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.

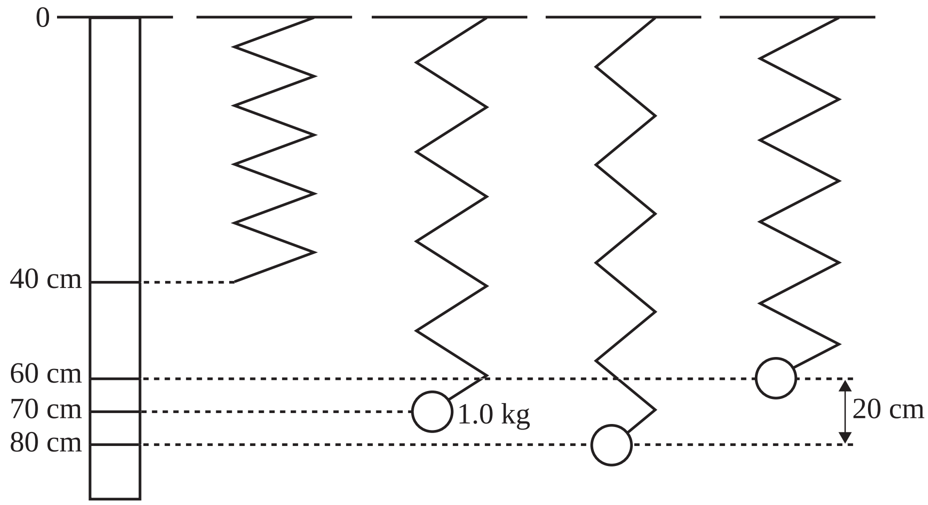


Figure 7

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?

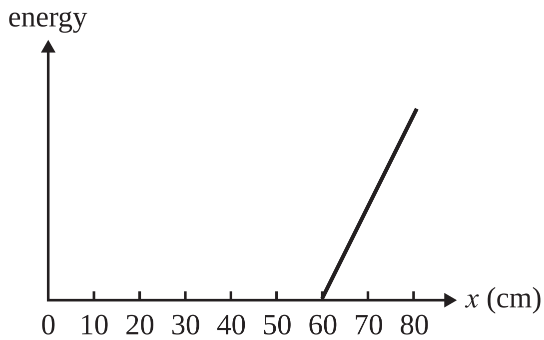
N m^{-1}

2 marks

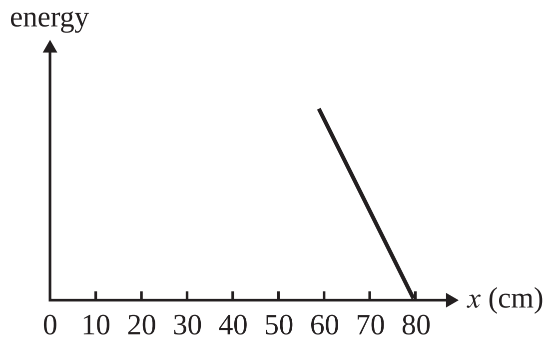
The spring is now pulled down a further 10 cm from 70 cm to 80 cm and released so that it oscillates. Gravitational potential energy is measured from the point at which the spring is released (80 cm on Figure 7).

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

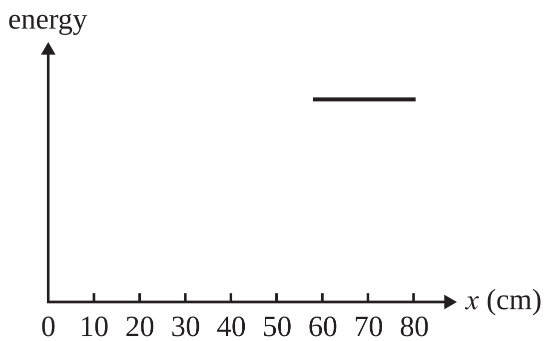
A.



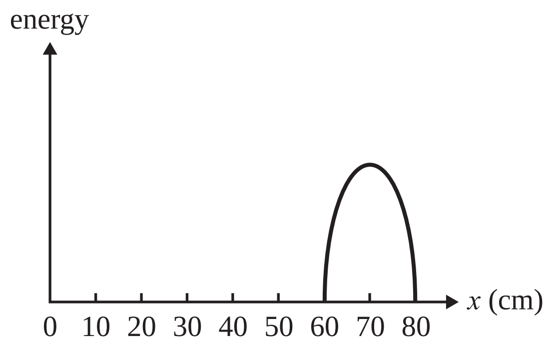
B.



C.



D.



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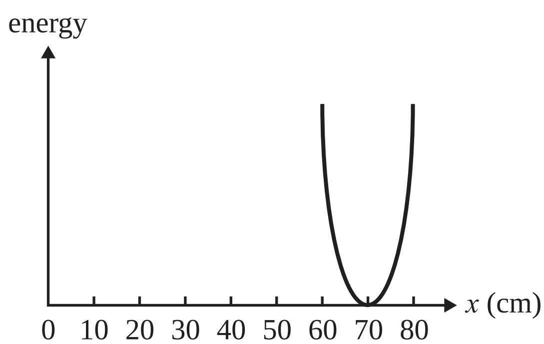
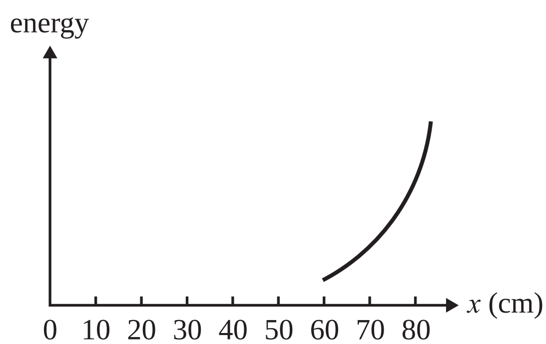
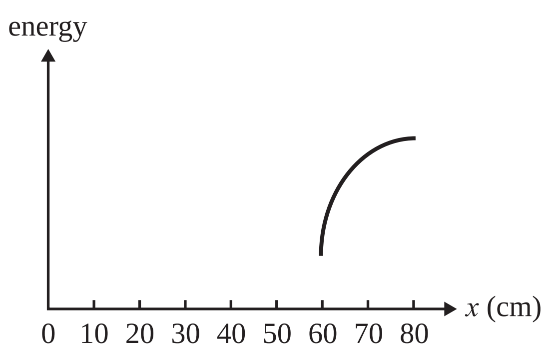


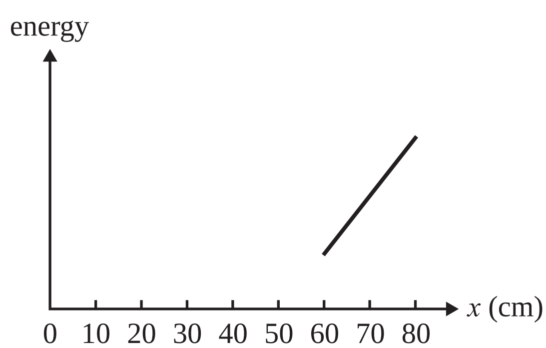
F.



G.



H.



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?

1 mark

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?

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?

1 mark

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.

3 marks

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.

Areas of study **Page**

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.

m s^{-1}

1 mark

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

J

1 mark

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

$N\ m^{-1}$

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.

N s

2 marks

N

Question 6 (6 marks)

Students hang a mass of 1.0 kg from a spring that obeys Hooke's law with $k = 10\ \text{N m}^{-1}$. 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.

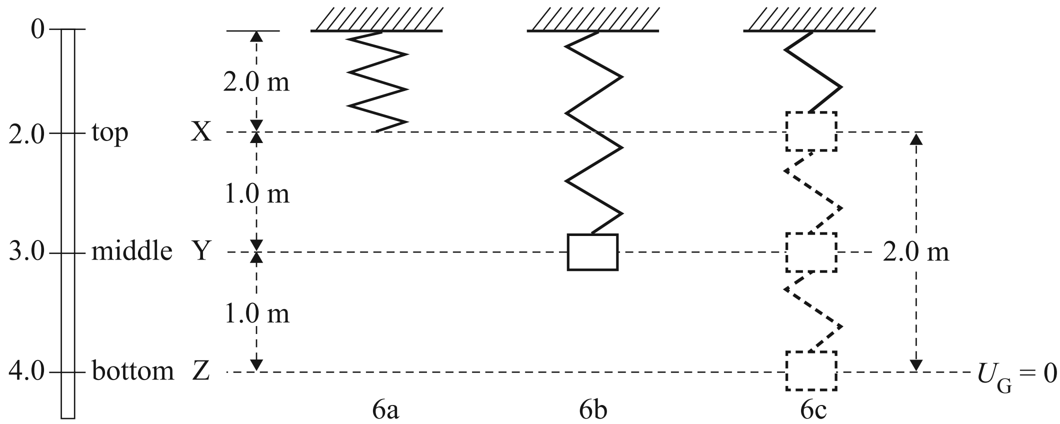


Figure 6
not to scale

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.

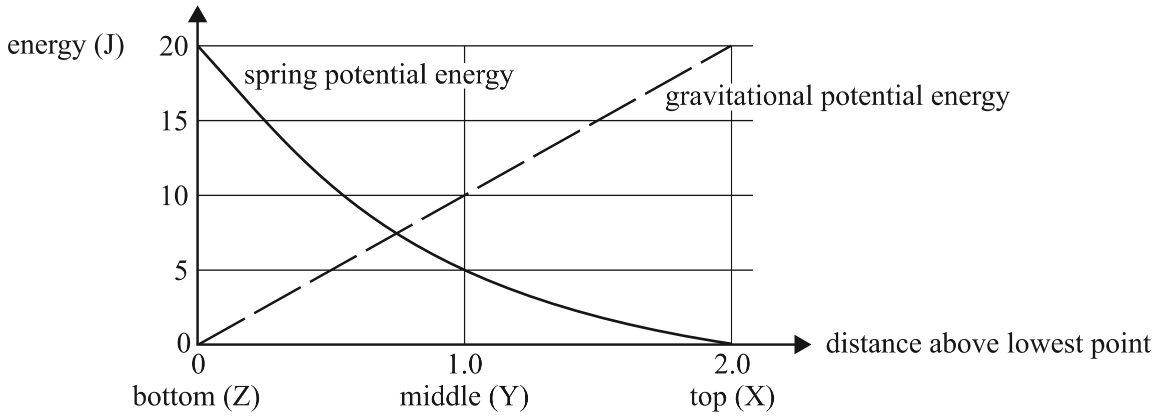


Figure 7

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

J

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

$m\ s^{-1}$

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.

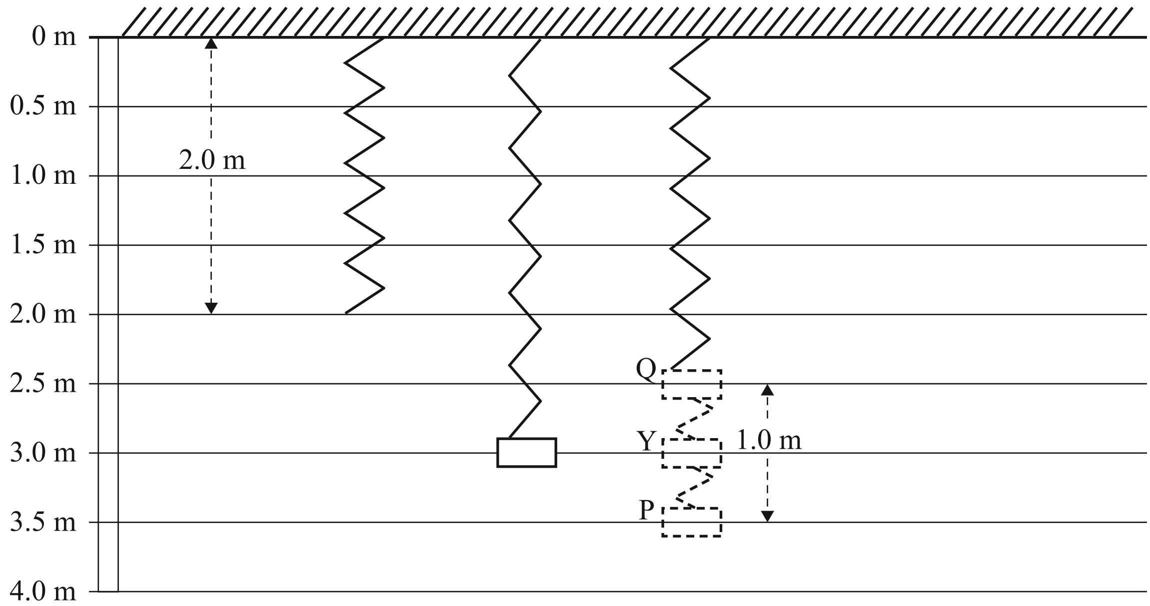


Figure 8

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 × 10 × 1.0 = 10 J	SPE = 0	KE = 0
P	GPE = 0	SPE = $\frac{1}{2}k(\Delta x)^2$ = ½ × 10 × 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

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.

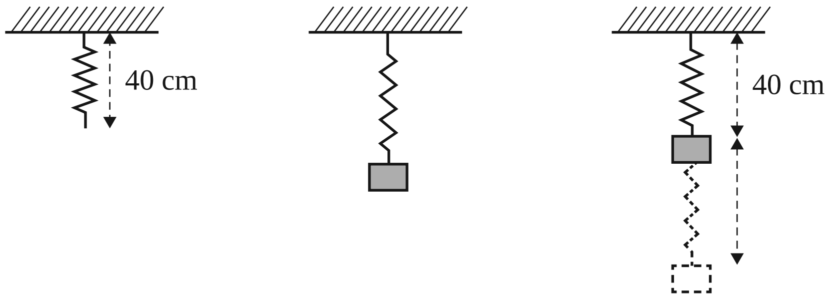


Figure 3a **Figure 3b** **Figure 3c**

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

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

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.

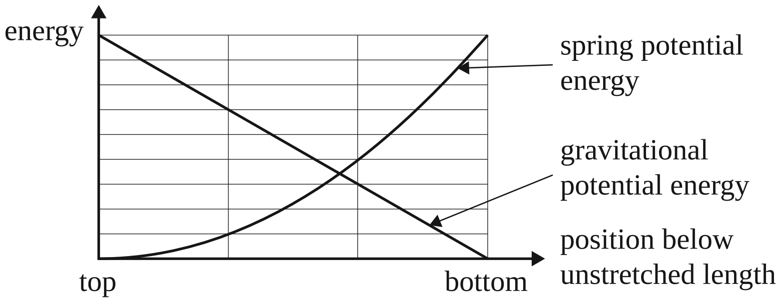


Figure 4

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

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

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.

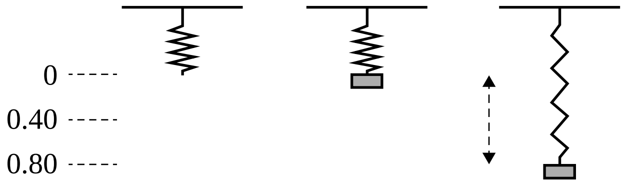


Figure 6

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

J

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

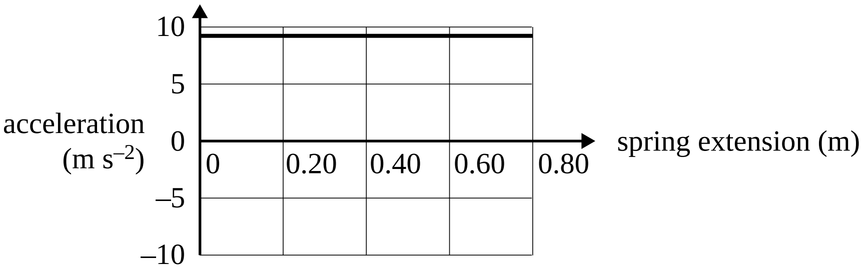
J

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

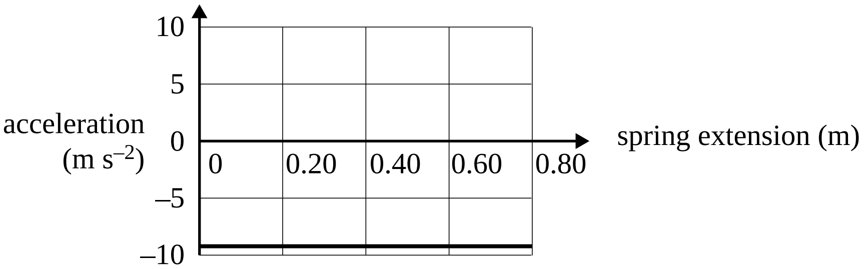
m s^{-1}

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

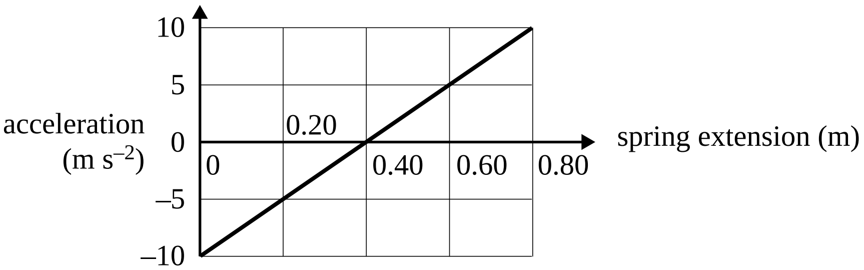
A.



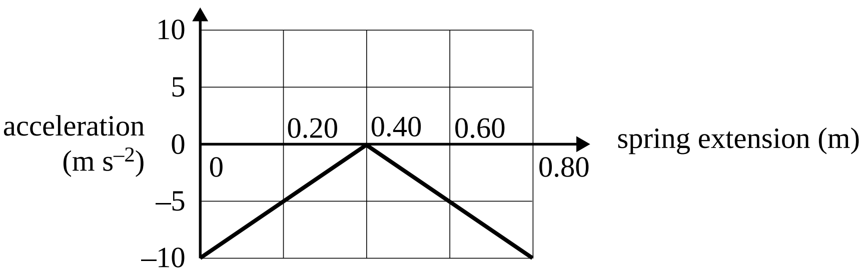
B.



C.



D.



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.

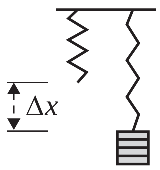


Figure 4a

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

N m^{-1}

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

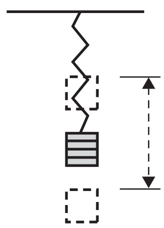
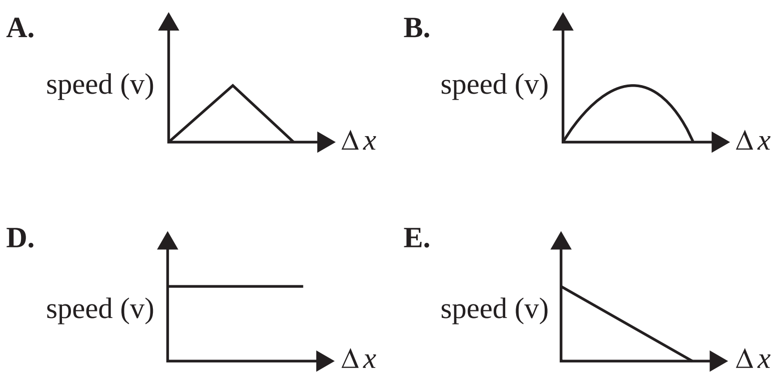


Figure 4b

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



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.

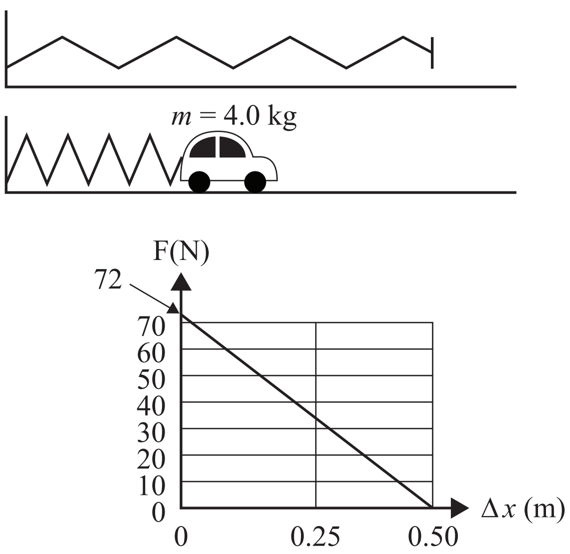


Figure 5

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

J

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

$m\ s^{-1}$

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

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

d. After the car leaves the spring at $2.0\ \text{m s}^{-1}$, 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

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.

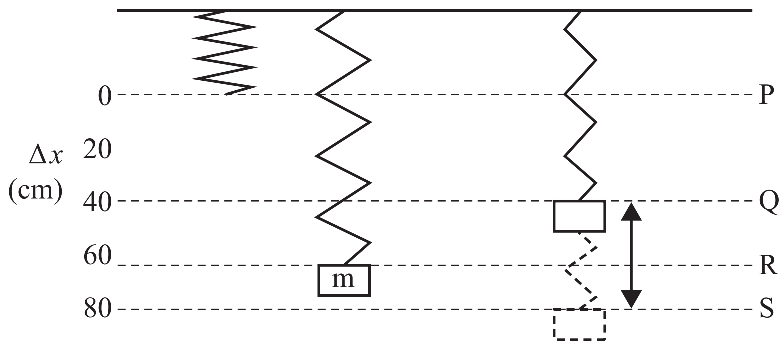


Figure 5a **Figure 5b**

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

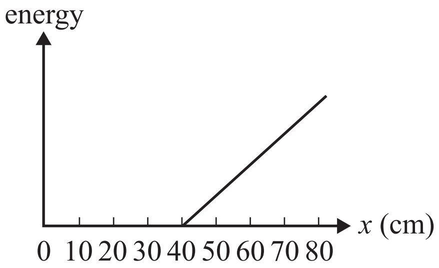
kg

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

J

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

A.


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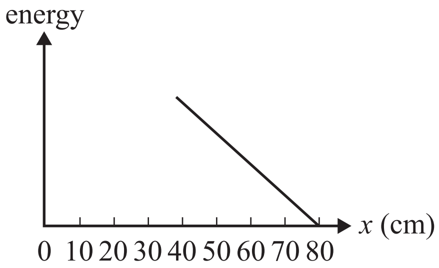

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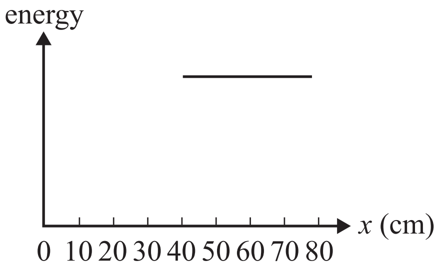

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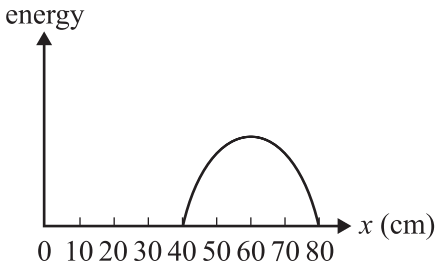
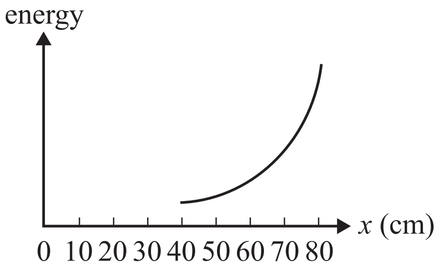
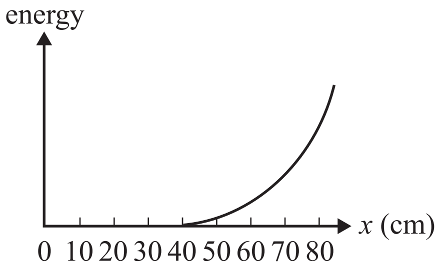
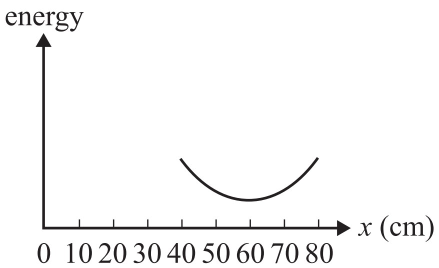
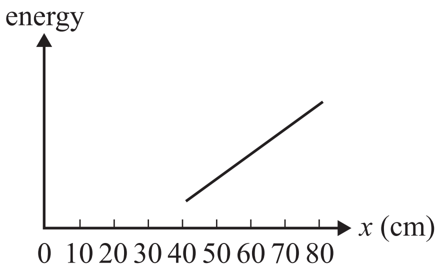


E.


F.


G.


H.


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	
Gravitational potential energy	
Kinetic energy	
Spring potential energy	

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.

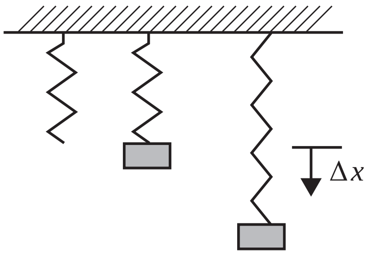


Figure 11

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

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

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.

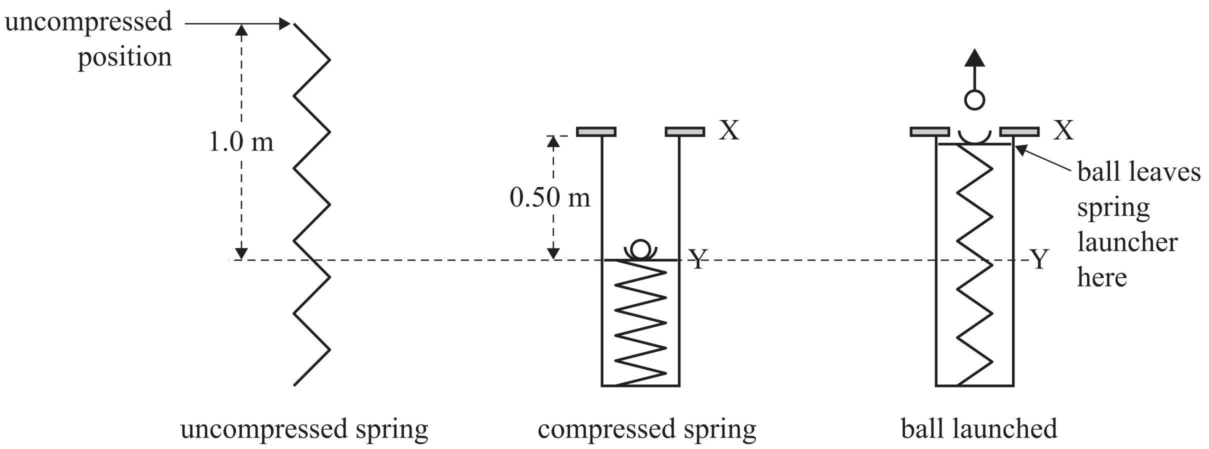


Figure 6

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.

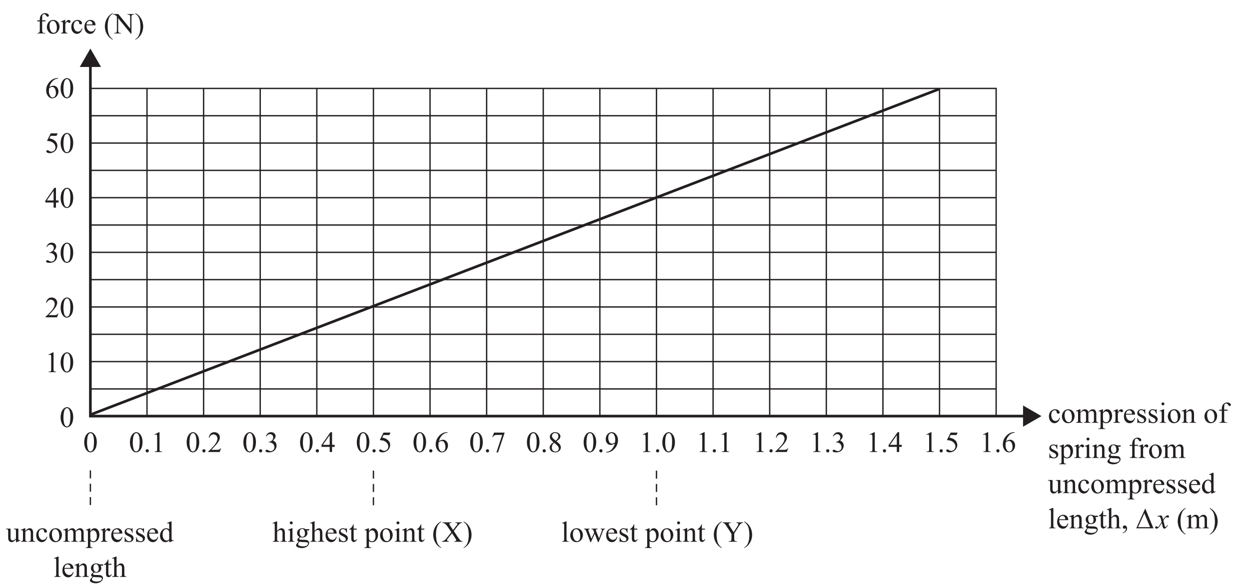


Figure 7

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

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

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

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.

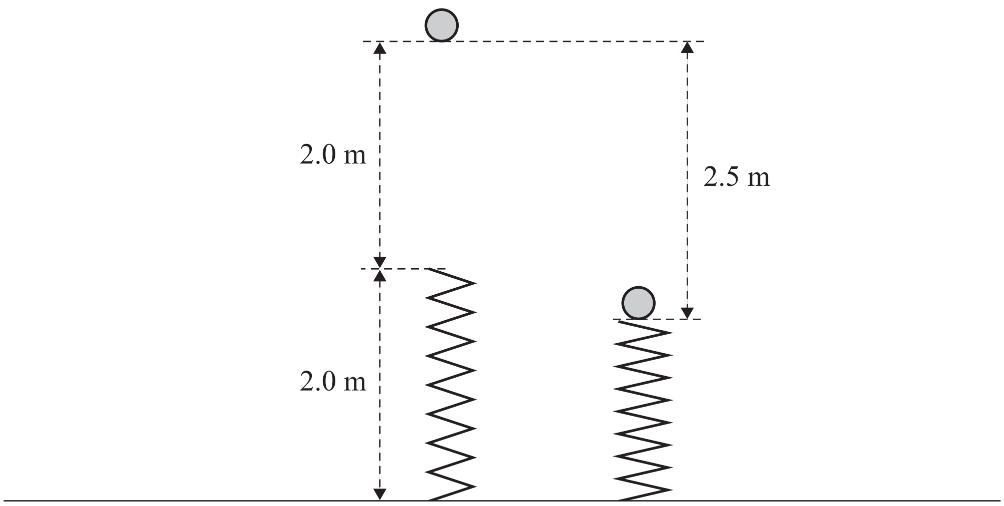


Figure 8

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

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

m s^{-2}

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

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.

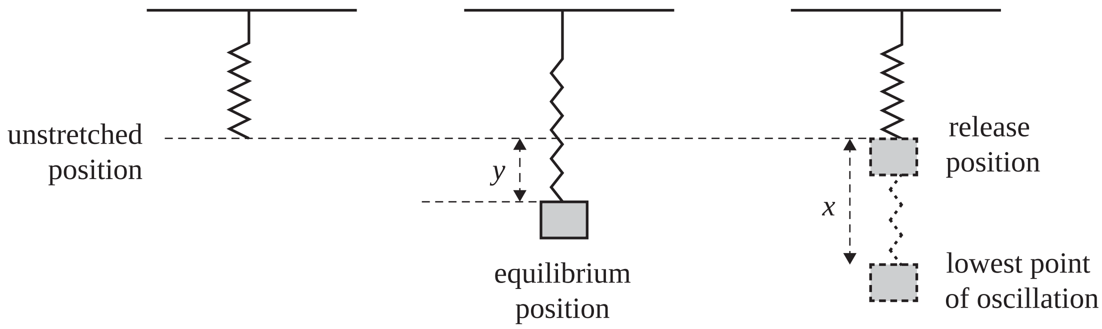


Figure 6

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

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

m

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

$m\ s^{-1}$