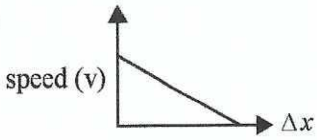
C.



D.



E.



$\boxed{B}$

Speed = 0 at the top and the bottom and max in the middle.

Question 4 (9 marks)

In a test, an unpowered toy car of mass 4.0 kg is held against a spring, compressing the spring by 0.50 m, and then released, as shown in Figure 5.

There is negligible friction while the car is in contact with the spring.

Figure 5 also shows the force–extension graph for the spring.

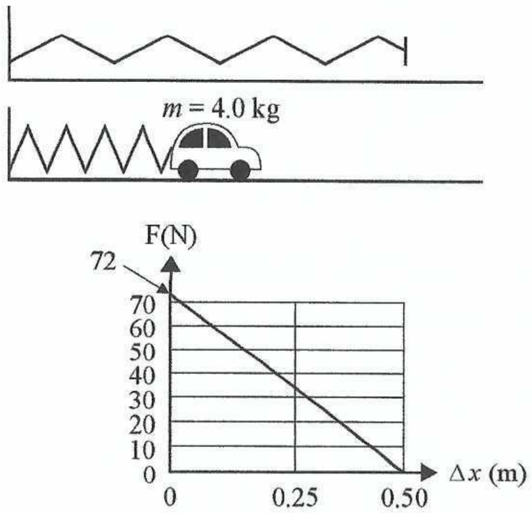


Figure 5

69%

a. Determine the energy stored in the spring before release. 2 marks

$E = \text{Area}$

$= \frac{1}{2} 0.5 \times 72$

18 J

73%

b. Calculate the speed of the car as it leaves the spring. Ignore any frictional forces. 2 marks

$\frac{Mv^2}{2} = 18$

$\frac{4v^2}{2} = 18$

$v^2 = 9$

3 m s^{-1}

A second test is done, where the spring is not compressed as far, and the car moves off at a speed of 2.0 m s^{-1}.

c. Calculate the impulse given to the car by the spring. Include an appropriate unit. 2 marks

52%

$Ft = \Delta p = 4 \times 2 = 8$

8 Ns

d. After the car leaves the spring at 2.0 m s^{-1}, the car has a constant frictional resistance of 2.0 N.

Calculate how far the car travels before it stops. Show your working. 3 marks

51%

$W = KE$

$Fs = \frac{mv^2}{2}$

$2s = \frac{4 \times 2^2}{2}$

$s = 4$

4 m

Question 4 (7 marks)

A spring has a spring constant, k, of 20 N m^{-1}. Point P shows the unstretched length of the spring.

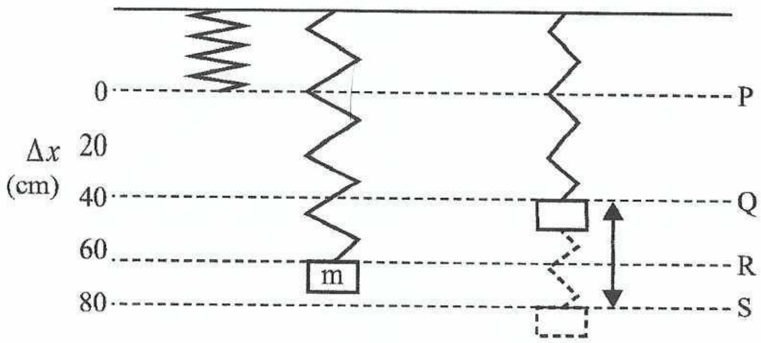


Figure 5a **Figure 5b**

not to scale

a. A mass, m, is hung from the spring.
It extends the spring 0.60 m to point R, as shown in Figure 5a.

Calculate the mass of m. 2 marks

$Mg = Kx$

$M = \frac{Kx}{g} = \frac{20 \times 0.6}{10}$

| 1.2 kg |

b. The mass is now raised to point Q and released, so that it oscillates between points Q and S, as shown in Figure 5b.

Calculate the change in spring potential energy in moving from point Q to point S. Show your working. 2 marks

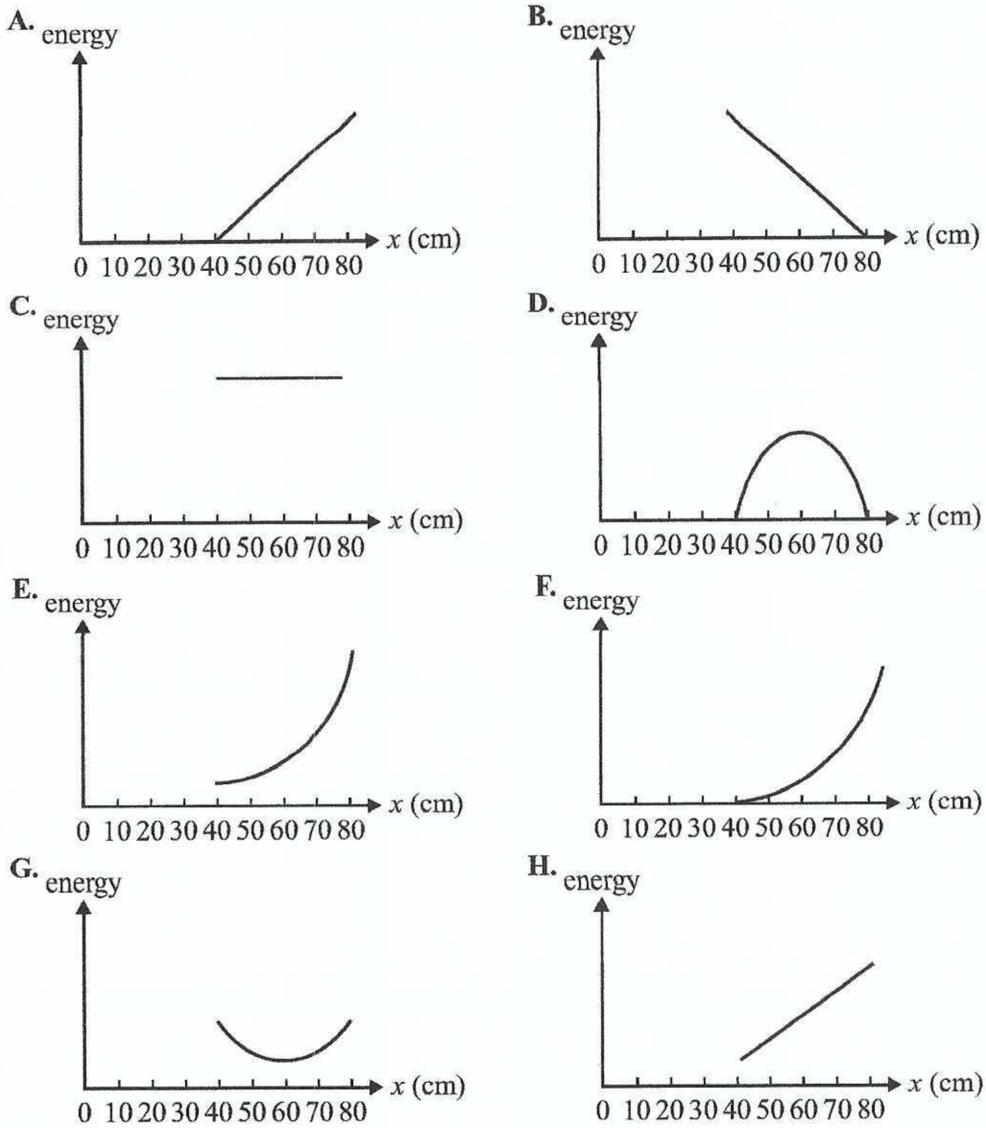
At Q SPE = $\frac{20 \times 0.4^2}{2} = 1.6$ J

At S SPE = $\frac{20 \times 0.8^2}{2} = 6.4$ J

Δ SPE = 4.8

| 4.8 J |

c. Eight graphs, **A.–H.**, are shown below.



In the boxes provided below, indicate which graph(s) (**A.–H.**) would show the total energy, the gravitational potential energy (take the zero of gravitational potential energy at the lowest point, S), the kinetic energy and the spring potential energy as the mass oscillates. 3 marks

Total energy	C
Gravitational potential energy	B
Kinetic energy	D
Spring potential energy	E

Question 13 (7 marks)

Pat and Robin hang a mass of 2.00 kg on the end of a spring with spring constant $k = 20.0 \text{ N m}^{-1}$.

They hold the mass at the unstretched length of the spring and release it, allowing it to fall, as shown in Figure 11.

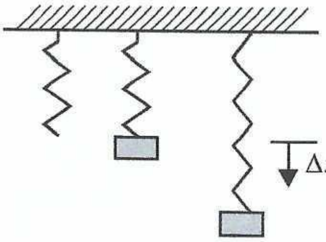


Figure 11

a. Determine how far the spring stretches until the mass comes momentarily to rest at the bottom. Show your working. 3 marks

30%

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

$$x = \frac{2mg}{k}$$

$$x = \frac{2 \times 2 \times 9.8}{20}$$

$\boxed{1.96 \text{ m}}$

b. Explain how the three energies involved and the total energy of the mass vary as the mass falls from top to bottom. Calculations are **not** required. 4 marks

GPE is max at the top and decreases as mass fall 16%

SPE is min at the top and increases — " —

KE = 0 at the top, increases to the middle and then decreases to 0 at the bottom.

Total energy of the mass decreases as mass fall.

Question 9 (9 marks)

A spring launcher is used to project a rubber ball of mass 2.0 kg vertically upwards. The arrangement is shown in Figure 6.

The ball is driven by a spring, which is compressed and released. When the spring reaches the top, point X, it is held stationary, but is still partly compressed as the ball leaves the launcher. Assume that the spring has no mass.

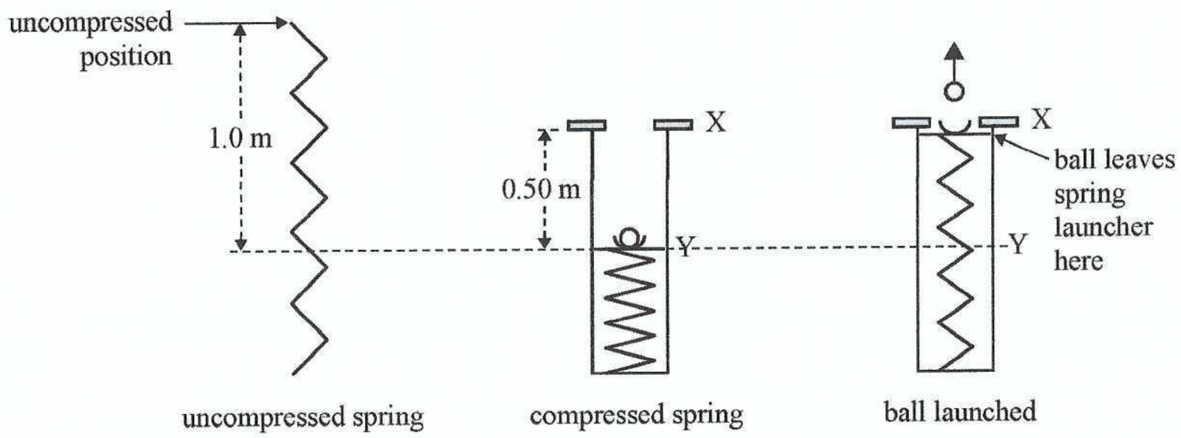


Figure 6

The force–distance graph of the spring is shown in Figure 7, on which the lower and upper positions of the spring in the spring launcher are marked.

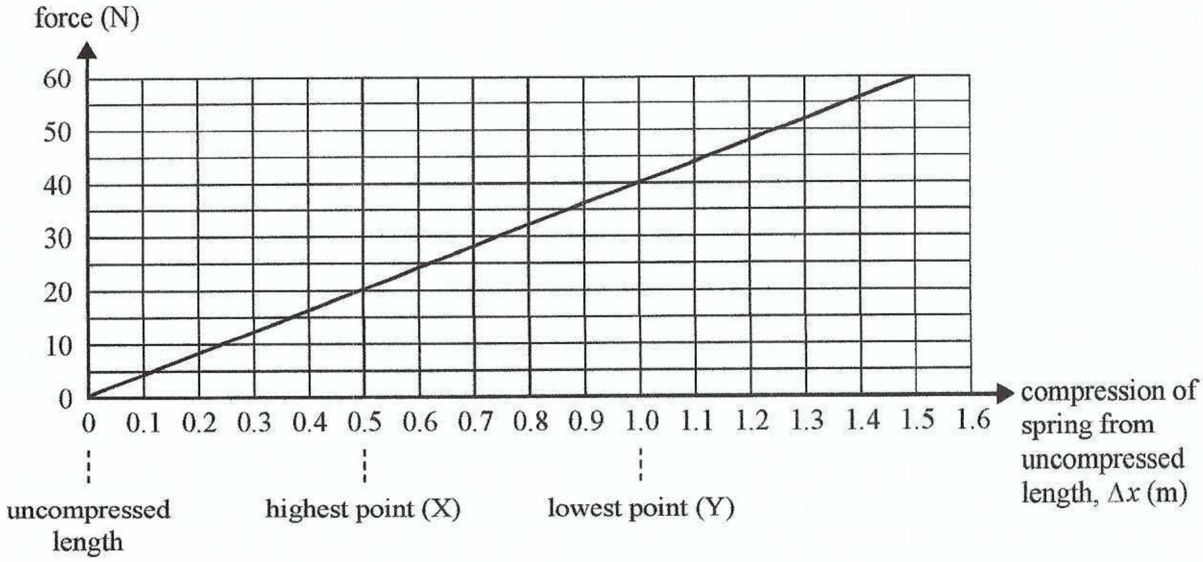


Figure 7

a. Calculate the spring constant, k, of the spring. 2 marks

Gradient $k = \frac{60}{1.5}$

40 N m^{-1}

b. Calculate the change in spring potential energy of the spring as it goes from the lowest point, Y, to the highest point, X. 3 marks

At Y $SPE = \frac{40 \times 1^2}{2} = 20\text{ J}$

At X $SPE = \frac{40 \times 0.5^2}{2} = 5\text{ J}$

$\Delta SPE = 15\text{ J}$

15 J

c. The spring, with a ball in place, is released from point Y. It moves up to point X, where it is stopped and the ball is launched.

Calculate the speed of the ball when it leaves the spring launcher. Show the steps involved in your working. 4 marks

$\frac{mv^2}{2} + mgh = \Delta SPE$

$\frac{2v^2}{2} + 2 \times 9.8 \times 0.5 = 15$

$v^2 = 15 - 9.8$

$v^2 = 5.2$

$v = 2.28$

2.3 m s^{-1}

Question 6 (7 marks)

A ball of mass 2.0 kg is dropped from a height of 2.0 m above a spring, as shown in Figure 8. The spring has an uncompressed length of 2.0 m. The ball and the spring come to rest when they are at a distance of 0.50 m below the uncompressed position of the spring.

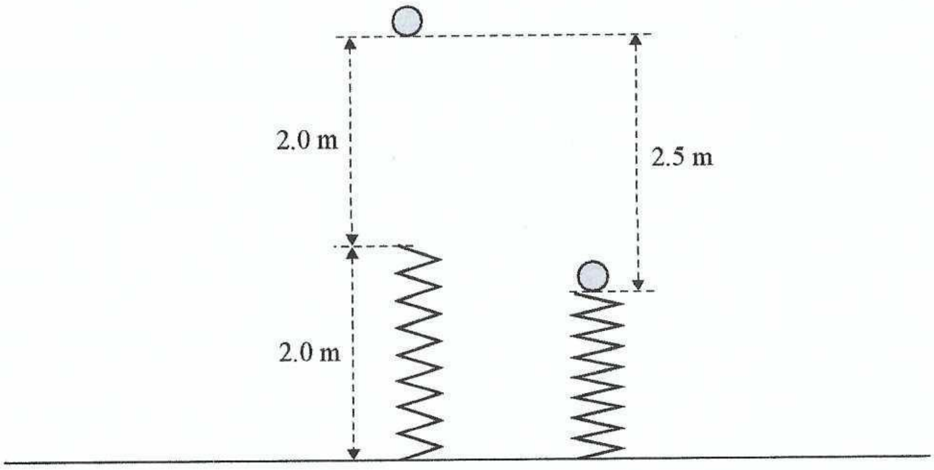


Figure 8

a. Using $g = 9.8$ N kg^{-1}, show that the spring constant, k, is equal to 392 N m^{-1}. Show your working. 3 marks

45%

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

$2 \times 9.8 \times 2.5 = \frac{k \times 0.5^2}{2}$

$k = \frac{49}{0.125} = 392$

b. Determine the acceleration of the ball when it reaches its maximum speed. Explain your answer. 2 marks

6%

0 m s^{-2}

Max speed is when acceleration = 0, $mg = kx$

c. Calculate the compression of the spring when the ball reaches its maximum speed. Show your working. 2 marks

13%

$mg = kx$

$2 \times 9.8 = 392x$

0.05 m

Question 5 (8 marks)

Students conduct an experiment in which a mass of 2.0 kg is suspended from a spring with spring constant $k = 100\ \text{N m}^{-1}$.

Ignore the mass of the spring.

Take the gravitational field, g, to be $10\ \text{N kg}^{-1}$.

Take the zero of gravitational potential energy when the mass is at its lowest point.

The experimental arrangement is shown in Figure 6.

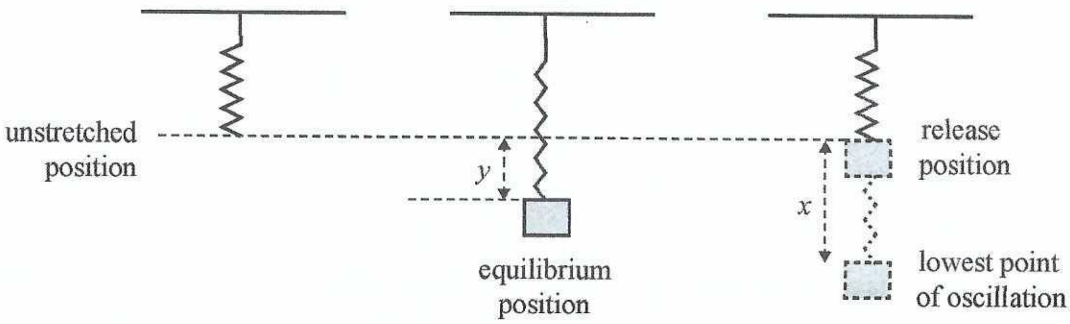


Figure 6

a. The mass is attached to the spring and slowly lowered to its equilibrium position.

Calculate the extension, y, of the spring from its unstretched position to its equilibrium position. Show your working. 2 marks

$mg = kx$

$x = \frac{mg}{k}$

$x = \frac{2 \times 10}{100}$

0.2 m

b. The mass is now raised to the unstretched length of the spring and released so that it oscillates vertically.

i. Determine the distance, x, from the release position to the point at which the mass momentarily comes to rest at the lowest point of oscillation. Ignore frictional losses. Show your working. 2 marks

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

$$x = \frac{2mg}{k}$$

0.4 m

ii. Calculate the maximum speed of the mass. Show your working. 4 marks

$$E_{total} = mg \times 0.4 = 8\text{ J}$$

$$\frac{2 \times \cancel{mm} v^2}{2} + 2 \times 10 \times 0.2 + \frac{100 \times 0.2^2}{2} = 8$$

$$v^2 = 8 - 4 - 2 = 2$$

1.4 m s^{-1}

Question 8 (9 marks)

A 250 g toy car performs a loop in the apparatus shown in Figure 8.

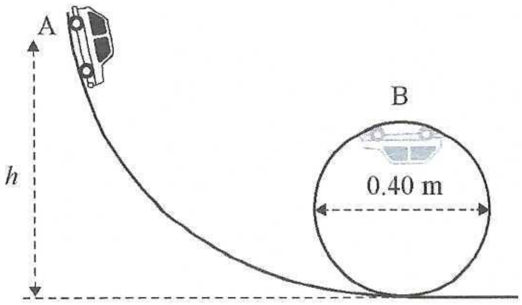


Figure 8

The car starts from rest at point A and travels along the track without any air resistance or retarding frictional forces. The radius of the car's path in the loop is 0.20 m. When the car reaches point B it is travelling at a speed of 3.0 m s^{-1}.

a. Calculate the value of h. Show your working. 3 marks

$mgh = \frac{mv^2}{2} + mg \times 0.4$

$h = \frac{v^2}{2g} + 0.4$

$= \frac{3^2}{2 \times 9.8} + 0.4$

$= 0.86$

0.86 m

b. Calculate the magnitude of the normal reaction force on the car by the track when it is at point B. Show your working. 3 marks

N

Question 19 (18 marks)

As part of their practical investigation, some students investigate a spring system consisting of two springs, A and B, and a top platform, as shown in Figure 20. The students place various masses on the top platform. Assume that the top platform has negligible mass.

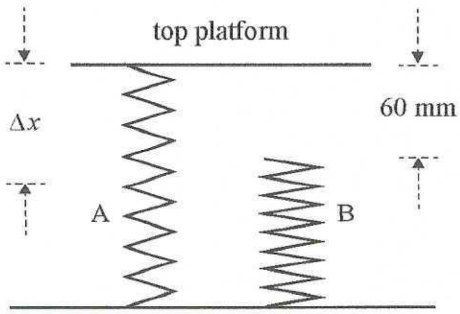


Figure 20

With no masses on the top platform of the spring system, the distance between the uncompressed Spring A and the top of Spring B is 60 mm.

The students place various masses on the top platform of the spring system and note the vertical compression, Δx, of the spring system.

They use a ruler with millimetre gradations to take readings of the compression of the spring(s), Δx, with an uncertainty of ± 2 mm.

The results of their investigation are shown in Table 1 below.

Table 1

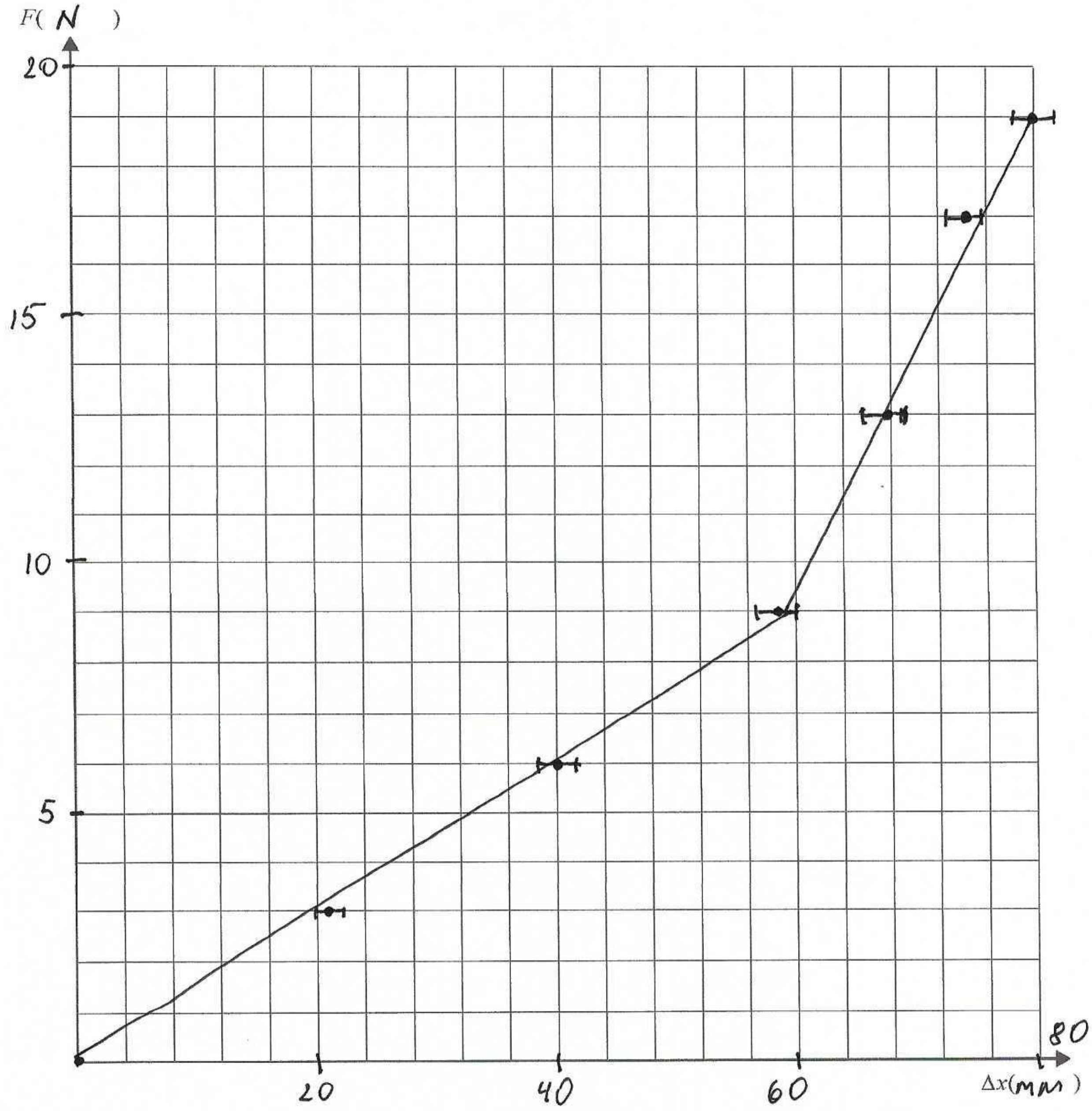
Mass (g)	Compression, Δx (mm)
0	0
300	21
600	40
900	60
1300	68
1700	75
1900	80

The students plot a force (F) versus compression (Δx) graph for the spring system and use $g = 10\ \text{N kg}^{-1}$ for the value of the magnitude of the gravitational field strength.

a. On the axes provided below:

- plot a graph of force (F) versus compression (Δx) for the spring system
- include scales and units on each axis
- insert appropriate uncertainty bars for the compression values on the graph
- draw lines that best fit the data for:
  - the effect of Spring A alone
  - the effect of Spring A and Spring B.

6 marks



b. **i.** Determine the spring constant for Spring A, k_A. Show your working. 2 marks

$F = K_A x$

$9 = K_A \times 0.06 \qquad K = \frac{9}{0.06}$

150 N m^{-1}

ii. Determine the spring constant for Spring B, k_B. Show your working. 2 marks

For 2 springs $K = K_A + K_B$ Gradient of the second graph $K = \frac{19-9}{0.08-0.06} = 500$ Nm^{-1}

350 N m^{-1}

$K_B = K - K_A$

$= 350$

c. Using the area under the force (F) versus compression (Δx) graph, or otherwise, determine

i. the potential energy (PE_A) stored in Spring A when the spring system is compressed by 80 mm. Show your working 2 marks

Area under graph $= \frac{1}{2} \times 12 \times 0.08$

$= 0.48$ J

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

$= \frac{1}{2} \times 150 \times 0.08^2$

0.48 J

ii. the potential energy (PE_{A+B}) stored in the spring system when the spring system is compressed by 80 mm. Show your working 2 marks

Area under the graph or easier $E_{ep} = E_A + E_B$

$E = \frac{1}{2} \times 150 \times 0.08^2 + \frac{1}{2} \times 350 \times 0.02^2 = 0.48 + 0.07$

$= 0.55$

0.55 J

iii. the work done to compress Spring B when the spring system is compressed by 80 mm. Show your working. 2 marks

$E = \frac{1}{2} 350 \times 0.02^2 = 0.07$

0.07 J

d. Explain how this type of spring system could be used in car spring suspension systems to enable the car to negotiate small bumps and more severe bumps in the road. 2 marks

First spring provides suspension for small bumps, together springs provide suspension for severe bumps

END OF QUESTION AND ANSWER BOOK

Question 9 (5 marks)

An ideal spring is compressed by 0.15 m. A ball of mass 0.20 kg is placed in contact with the compressed spring. The spring is then released, causing the ball to move horizontally, with a velocity of *v*, across a smooth surface, as shown in Figure 9.

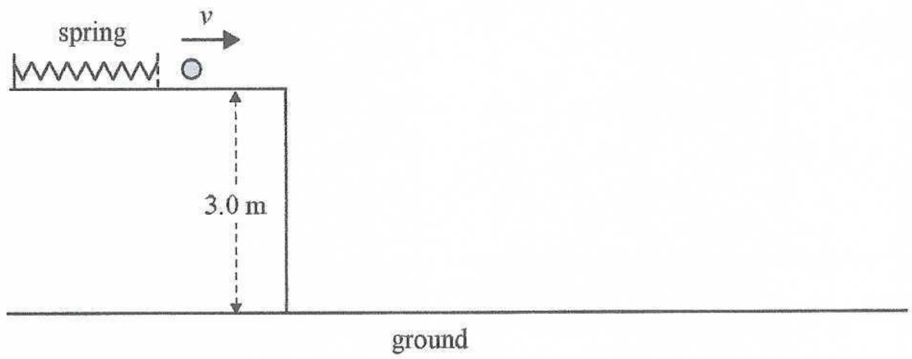


Figure 9

a. If the spring constant is 1250 N m^{-1}, show that the magnitude of the initial velocity, *v*, of the ball is 12 m s^{-1}, correct to two significant figures. Show your working. 2 marks

68%

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

$v = \sqrt{\frac{k}{m}}\, x = \sqrt{\frac{1250}{0.2}} \times 0.15 = 12 \text{ ms}^{-1}$

b. Calculate the speed of the ball after it has fallen a vertical distance of 2.5 m. Show your working. 3 marks

43%

$v_x = 12 \text{ m s}^{-1}$

$v_y^2 = u_y^2 + 2gh$

$v_y^2 = 0 + 2 \times 9.8 \times 2.5$

$v_y = 7 \text{ m s}^{-1}$

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{12^2 + 7^2} = 13.89 = 14 \text{ ms}^{-1}$

14 m s^{-1}

Question 9 (10 marks)

In a model of a proposed ride at a theme park, a 5.0 kg smooth block slides down a ramp from point W and into an ideal spring bumper without any friction or air resistance, as shown in Figure 13. The final section of the ramp, between points X and Y, is horizontal. The block comes to an instantaneous stop at point Y.

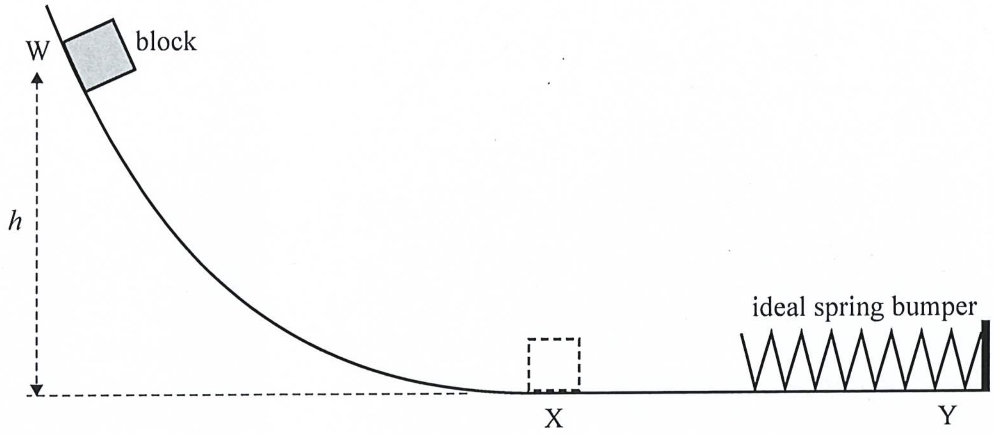


Figure 13

a. Describe the acceleration of the block at points W, X and Y. 4 marks

W: acceleration $< 9.8 ms^{-2}$ and > 0

X: acceleration $= 0$

Y: acceleration > 0, direction to the left

b. The maximum compression of the spring is measured as 3.0 m and its spring constant, k, is 100 N m^{-1}.

Calculate the release height, h. Show your working. 3 marks

$mgh = \frac{Kx^2}{2}$

$h = \frac{Kx^2}{2mg} = \frac{100 \times 3^2}{2 \times 5 \times 9.8}$

9.2 m

c. Calculate the magnitude of the maximum momentum of the block. Show your working. 2 marks

$\frac{Kx^2}{2} = \frac{mv^2}{2}$

$v = x\sqrt{\frac{K}{m}} = 3 \times \sqrt{\frac{100}{5}} = 13.4 \text{ m s}^{-1}$

$p = mv = 5 \times 13.4$

$\boxed{67 \text{ kg m s}^{-1}}$

d. When the block comes to rest, its momentum is zero.

In terms of the principle of conservation of momentum, state what has happened to the momentum of the block as it comes to rest. 1 mark

The momentum is transfered to the earth

Question 18 (15 marks)

A small rubber ball of mass 50 g falls vertically from a given height and rebounds from a hard floor. The ball's speed immediately before impact is 3.6 m s^{-1}. The ball rebounds upward at a speed of 3.3 m s^{-1} immediately after it leaves the floor. The ball is in contact with the floor for 40 ms.

a. Calculate the magnitude and direction of the net average force acting on the 50 g ball while it is in contact with the floor. Show your working. 4 marks

$Ft = \Delta p$

$\Delta p = 0.05 \times (3.6 + 3.3) = 0.345$ Ns

$F = \frac{\Delta p}{t} = \frac{0.345}{0.04} = 8.6$

8.6 N	Up

b. Just before the ball hits the floor, it has a certain amount of kinetic energy, E_k. At one instant when the ball is in contact with the floor, it is stationary before it rebounds.

Explain what has happened to the kinetic energy, E_k, of the ball when it is stationary. 2 marks

It is converted into elastic potential energy of the ball's deformation as well as into the heat and sound

c. Just before the ball hits the floor, it has a certain amount of vertical momentum, p. At one instant when the ball is in contact with the floor, it is stationary before it rebounds.

What has happened to the vertical momentum, p, of the ball when it is stationary? 1 mark

It is transferred to the earth

Question 8 (7 marks)

Maia is at a skatepark. She stands on her skateboard as it rolls in a straight line down a gentle slope at a constant speed of 3.0 m s^{-1}, as shown in Figure 8. The slope is 5° to the horizontal.

The combined mass of Maia and the skateboard is 65 kg.

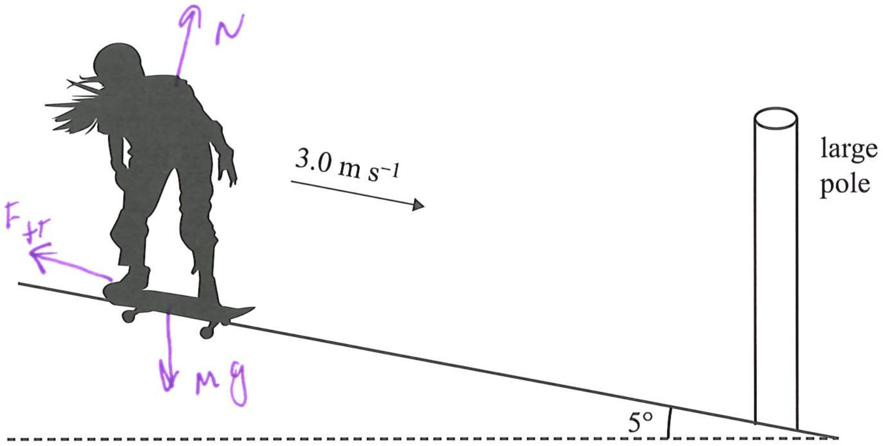


Figure 8

a. In Figure 9, the combined system of Maia and the skateboard is modelled as a small box with point M at the centre of mass.

Draw and label arrows to represent each of the forces acting on the system – that is, Maia and skateboard, as they roll down the slope. 3 marks

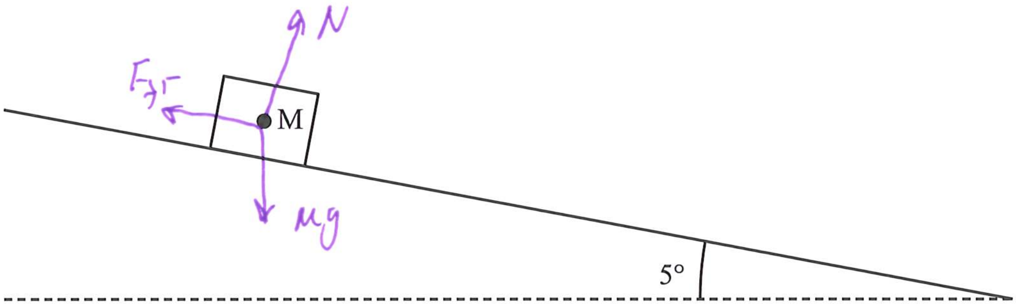


Figure 9

b. Calculate the magnitude of the total frictional forces acting on Maia and the skateboard. 2 marks

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

$= 65 \times 9.8 \sin 5°$

$= 55.5$ N

55.5 N

Near the bottom of the ramp, Maia takes hold of a large pole and comes to a complete rest while still standing on the skateboard. Maia and the skateboard now have no momentum or kinetic energy.

c. Explain what happened to both the momentum and the kinetic energy of Maia and the skateboard. No calculations are required. 2 marks

Momentum to Earth

Energy into heat, sound etc.

DO NOT WRITE IN THIS AREA