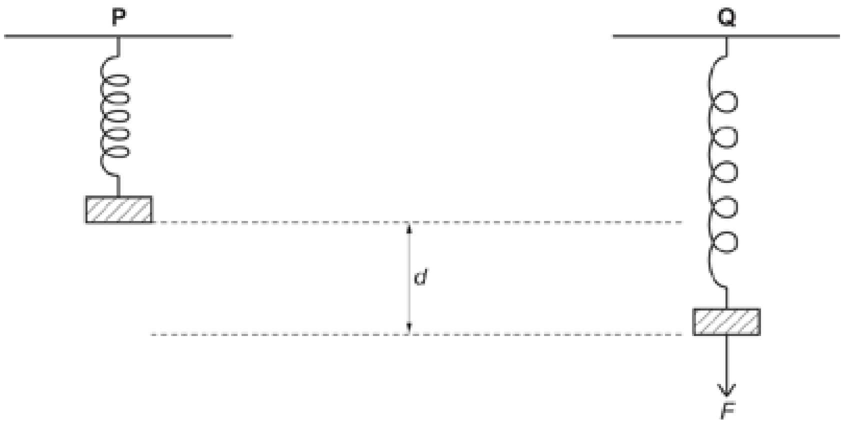
1(a). The length of an unloaded spring is approximately 4 cm.

The force constant k of the spring is 0.62 N cm^{-1}.

The figure below shows a block of mass 0.20 kg attached to one end of the spring. The other end of the spring is attached to a fixed support vertically above the block.

In position **P** the block rests in equilibrium. The extension of the spring is 3.2 cm.

In position **Q** a downwards force F has been applied to the block, so that it now rests a distance d below its position at **P**. The extension of the spring is now 8.5 cm.



The force F is removed.

i. Calculate the magnitude of the block's initial acceleration at the instant that the force F is removed.

Assume that the spring is not extended beyond its limit of proportionality.

acceleration = ... m s^{-2} **[3]**

ii. The block now moves with simple harmonic motion.

Calculate the frequency of this motion.

frequency = ... Hz **[3]**

(b). The block is replaced by a strong magnet **L** of slightly greater mass.

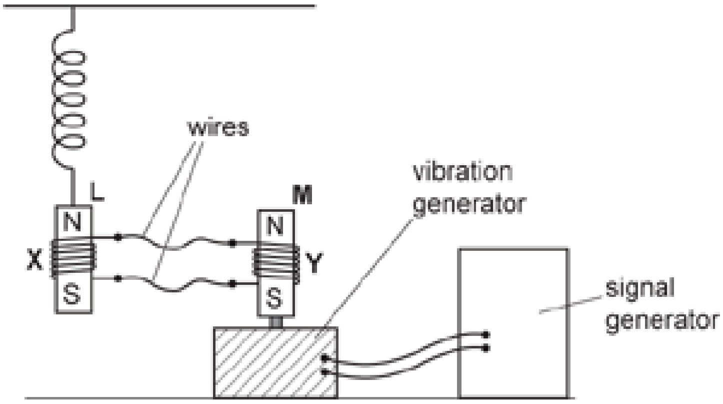
The oscillation frequency of this new arrangement is 2.5 Hz.

The magnet **L** is placed inside a coil **X** of insulated copper wire.

The coil **X** is connected with long wires to a second, identical coil **Y**.

A second strong magnet **M** is placed inside **Y** and attached to a vibration generator.

The vibration generator is then forced to oscillate with a frequency of approximately 2.5 Hz by adjusting the signal generator.



i. As magnet **M** oscillates, it moves in and out of coil **Y**.

The magnet **L** also begins to oscillate.

Explain why **L** oscillates.

[3]

ii. The frequency of the vibration generator is now varied between 0.5 Hz and 5.0 Hz.

Suggest how the amplitude and frequency of the oscillations of **L** will change as the frequency of the generator is varied.

You may draw a diagram to support your answer.

[3]

2. A mass suspended from a spring is pulled down 0.05 m from the equilibrium point and released.

It oscillates in simple harmonic motion. The frequency of the motion is 2 Hz.

At time t = 0 the mass passes through the equilibrium point.

What is the displacement in metres from the equilibrium point at time t?

A $0.05 \cos 2t$
B $0.05 \cos 4\pi t$
C $0.05 \sin 2t$
D $0.05 \sin 4\pi t$

Your answer ☐ **[1]**

3. The natural frequency of an oscillator vibrating in air is 20 Hz.

Which statement is correct about this oscillator?

A The natural period of the vibrating oscillator is 5.0 ms.
B The oscillator can be forced to vibrate at maximum amplitude at a frequency of about 20 Hz.
C The oscillator can be made to resonate at a frequency of about 40 Hz.
D The period of the freely vibrating oscillator gets smaller as its amplitude decreases.

Your answer ☐ **[1]**

4. An object is released from rest and oscillates with simple harmonic motion. The maximum kinetic energy is U.

The object is stopped and the process is repeated with the initial displacement doubled.

What is the new maximum kinetic energy?

A U
B $1.4U$
C $2U$
D $4U$

Your answer ☐ **[1]**

5(a). The figure below shows a stationary glider of mass *m* on an air track.

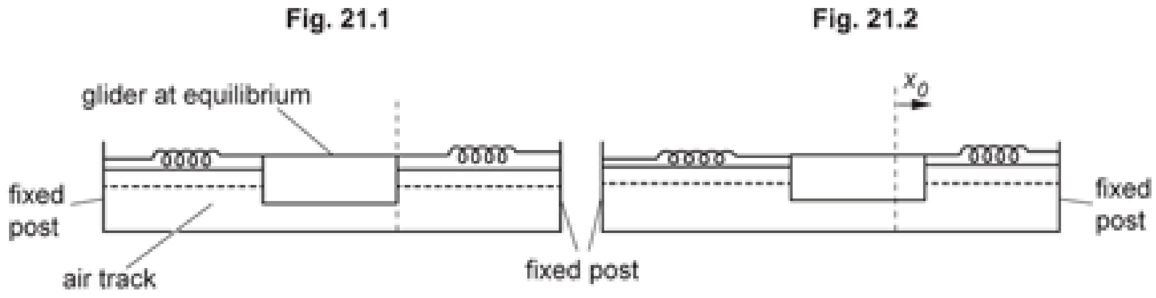
The glider has identical springs with force constant *k* attached to each end which are secured to fixed posts.

The air track blower is turned on and the glider is displaced a small distance x_0 , as seen in the figure. It is then released.

The glider moves horizontally in simple harmonic motion.

The springs remain in tension throughout the motion.

The time taken for 20 complete oscillations is measured, and the period *T* calculated.



The relationship between the period *T*, the mass of the glider *m* and the force constant *k* is described by the equation $T^2 = \frac{2\pi^2 m}{k}$.

i. Show that the equation above is homogeneous by reducing the equation to SI base units.

[2]

ii. Explain why the magnitude of the resultant force *F* on the glider is given by *F* = 2*kx* where *x* is the displacement at any time.

[2]

iii. State and explain the effect, if any, of increasing the initial displacement on the period of the subsequent motion.

[2]

(b). Masses are added to the glider, and the measurement of 20*T* repeated.

The results table is below.

m / kg	20*T* / s	*T*	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

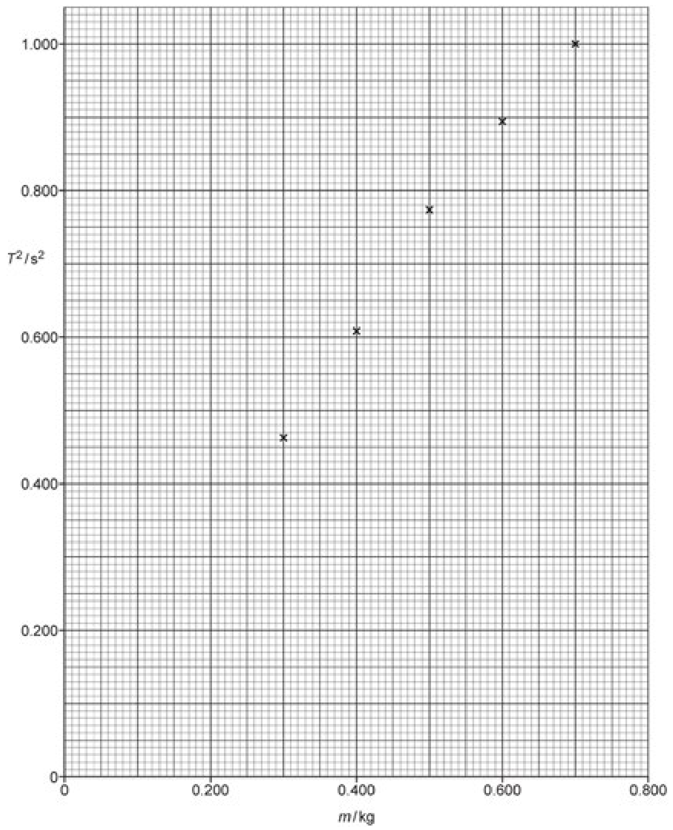
i. Describe **two** different errors in the table.

1 ____

2 ____

[2]

ii. Plot the **first** data point from the table on the graph below.
The other points have all been plotted. The table of results is repeated on the opposite page.
Include on your graph a line of best fit.



m / kg	20*T* / s	*T*	T^2
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0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

[2]

iii. Use the graph to determine the value of *k*.

k = ... N m^{-1} **[3]**

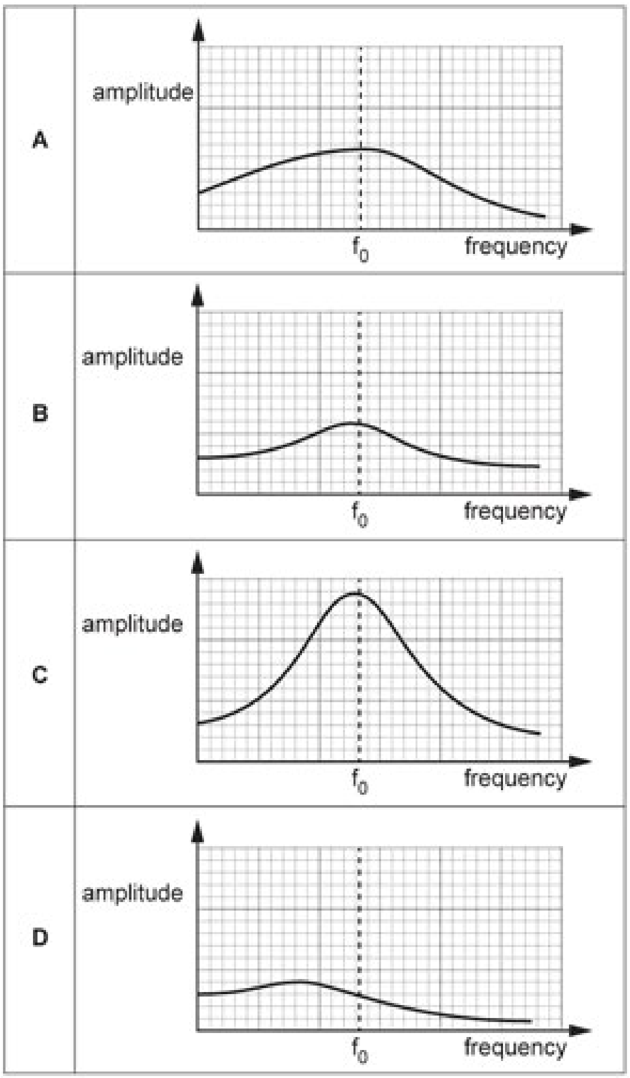
(c). When the initial displacement is increased, one spring increases its extension while the extension of the other spring decreases.

Explain why the **maximum** kinetic energy of the motion increases.

____ **[4]**

6. Four different oscillator systems are forced to oscillate at various frequencies. The graphs show the amplitude of oscillation for each frequency. f_0 is the undamped resonant frequency for each oscillator. The vertical axes on the graphs are all to the same scale.

Which of the oscillators, **A** to **D**, is the most heavily damped?



Your answer **[1]**

7. A student experiments with microwaves emitted from a transmitter. The frequency *f* of the microwaves from the transmitter can be adjusted.

The microwaves are produced by an alternating current in the transmitter.

In one experiment, *f* is 11 GHz. In a wire in the transmitter, the magnitude of the **maximum** alternating current is 20 mA. The wire has cross-sectional area 1.4×10^{-8} m^2 and is made of a metal with free electron number density 8.0×10^{28} m^{-3}.

i. Show that the maximum drift velocity of each free electron in the wire is about 0.1 mms^{-1}.

[3]

ii. The student models the average motion of the free electrons in the wire as simple harmonic motion.

Use your answer to **(i)** to calculate the amplitude *A* of this motion.

A = ... m **[3]**

iii. Without further calculation, explain how the maximum acceleration of a free electron varies as the frequency *f* is adjusted, provided that the maximum alternating current remains constant.

[2]

8(a). A student investigates the oscillations of a uniform rod of length *L* which is pivoted at the top, as shown in **Fig. 2. 1**.

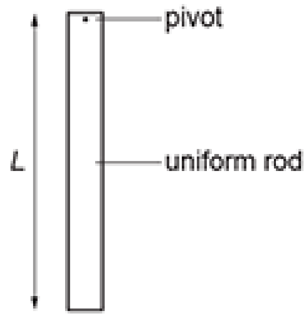


Fig. 2.1

Describe how to determine accurately the period *T* of oscillations of this rod.

[2]

(b). The relationship between the frequency *f* of the oscillations of the rod and its length *L* is

$$f = \frac{1}{2\pi}\sqrt{\frac{3g}{2L}},$$

where *g* is the acceleration of free fall.

The student varies the length *L* of the rod and determines the period *T* for each length.

The student plots a graph of T^2 against *L*, shown in **Fig. 2.2**. A line of best fit has already been drawn.

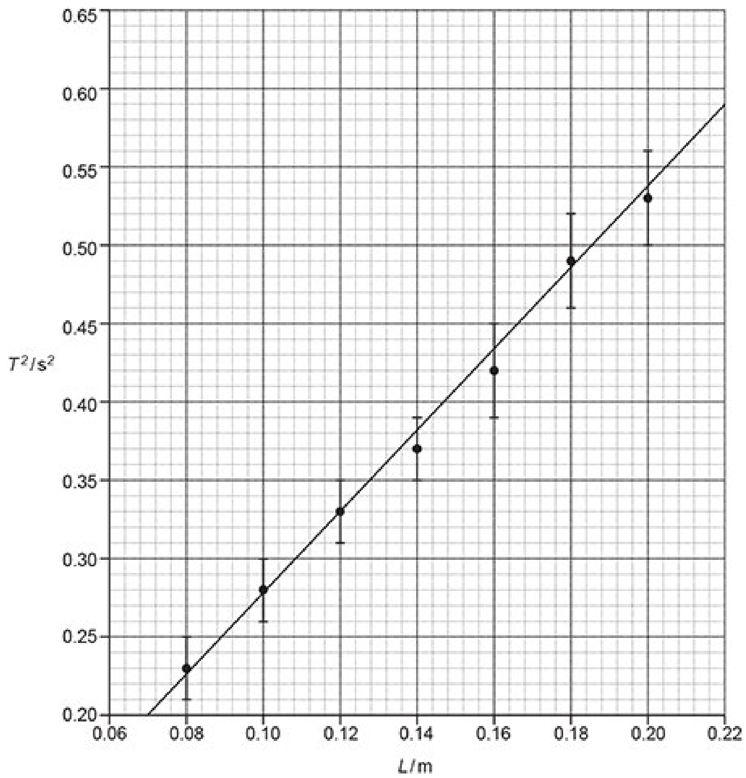


Fig. 2.2

i. Show that the gradient of the graph is given by the equation

gradient = $\frac{8\pi^2}{3g}$

[2]

ii. The gradient of the line of best fit on **Fig. 2.2** is 2.64 $s^2\ m^{-1}$.

Use this value to determine *g*.

g = ... ms^{-2} **[2]**

iii. Draw a line of worst fit on **Fig. 2.2**.

[1]

iv. Use your line of worst fit to calculate the percentage uncertainty in *g*.

percentage uncertainty = ...% **[3]**

v. Use the true value of g (9.81 ms^{-2}) to evaluate the accuracy of the student's value of g from this experiment. Include a calculation in your answer.

[2]

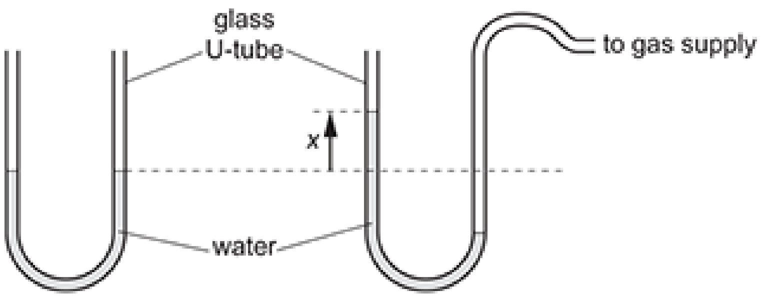
9(a).

For a simple harmonic oscillator, the acceleration a is given by the equation $a = -\omega^2 x$, where ω is the angular frequency and x is the displacement.

Show that this equation is homogeneous by reducing both sides to S.I. base units.

[2]

(b). The diagram shows a glass U-tube partially filled with a mass of water.



One end of the U-tube is connected to a gas supply of **constant** pressure and the other end is open to the atmosphere. The displacement of the water from its equilibrium position is x.
The density ρ of water is 1000 kg m^{-3}.

i. The pressure from the gas supply raises the water in the U-tube.
The vertical distance between the two levels of water in the two vertical sections of the U-tube is 10.0 cm (x = 5.0 cm).

Δp is the difference between the gas pressure and atmospheric pressure.
Calculate Δp.

Δp = ... Pa **[2]**

ii. When the gas supply is disconnected, the water levels in the U-tube oscillates with simple harmonic motion. The acceleration a of the water level in the left-hand side of the U-tube is given by the equation

$$a = -\frac{2\rho g A}{m}x$$

where m is the mass of the water in the U-tube, A is the internal cross-sectional area of the U-tube, ρ is the density of water, g is the acceleration of free fall and x is the displacement of the water level in the left-hand side of the U-tube.

For this U-tube, $A = 1.0 \times 10^{-4}$ m^2 and $m = 0.052$ kg.

Show that the period T of the oscillations is about 1 second.

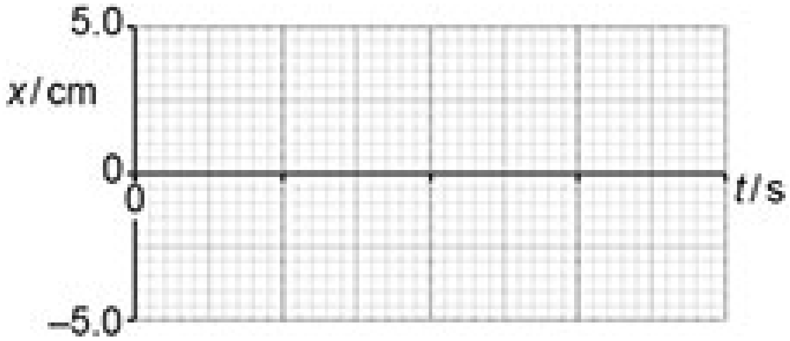
1

[3]

The oscillations of the water level are slightly **damped**.
At time $t = 0$, $x = 5.0$ cm.

2

Sketch a suitable graph of displacement x against time t for the oscillating water level. Add suitable values to the time t axis.



[3]

The U-tube is now connected to another gas supply where the pressure oscillates at a frequency of about 1 Hz.

3

Explain the effect this will have on the water in the U-tube.

____

____

____ **[2]**

10. A mass is attached to the bottom end of a spring which is fixed at its top end.
The mass is displaced vertically, and then released. The mass oscillates with a simple harmonic motion.

Which row correctly describes the energy of this spring-mass system when the mass is at its **lowest** point in its oscillations?

	Elastic potential energy	**Gravitational potential energy**	**Kinetic energy**
A	Maximum	Maximum	Maximum
B	Maximum	Minimum	Zero
C	Minimum	Maximum	Zero
D	Minimum	Minimum	Maximum

Your answer ☐ **[1]**

END OF QUESTION PAPER