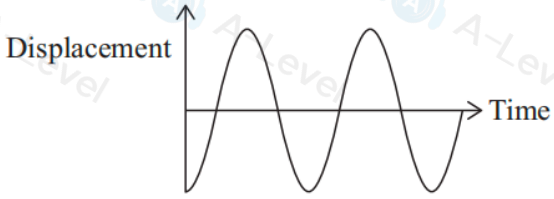
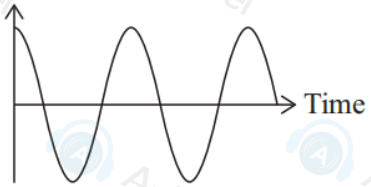
Questions 9 and 10 refer to the following information.

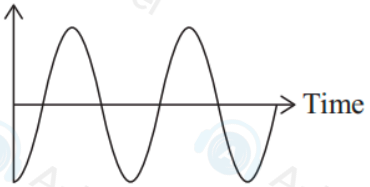
The graph shows how the displacement varies with time for an object performing simple harmonic motion.



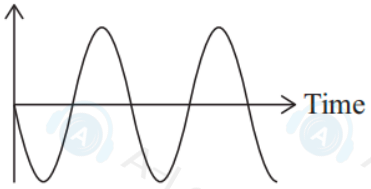
Four graphs of a quantity plotted against time, for the same period of time, are shown below.



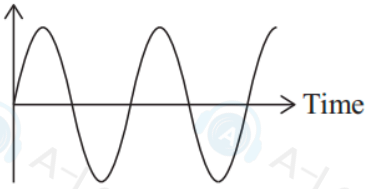
A



B



C



D

9: Which graph shows how the velocity of the object varies with time?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 9 = 1 mark)

10: Which graph shows how the acceleration of the object varies with time?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 10 = 1 mark)

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6 Buildings in earthquake zones often have a structure that includes ductile materials. These materials help to damp oscillations of the building during an earthquake.

Which of the following describes a ductile material?

- ☒ **A** A material that behaves elastically under tension.
- ☒ **B** A material that has a large plastic deformation before it breaks.
- ☒ **C** A material that has a large value of breaking stress.
- ☒ **D** A material that has a large value of the Young modulus.

(Total for Question 6 = 1 mark)

DO NOT WRITE IN THIS AREA

4 A mass is forced into oscillation by a vibration generator. After a short time the oscillation becomes steady.

Which of the following statements about the steady oscillation of the mass is always true?

- ☒ **A** The amplitude of oscillation of the mass will be a maximum.
- ☒ **B** The mass will oscillate at its natural frequency.
- ☒ **C** The mass will oscillate at the frequency of the vibration generator.
- ☒ **D** The transfer of energy to the mass will be a maximum.

(Total for Question 4 = 1 mark)

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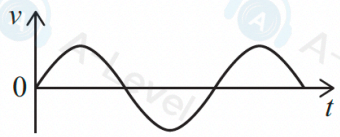
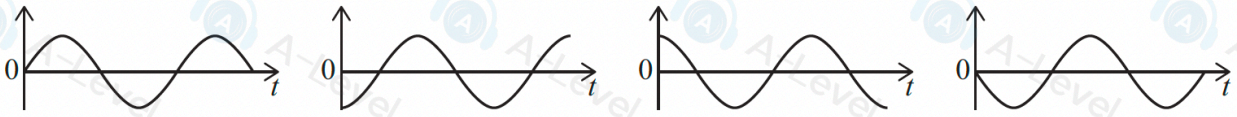
The graph shows how the velocity v varies with time t for an object performing simple harmonic motion.



Four graphs for the same period of time are shown below.



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

9 Which graph shows how the acceleration of the object varies with t?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 9 = 1 mark)

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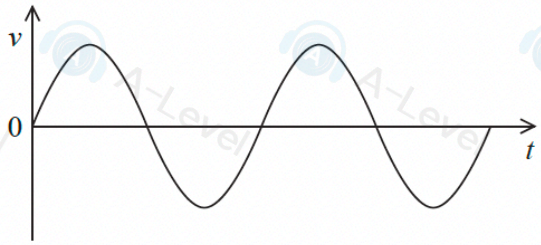
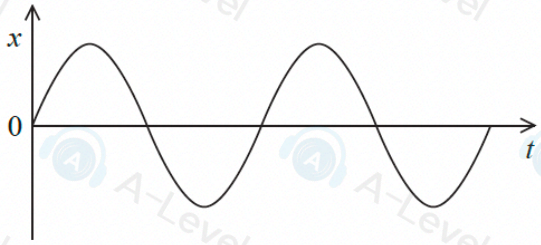
10 A particle is undergoing simple harmonic motion.

The graph shows how the velocity v varies with time t for the particle.

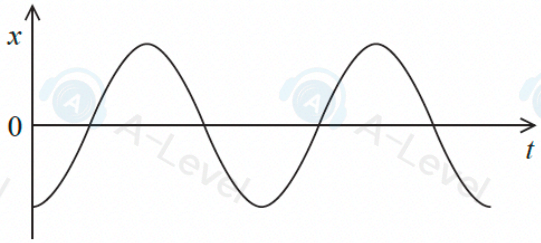


Which of the following graphs shows how the displacement x varies with t during the same time interval?

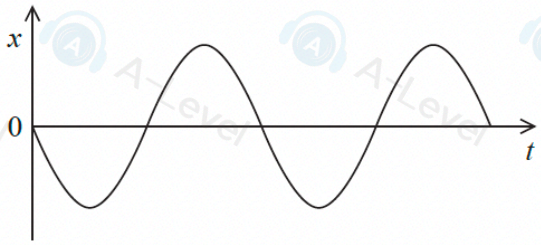
☒ **A**



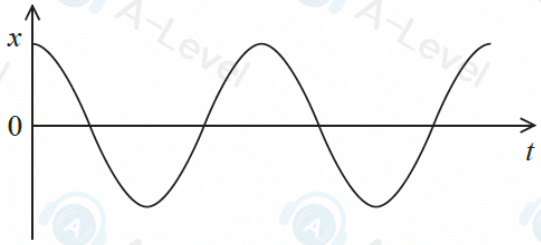
☒ **B**



☒ **C**



☒ **D**



(Total for Question 10 = 1 mark)

6 A mass is hung on a spring. The mass is set into vertical oscillation with frequency of oscillation f.

The mass on the spring is doubled.

What is the new frequency of oscillation?

- ☒ **A** $\frac{f}{2}$
- ☒ **B** $\frac{f}{\sqrt{2}}$
- ☒ **C** $\sqrt{2}f$
- ☒ **D** $2f$

(Total for Question 6 = 1 mark)

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2: A mass is driven into oscillation, and resonance takes place.

Which of the following statements is **not** correct?

- ☒ **A** The amplitude of oscillation of the mass is a maximum.
- ☒ **B** The frequency of oscillation of the mass is a maximum.
- ☒ **C** The mass is driven at its natural frequency.
- ☒ **D** The transfer of energy to the mass is a maximum.

(Total for Question 2 = 1 mark)

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7 A mass oscillates with simple harmonic motion. The mass has an angular velocity of $2\,\text{rad}\,\text{s}^{-1}$ and a maximum velocity of $10\,\text{cm}\,\text{s}^{-1}$.

Which of the following gives the magnitude of the amplitude A of the oscillation in cm?

- ☒ **A** $A = \frac{2}{10}$
- ☒ **B** $A = \frac{10}{2}$
- ☒ **C** $A = \frac{2\sin 2t}{10}$
- ☒ **D** $A = \frac{10}{2\sin 2t}$

(Total for Question 7 = 1 mark)

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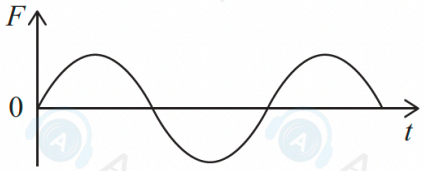
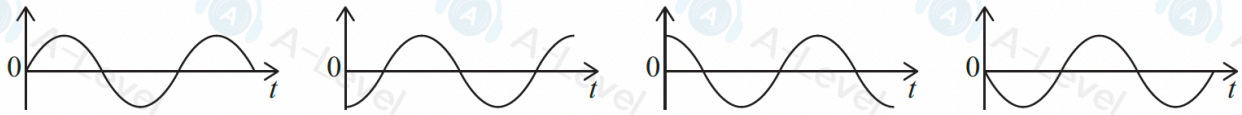
The graph shows how the force F varies with time t for an object performing simple harmonic motion.



Four graphs of different quantities plotted against time, for the same period of time, are shown below.

The scale on the x-axis is the same for each graph.



9 Which graph shows how the displacement of the object varies with t?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 9 = 1 mark)

3 A mass-spring system is set into oscillation. The maximum kinetic energy of the mass is E.

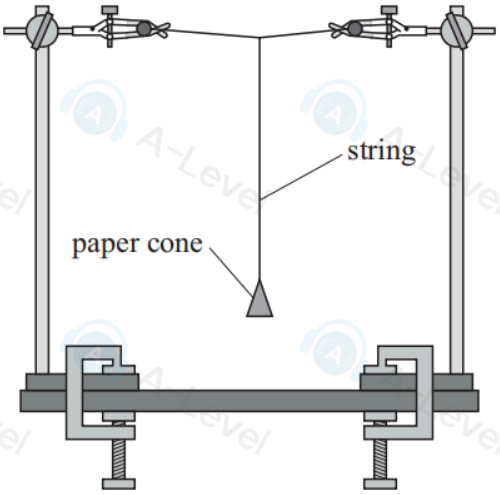
The amplitude of oscillation is then doubled.

What is the new maximum kinetic energy of the mass?

- ☒ **A** $4E$
- ☒ **B** $2E$
- ☒ **C** E
- ☒ **D** $0.5E$

(Total for Question 3 = 1 mark)

8 A pendulum is made by attaching a light paper cone to a thin string, as shown.



The pendulum is displaced and set into oscillation.

Plasticine is then added to the paper cone to increase the mass of the pendulum.

The pendulum is set into oscillation again.

Which of the following is correct for the paper cone with plasticine?

- ☒ **A** The frequency of oscillation has decreased.
- ☒ **B** The period of oscillation has increased.
- ☒ **C** The amplitude of oscillation decreased more quickly.
- ☒ **D** The amplitude of oscillation decreased more slowly.

(Total for Question 8 = 1 mark)

2 During an earthquake, steel-framed buildings remove energy from the oscillation of the building.

Which of the following is the reason for this?

- ☒ **A** Steel is a ductile material.
- ☒ **B** Steel is an elastic material.
- ☒ **C** Steel is a stiff material.
- ☒ **D** Steel is a strong material.

(Total for Question 2 = 1 mark)

10 Which graph shows how the displacement of the object varies with t?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 10 = 1 mark)

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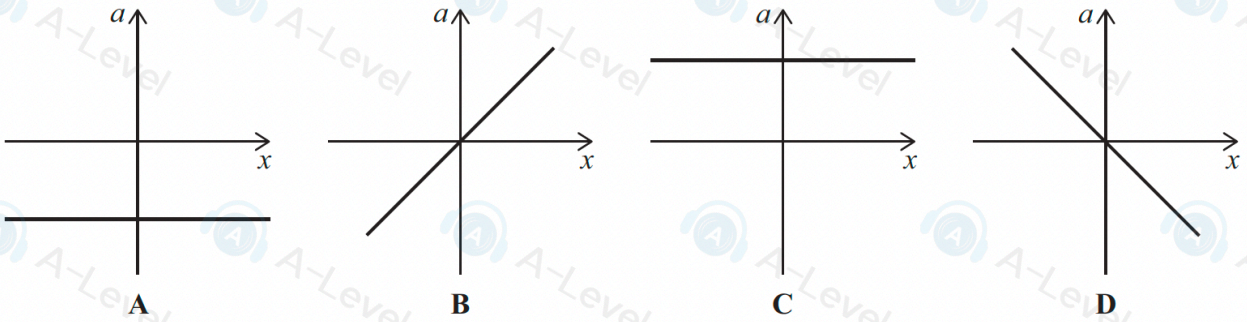
4 A simple pendulum consists of a mass attached to a string. The pendulum is set into simple harmonic motion.
The acceleration of the mass is a and the displacement of the mass is x.

Which of the following graphs shows how a varies with x?



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 4 = 1 mark)

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4 A mass suspended from a spring is oscillating vertically. The oscillations are damped.

Which of the following statements is correct?

☒ **A** The damping force is always in the opposite direction to the acceleration.

☒ **B** The damping force is always in the opposite direction to the velocity.

☒ **C** The damping force is always in the same direction as the acceleration.

☒ **D** The damping force is always in the same direction as the velocity.

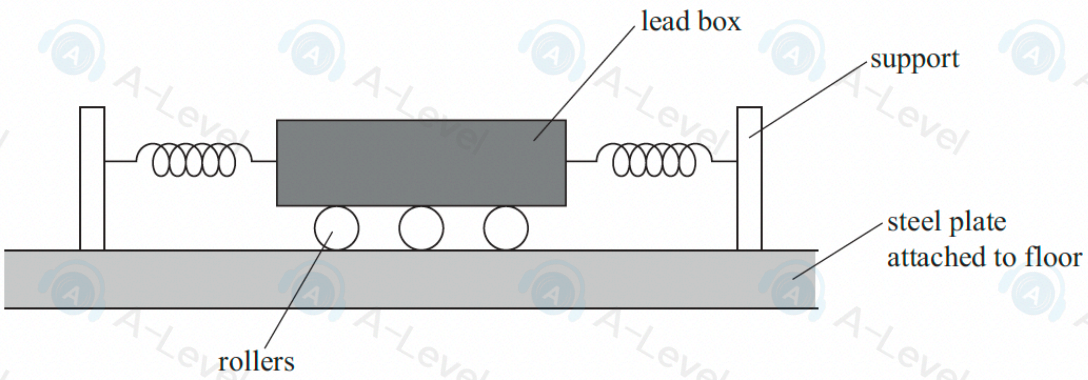
(Total for Question 4 = 1 mark)

20 The photograph shows the 60-storey John Hancock Tower in Boston. This is the tallest building in the state of Massachusetts in the USA.

(Source: © 2265524729/Shutterstock)

Shortly after the building was completed in 1976 it was discovered that the wind caused the building to have large amplitude oscillations. To reduce the amplitude, a damper system was installed on the 58th floor.

The damper system consists of a lead box supported between springs, as shown below.



When the lead box is displaced, it moves with damped simple harmonic motion.

(a) State what is meant by simple harmonic motion.

(2)

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(b) When the wind blows at a certain speed, the building oscillates with a frequency of 0.17 Hz.

(i) Explain why the damper system should be designed to oscillate at this frequency.

(2)

(ii) The dimensions of the lead box are 5.20 m by 5.20 m by 0.90 m.

Calculate the stiffness of the spring system that attaches the lead box to the supports.

density of lead = 11 300 kg m^{-3}

(4)

Stiffness of spring system = ...

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(iii) When the building oscillates, the floor moves but the lead box tends to remain at rest.

Suggest why the lead box tends to remain at rest.

(2)

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(c) As the floor moves, the rollers force oil through holes in the steel plate.

Explain why this reduces the amplitude of oscillation of the building.

(2)

(Total for Question 20 = 12 marks)

15 Doctors can use ultrasound to monitor the heartbeat of a baby when it is developing inside the mother.

(a) A baby's heart was beating at 142 beats minute^{-1}. The wall of the baby's heart was moving with a maximum velocity of 22.0 mm s^{-1}.

Calculate the maximum displacement, in mm, of the wall of the baby's heart. Assume that the motion of the wall of the baby's heart is simple harmonic.

(4)

Maximum displacement of wall of heart = ... mm

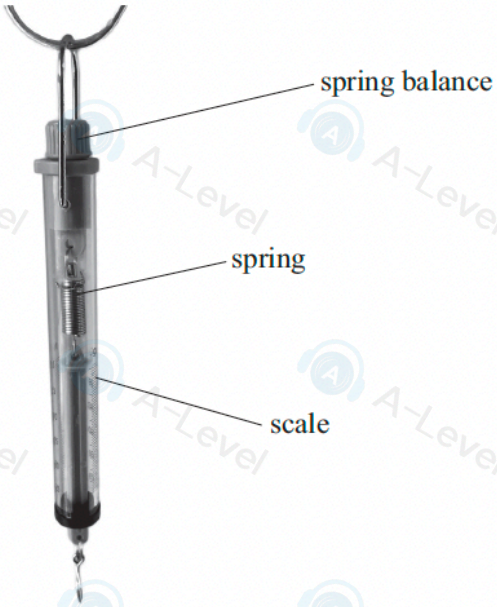
(b) The motion of the wall of the baby's heart only approximates to simple harmonic.

State what is meant by simple harmonic motion.

(2)

(Total for Question 15 = 6 marks)

19 The photograph shows a spring balance.



A scientist calibrated the spring balance. She added known masses to the balance and determined the extension of the spring.

(a) A mass of 550 g was added to the balance and the spring extended by 11.9 cm.

(i) Show that the stiffness of the spring is about 45 $N m^{-1}$.

(3)

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(ii) The spring balance can be used to determine the mass of a small animal without causing harm to the animal.

The animal is placed in a bag. The bag is hung from the spring balance, as shown.

(Source: © Nature Picture Library / Alamy Stock Photo)

The spring extended by 5.8 cm when the bag with the animal was hung from the spring balance.
When the mass of the animal was being determined, the bag started to oscillate with simple harmonic motion.

Calculate the frequency of oscillation of the bag.

(4)

Frequency of oscillation = ...

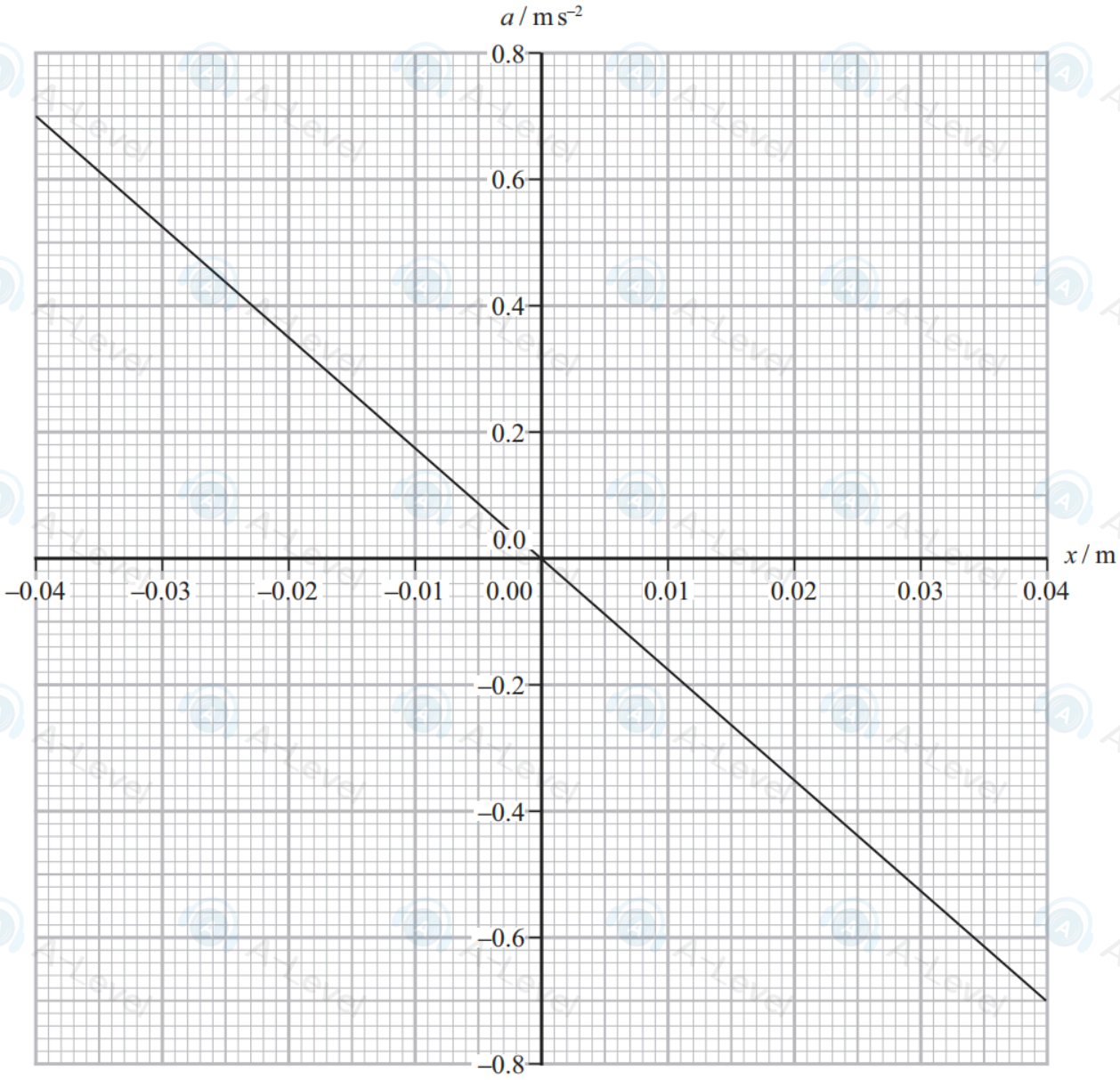
(b) When the mass of one animal was being determined, the amplitude of oscillation of the bag was observed to increase to a large value.

Explain this observation.

(2)

(Total for Question 19 = 9 marks)

17 The graph shows how the acceleration a of an object varies with the displacement x of the object from its equilibrium position.



(a) Explain how the graph shows that the mass is moving with simple harmonic motion.

(2)

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(b) (i) Calculate the maximum kinetic energy of the object.

mass of object = 0.25 kg

(5)

Maximum kinetic energy of object = ...

(b) (i) Calculate the maximum kinetic energy of the object.

mass of object = 0.25 kg

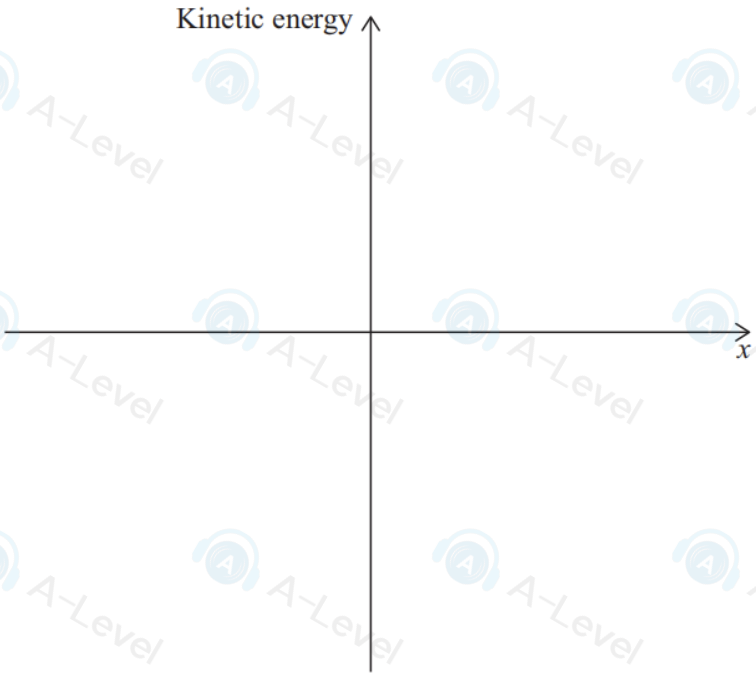
(5)

Maximum kinetic energy of object = ...

(ii) Sketch a graph on the axes below to show how the kinetic energy of the object varies with displacement x.

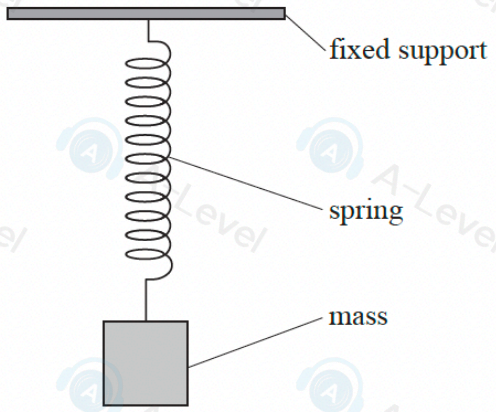
You do not need to do any more calculations.

(2)



(Total for Question 17 = 9 marks)

20 A 150 g mass was hung from a spring as shown. The spring extended by 7.5 cm.



The mass was displaced vertically 3.0 cm from its equilibrium position and then released. The mass oscillated vertically.

(a) Explain why the motion of the mass was simple harmonic motion.

(2)

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(b) Calculate the maximum velocity of the oscillating mass.

(6)

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Maximum velocity of mass = ...

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(c) Explain why the maximum velocity of the oscillating mass decreased over time.

(2)

(Total for Question 20 = 10 marks)