SL Paper 2

This question is about thermal properties of matter.

a. Explain, in terms of the energy of its molecules, why the temperature of a pure substance does not change during melting. [3]

b. Three ice cubes at a temperature of 0°C are dropped into a container of water at a temperature of 22°C. The mass of each ice cube is 25 g and the mass of the water is 330 g. The ice melts, so that the temperature of the water decreases. The thermal capacity of the container is negligible. [4]

The following data are available.

Specific latent heat of fusion of ice $= 3.3 \times 10^5$ J kg^{-1}

Specific heat capacity of water $= 4.2 \times 10^3$ J kg^{-1} K^{-1}

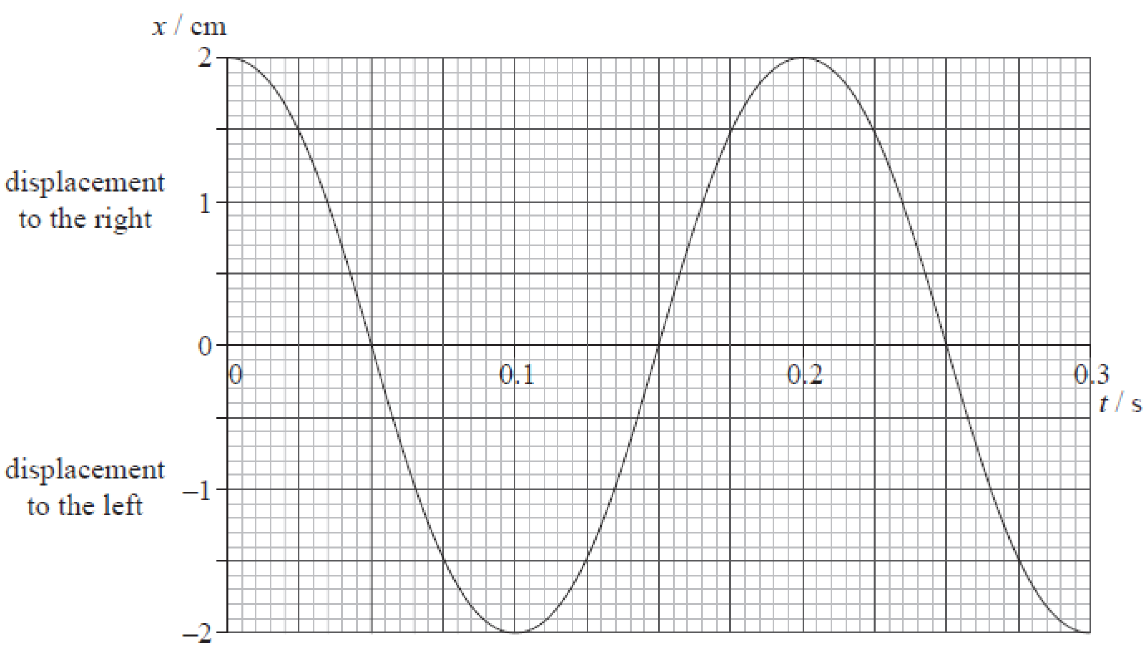
Calculate the final temperature of the water when all of the ice has melted. Assume that no thermal energy is exchanged between the water and the surroundings.

Part 2 Simple harmonic oscillations

A longitudinal wave travels through a medium from left to right.

Graph 1 shows the variation with time *t* of the displacement *x* of a particle P in the medium.

Graph 1



a. For particle P, [6]

(i) state how graph 1 shows that its oscillations are not damped.

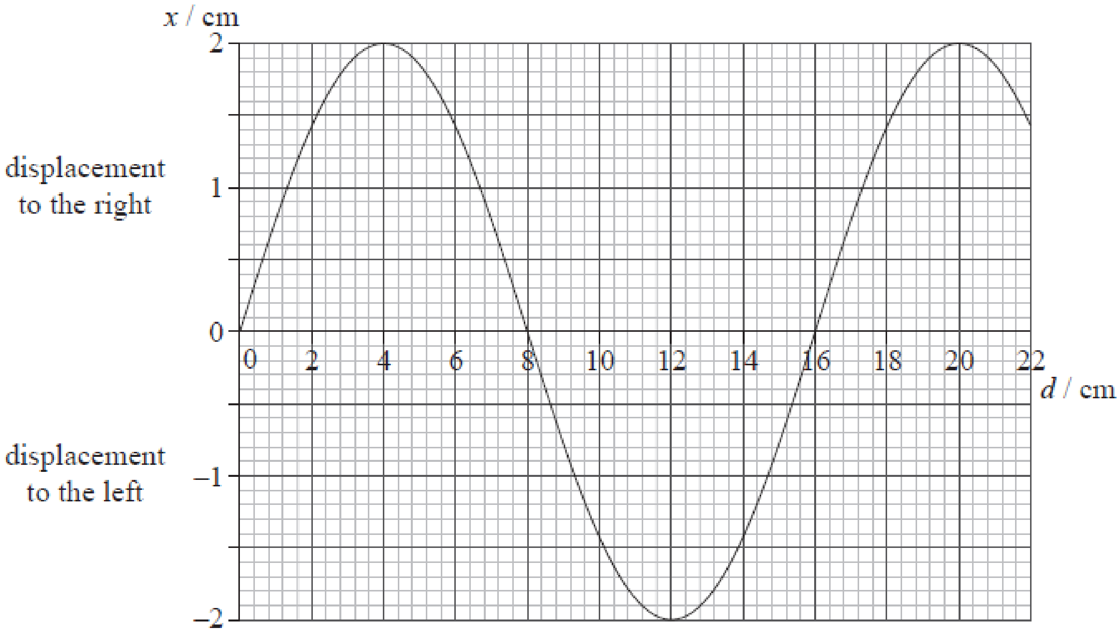
(ii) calculate the magnitude of its maximum acceleration.

(iii) calculate its speed at t=0.12 s.

(iv) state its direction of motion at t=0.12 s.

b. Graph 2 shows the variation with position d of the displacement x of particles in the medium at a particular instant of time. [4]

Graph 2

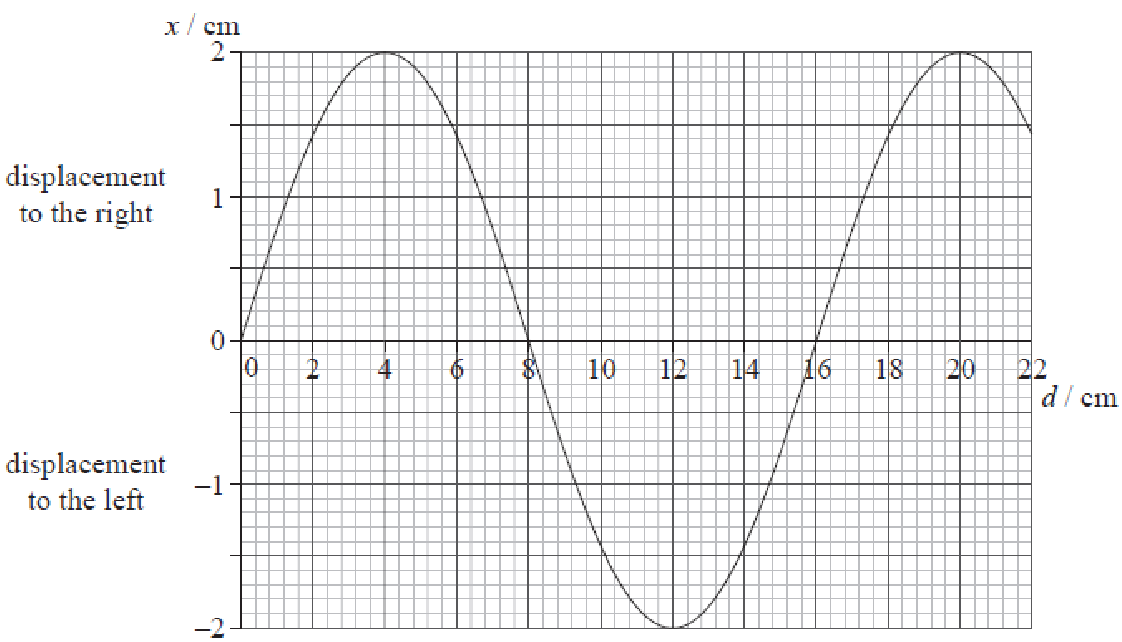


Determine for the longitudinal wave, using graph 1 and graph 2,

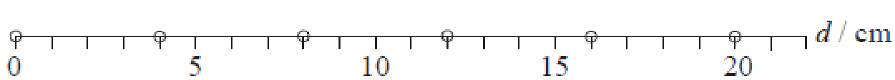
(i) the frequency.

(ii) the speed.

c. **Graph 2** – reproduced to assist with answering (c)(i). [4]



(c) The diagram shows the equilibrium positions of six particles in the medium.



(i) On the diagram above, draw crosses to indicate the positions of these six particles at the instant of time when the displacement is given by graph 2.

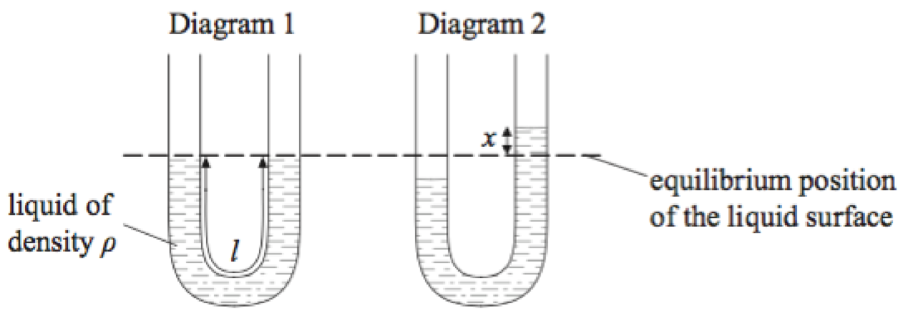
(ii) On the diagram above, label with the letter C a particle that is at the centre of a compression.

This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and a wave in a string. **Part 2** is about the unified atomic mass unit and a nuclear reaction.

Part 1 Simple harmonic motion and a wave in a string

a. By reference to simple harmonic motion, state what is meant by amplitude. [1]

b. A liquid is contained in a U-tube. [5]



The pressure on the liquid in one side of the tube is increased so that the liquid is displaced as shown in diagram 2. When the pressure is suddenly released the liquid oscillates. The damping of the oscillations is small.

(i) Describe what is meant by damping.

(ii) The displacement of the liquid surface from its equilibrium position is *x*. The acceleration *a* of the liquid in the tube is given by the expression

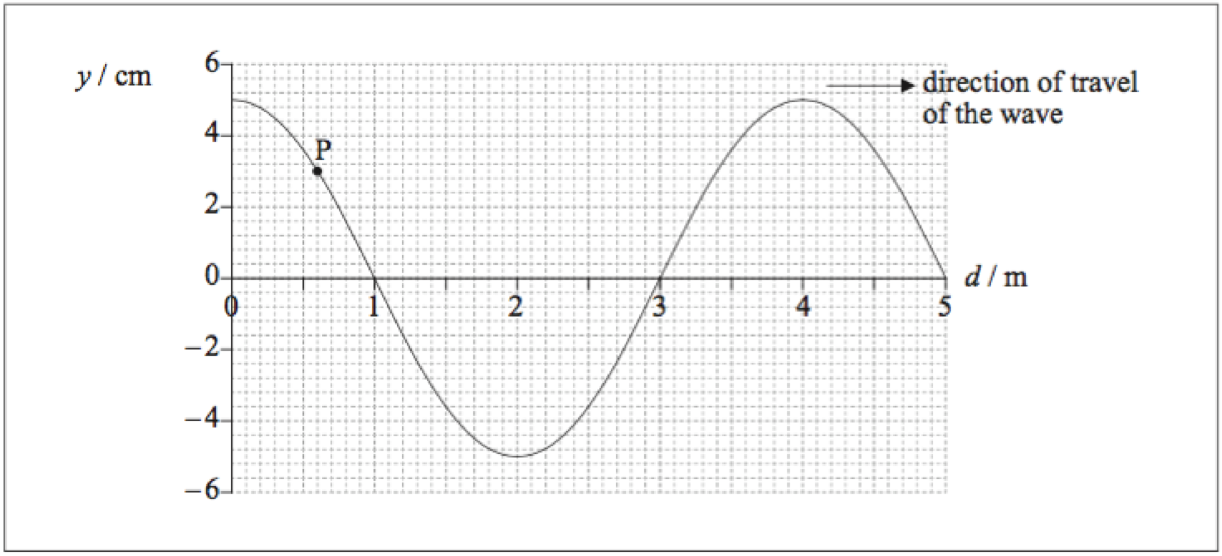
$$a = -\frac{2g}{l}x$$

where *g* is the acceleration of free fall and *l* is the total length of the liquid column. The total length of the liquid column in the tube is 0.32m. Determine the period of oscillation.

c. A wave is travelling along a string. The string can be modelled as a single line of particles and each particle executes simple harmonic motion. [9]

The period of oscillation of the particles is 0.80s.

The graph shows the displacement *y* of part of the string at time *t*=0. The distance along the string is *d*.



(i) On the graph, draw an arrow to show the direction of motion of particle P at the point marked on the string.
(ii) Determine the magnitude of the velocity of particle P.
(iii) Show that the speed of the wave is 5.0 ms^{-1}.

(iv) On the graph opposite, label with the letter X the position of particle P at t=0.40 s.

This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about a mass on a spring.

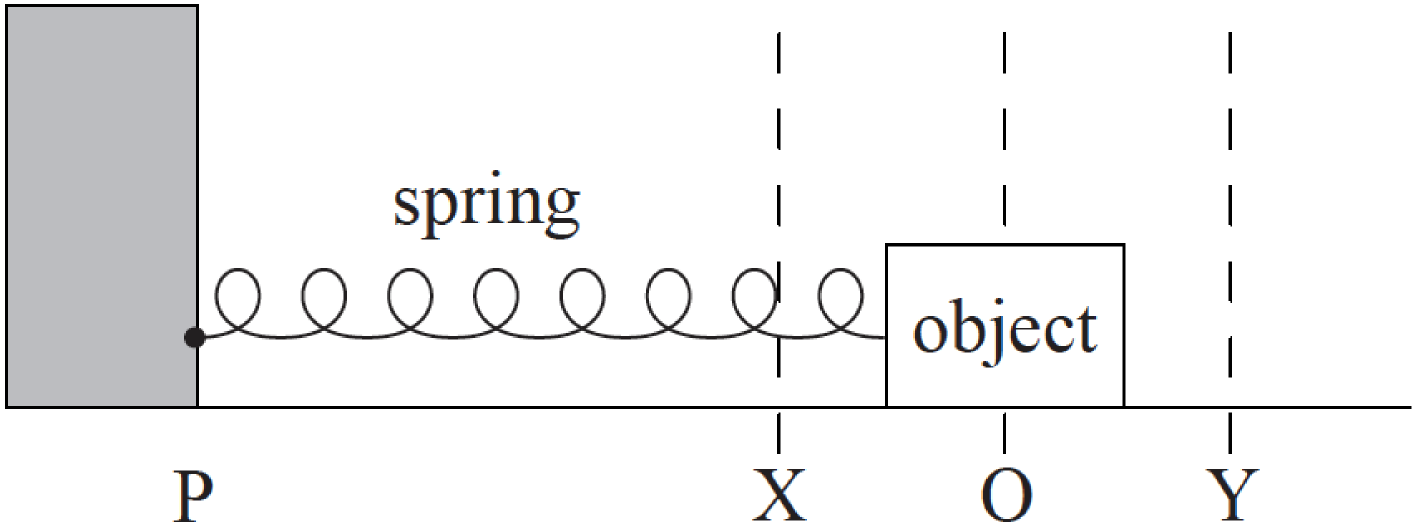
Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	$7.0\times10^{8}\,\text{m}$
Surface temperature of Sun	T	$5.8\times10^{3}\,\text{K}$
Distance from Sun to Earth	d	$1.5\times10^{11}\,\text{m}$
Stefan-Boltzmann constant	σ	$5.7\times10^{-8}\,\text{W}\,\text{m}^{-2}\,\text{K}^{-4}$

Part 2 A mass on a spring

An object is placed on a frictionless surface and attached to a light horizontal spring.



The other end of the spring is attached to a stationary point P. Air resistance is negligible. The equilibrium position is at O. The object is moved to position Y and released.

a. State the Stefan-Boltzmann law for a black body. [2]

b. Deduce that the solar power incident per unit area at distance *d* from the Sun is given by [2]

$$\frac{\sigma R^2 T^4}{d^2}$$

c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. [2]

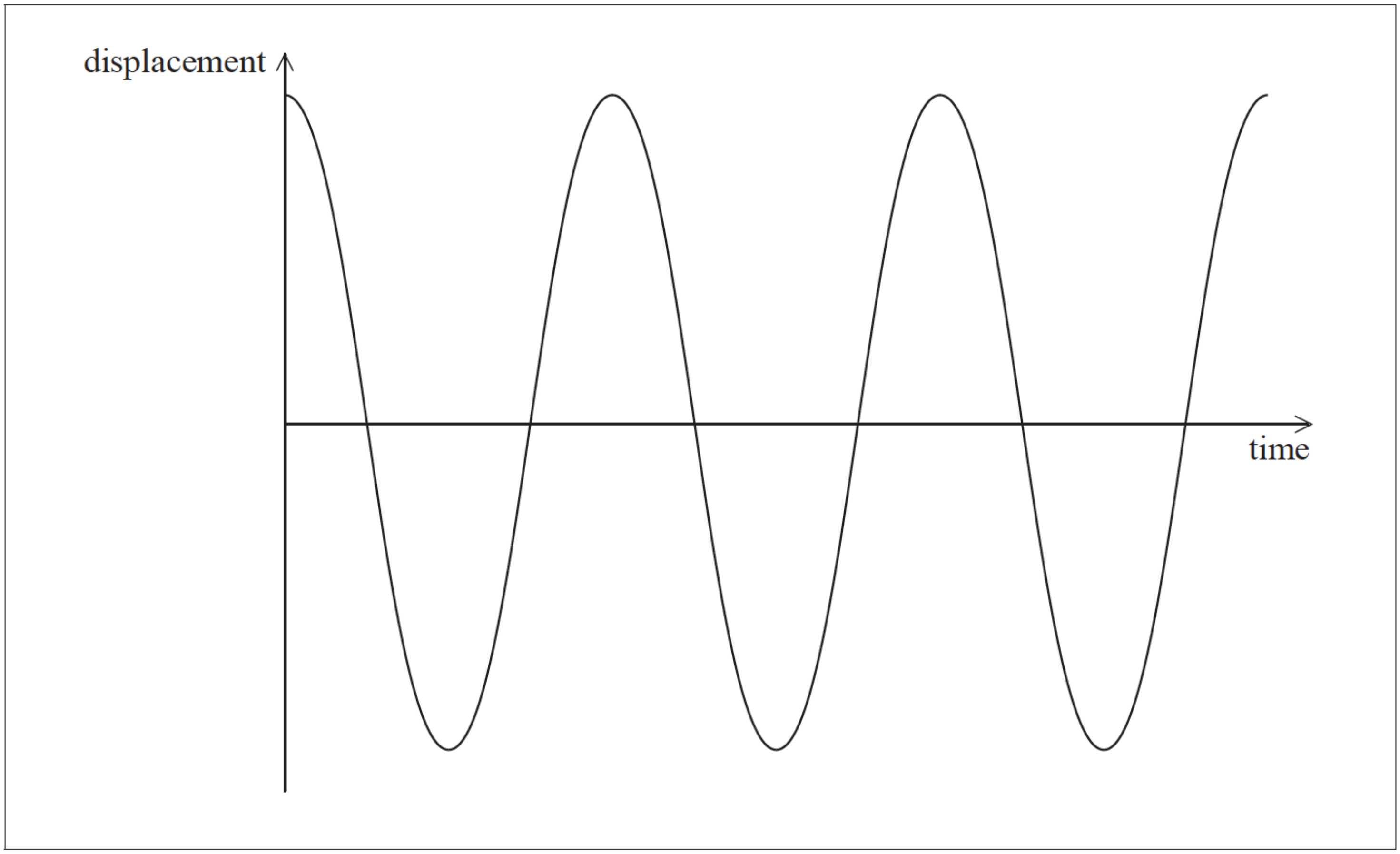
d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). [2]

e. The average power absorbed per unit area at the Earth's surface is 240Wm^{-2}. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. [2]

f. Explain why the actual surface temperature of the Earth is greater than the value in (e). [3]

h. Outline the conditions necessary for the object to execute simple harmonic motion. [2]

i. The sketch graph below shows how the displacement of the object from point O varies with time over three time periods. [4]



(i) Label with the letter A a point at which the magnitude of the acceleration of the object is a maximum.

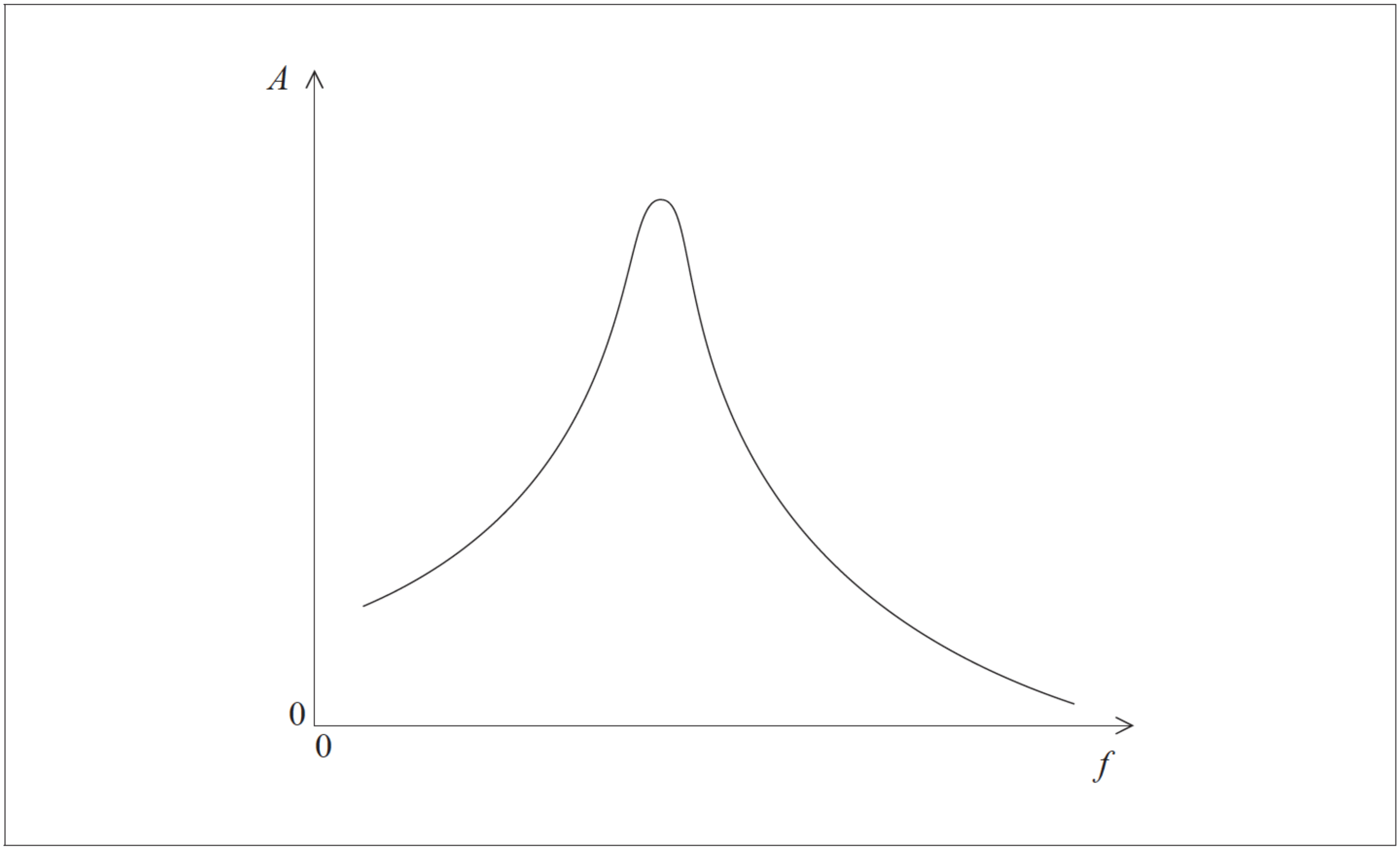
(ii) Label with the letter V a point at which the speed of the object is a maximum.

(iii) Sketch on the same axes a graph of how the displacement varies with time if a **small** frictional force acts on the object.

j. Point P now begins to move from side to side with a small amplitude and at a variable driving frequency *f*. The frictional force is still small. [4]

At each value of *f*, the object eventually reaches a constant amplitude *A*.

The graph shows the variation with *f* of *A*.



(i) With reference to resonance and resonant frequency, comment on the shape of the graph.

(ii) On the same axes, draw a graph to show the variation with *f* of *A* when the frictional force acting on the object is increased.