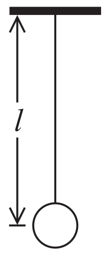
5 A student is using a simple pendulum to determine a value for the acceleration of free fall *g*.



(a) She measures the length l of the pendulum four times with a metre rule and records the following values.

l / cm			
l_1	l_2	l_3	l_4
85.5	86.0	87.5	85.5

She calculates the mean length l_m of the pendulum using the following method:

$$l_m = \frac{85.5 + 86.0 + 87.5 + 85.5}{4} = 86.1\ \text{cm}$$

(i) Calculate a more accurate value for l_m.

(2)

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l_m = ...

(ii) Determine the time period of the oscillations of this pendulum, using your calculated value for l_m.

(2)

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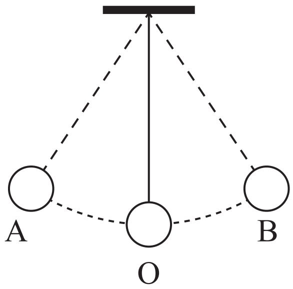
Time period of oscillations = ...

(b) She sets the pendulum into oscillations with small amplitude and uses a stopwatch to determine the time period.



The student releases the pendulum at A and simultaneously starts the stopwatch. She measures the time taken for 5 oscillations and divides the value by 5. She repeats the procedure twice and calculates a mean time period.

Explain two modifications to the student's method that would improve the value obtained for the time period.

(4)

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(Total for Question 5 = 8 marks)

11 The International Space Station (ISS) is in a low Earth orbit. Astronauts in ISS have an apparent weight of zero. In order to determine their mass, the astronauts must secure themselves to a platform which is set into oscillation and moves with simple harmonic motion.

(a) Explain why the astronauts in the ISS have an apparent weight of zero.

(2)

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

(2)

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(c) Describe how, using a stopwatch and a ruler, the following quantities could be determined for the oscillating platform:

(i) the frequency of oscillation

(2)

(ii) the maximum speed of the platform.

(2)

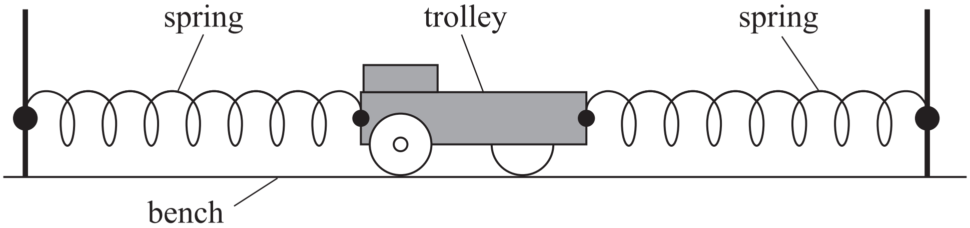
(d) The platform continues to move with simple harmonic motion at the same frequency, but its amplitude is doubled.

Explain how the maximum kinetic energy of the platform will change.

(2)

(Total for Question 11 = 10 marks)

7 A trolley is attached to the ends of two springs as shown. When displaced from its equilibrium position, the trolley moves with simple harmonic motion.



(a) A student has a stopwatch and metre rule available.

(i) Explain the procedure that the student should follow to make an accurate determination of the time period T of the trolley.

(6)

(ii) Describe how the student should use her value of T to determine the maximum speed of the trolley.

(3)

(b) Another student suggests that a more accurate value for T could be obtained by using a position sensor and data logger.

Comment on this suggestion.

(1)

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(c) The student displaces the trolley a greater distance from the equilibrium position, so the amplitude of oscillation is doubled. The trolley still moves with simple harmonic motion.

Explain how the maximum kinetic energy of the trolley will change.

(3)

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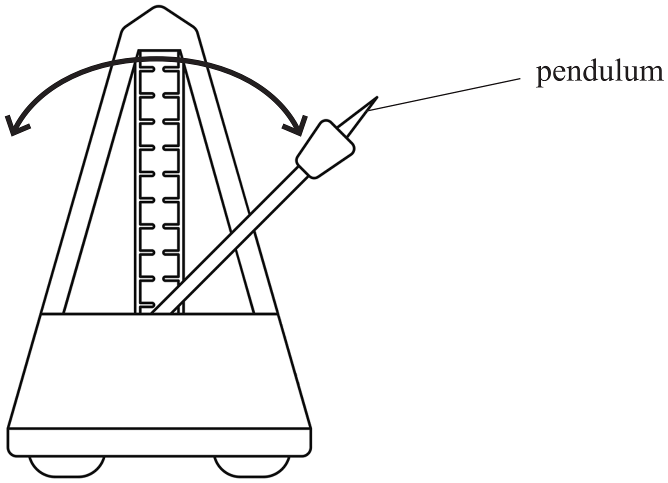
(Total for Question 7 = 13 marks)

4 The diagram shows a metronome, which includes an inverted pendulum, used by musicians to set a tempo. The pendulum oscillates with simple harmonic motion and makes a loud click at regular intervals.



(Source: Getty Images)

A faulty metronome stopped making a clicking noise. A student tried to check the accuracy of the period *T* of the metronome, using a stopwatch. The student timed the pendulum as it moved from one extreme of the oscillation to the other.

Explain how the procedure used by the student to determine *T* could have been improved.

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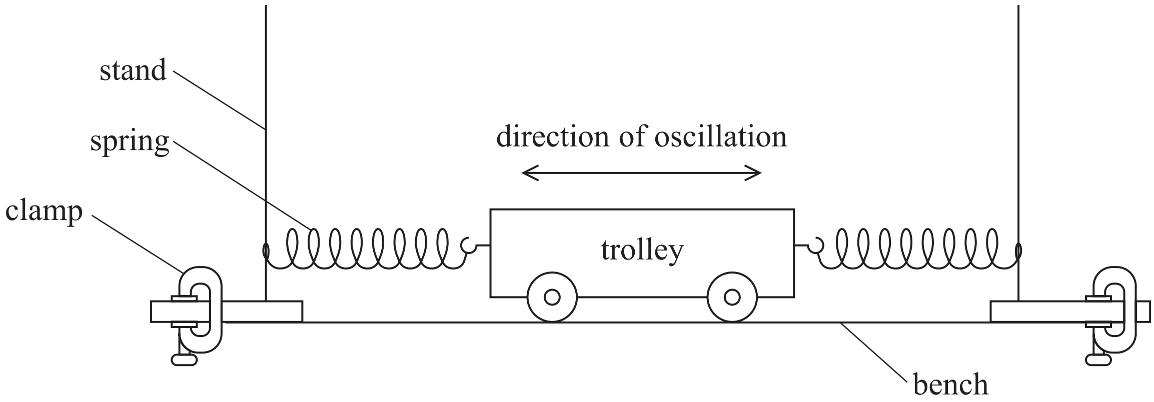
(Total for Question 4 = 5 marks)

6 A student investigated the horizontal oscillations of a trolley between two springs, using the apparatus shown.



The student displaced the trolley from its equilibrium position. She then released the trolley and started a stopwatch. She stopped the stopwatch when the trolley had completed one oscillation.

(a) Describe how the method used by the student could be improved to determine a more accurate value of the time period.

(4)

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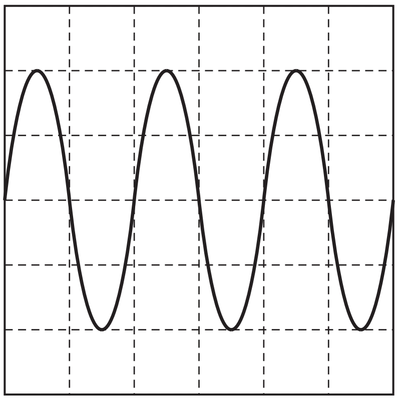
(b) The student displaced the trolley 6.0 cm from the equilibrium position.
She recorded the velocity of the oscillating trolley using a sensor connected to a data logger.

The output from the data logger is shown below.



The time-base of the data logger output was set to $250\,\text{ms div}^{-1}$.

Determine the maximum velocity of the trolley.

(5)

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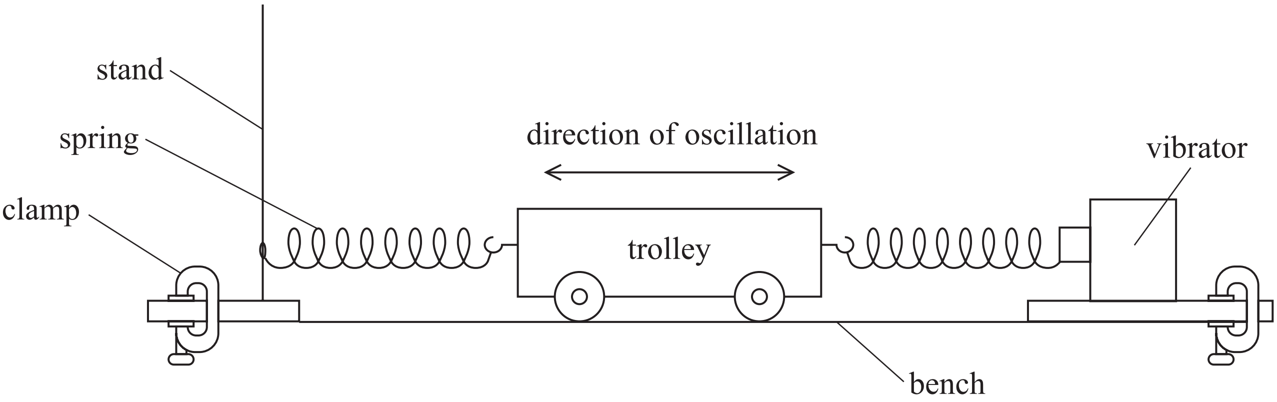
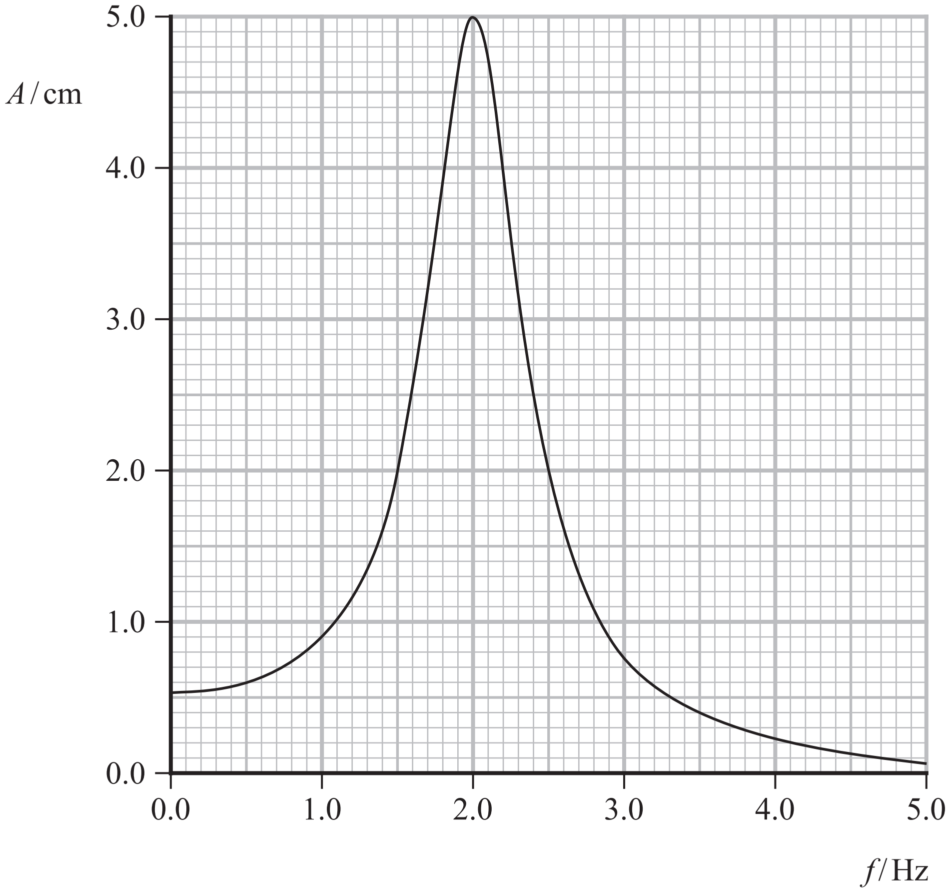
Maximum velocity of trolley = ...

(c) The student modified the apparatus so that the trolley was driven into oscillation by a vibrator, as shown.

A sensor connected to a data logger recorded the amplitude *A* of the oscillations.



The graph shows how *A* varied as the student increased the frequency *f* of the oscillations.



(i) Explain the shape of the graph.

(4)

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(ii) Determine the effective spring constant k of the oscillating trolley system.

mass of trolley = 0.87 kg

(2)

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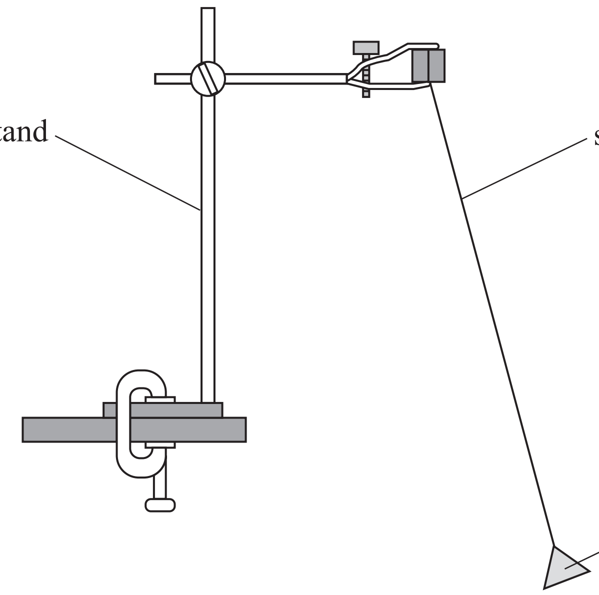
k = ...

(Total for Question 6 = 15 marks)

10 A student made a simple pendulum by connecting a paper cone to a piece of string. She attached the pendulum to a clamp as shown.



(a) (i) The student displaced the pendulum through a small angle so that it oscillated. She determined the time period T as 2.50 s.

Calculate the length of the pendulum.

(2)

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Length of pendulum = ...

(ii) Explain why the amplitude of oscillation of the pendulum did not stay constant.

(3)

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(b) The student recorded how the amplitude of oscillation varied over time.

(i) It is suggested that the relationship between amplitude A and time t is

$$A = A_0 e^{-\frac{kt}{T}}$$

where A_0 is the initial amplitude of the oscillation and k is a constant.

Explain why a graph of $\ln A$ against t would give a straight line.

(2)

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(ii) The table shows the student's data.

***t* / s**	***A* / cm**	
2.5	17.6	
5.0	14.3	
7.5	11.6	
10.0	9.4	
12.5	7.6	

Plot a graph of $\ln A$ against t on the grid opposite. Use the additional column to show your processed data.

(5)

(iii) Determine values for A_0 and k.

(4)

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A_0 = ...

k = ...

(Total for Question 10 = 16 marks)