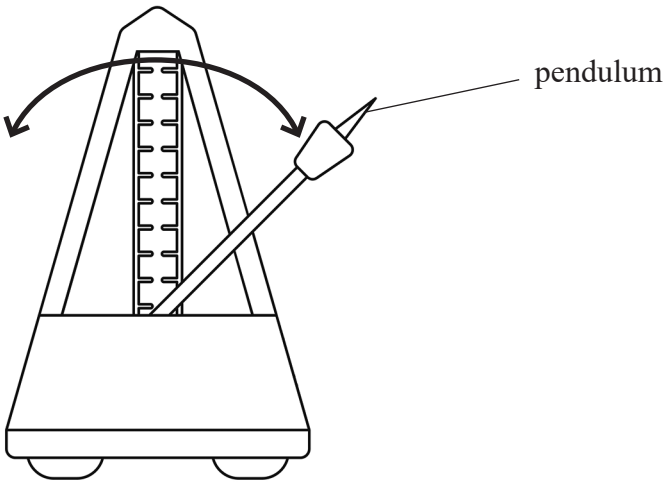
4 The diagram shows a metronome, which includes an inverted pendulum, used by musicians to set a tempo. The pendulum oscillates with simple harmonic motion and makes a loud click at regular intervals.



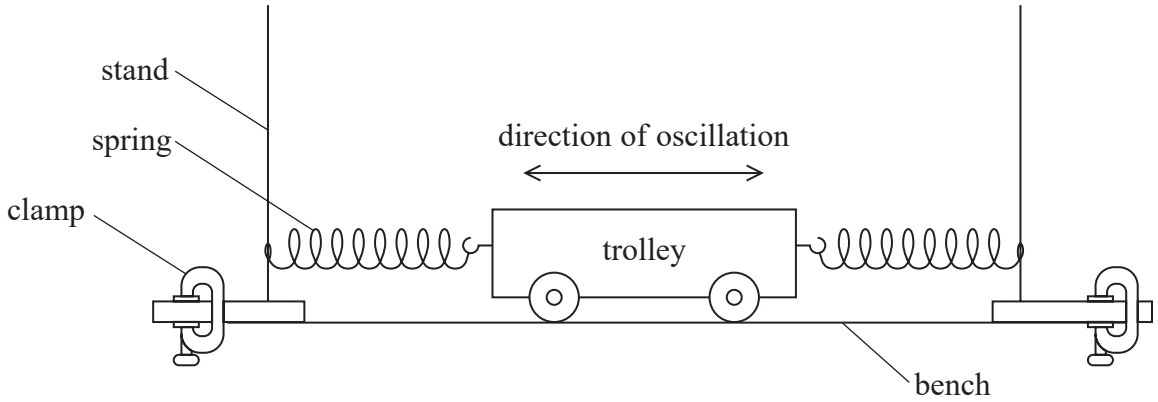
(Source: Getty Images)

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.

(Total for Question 4 = 5 marks)

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



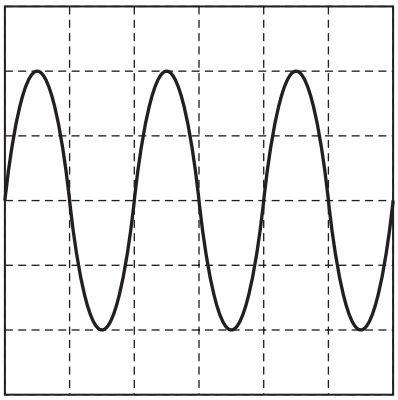
The student displaced the trolley from its equilibrium position. She then released the trolley and started a stopwatch. She stopped the stopwatch when the trolley had completed one oscillation.

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

(4)

(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 ms div^{-1}.

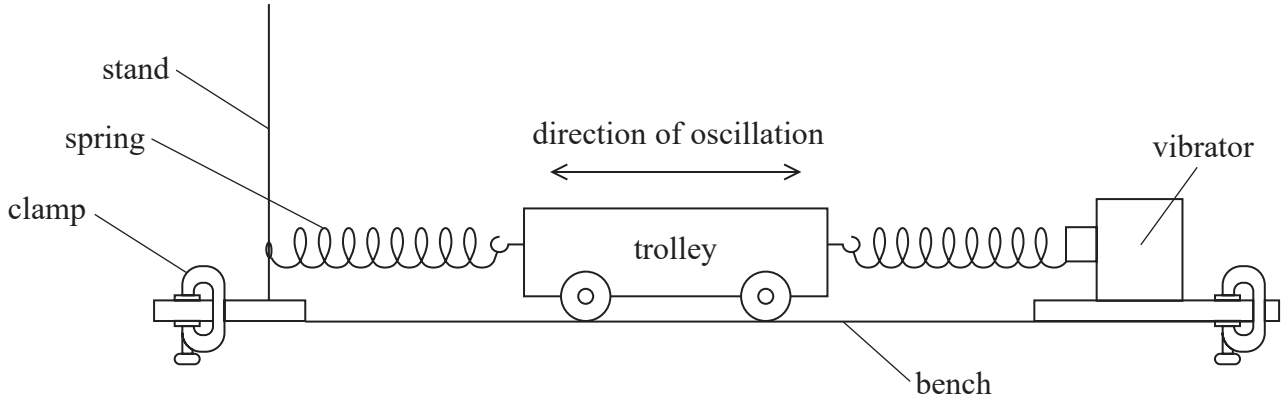
Determine the maximum velocity of the trolley.

(5)

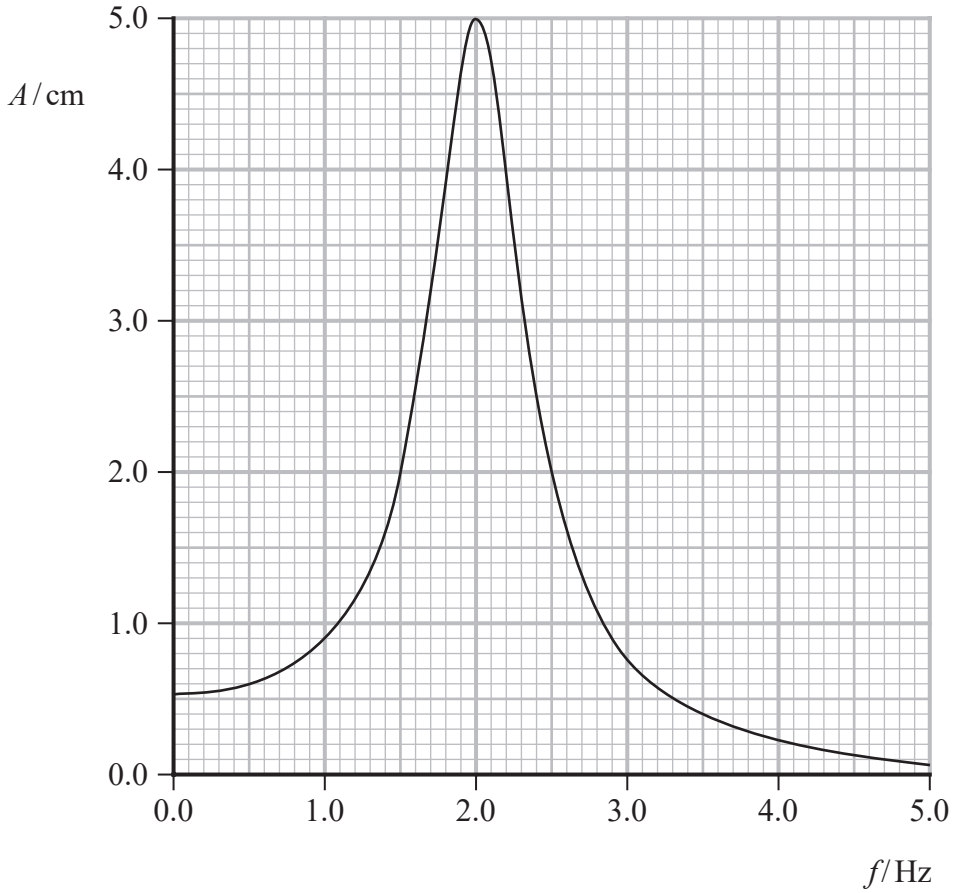
Maximum velocity of trolley = ...

(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)

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

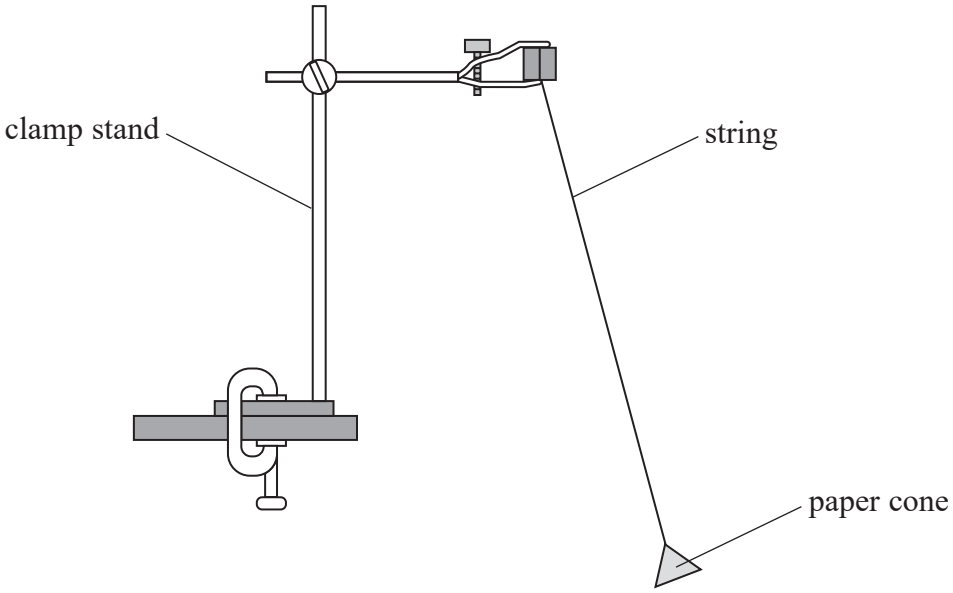
mass of trolley = 0.87 kg

(2)

$k =$ .....

(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)

Length of pendulum = ...

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

(3)

(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)

.....

.....

.....

(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)

.....

.....

.....

.....

$A_0 =$ .....

$k =$ .....

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(Total for Question 10 = 16 marks)