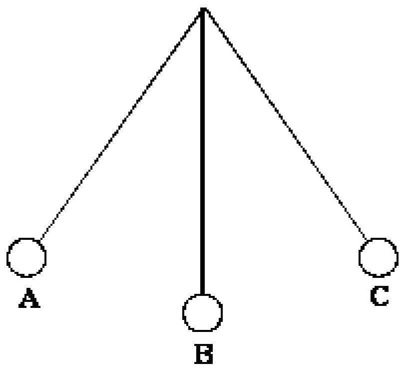
4 The diagram below shows a simple pendulum that consists of a large mass at the end of a long string. **A**, **B** and **C** are positions of the pendulum as it oscillates in the air. **A** and **C** are the extreme positions of the motion and **B** is the centre of the motion.



(a) State clearly in terms of the positions shown on the diagram what is meant by the *period of oscillation* of the pendulum.

period is time from A to C and back to A. Or C to A....
or B->C->A->B

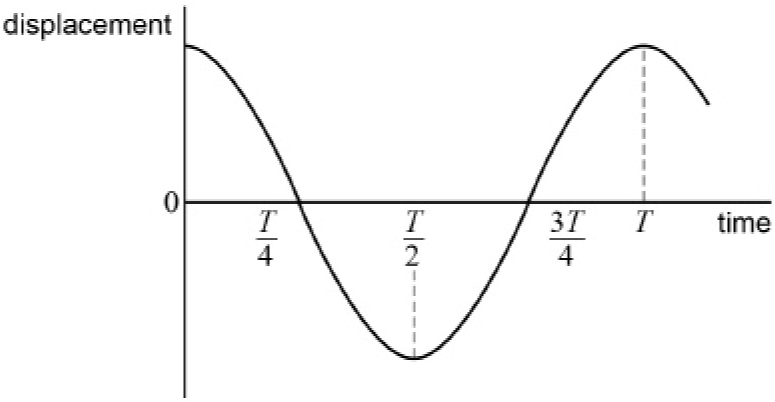
(2)

(b) The diagram shows positions of the bob during an oscillation. State at which position the damping is greatest. Explain why the damping is greatest in the position you have quoted.

Position B. This is the point where the velocity is greatest, and therefore the resistive/drag forces are too

(3)
(Total 5 marks)

8 The graph shows how the displacement of a particle performing simple harmonic motion varies with time.



Which statement is **not** correct?

✓ **A** The speed of the particle is a maximum at time $\frac{T}{4}$ ☐

✓ **B** The potential energy of the particle is zero at time $\frac{3T}{4}$ ☐

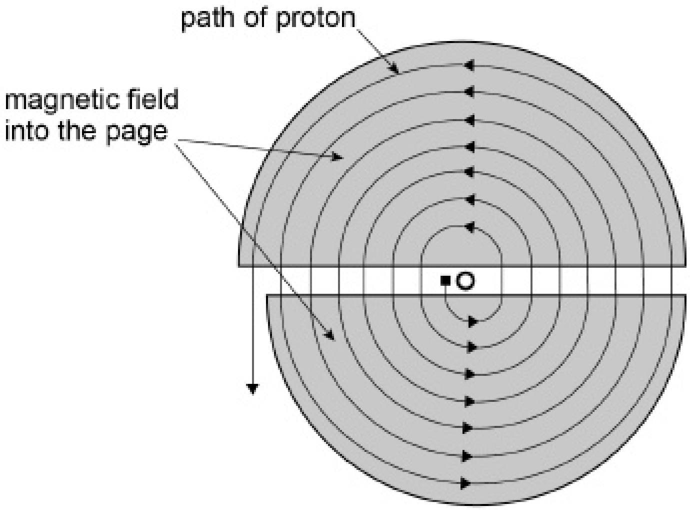
✓ **C** The acceleration of the particle is a maximum at time $\frac{T}{2}$ ☐

✗ **D** The restoring force acting on the particle is zero at time T ☑

(Total 1 mark)

9 A cyclotron has two D-shaped regions where the magnetic flux density is constant.
The D-shaped regions are separated by a small gap.
An alternating electric field between the D-shaped regions accelerates charged particles. The magnetic field causes the charged particles to follow a circular path.

The diagram shows the path followed by a proton that starts from **O**.



(a) Explain why it is **not** possible for the magnetic field to alter the speed of a proton while it is in one of the D-shaped regions.

the force from the B-field acts at 90 degrees to the direction of movement and is therefore doing no work (and can only change the direction)

(1)

(b) Derive an expression to show that the time taken by a proton to travel round one semi-circular path is independent of the radius of the path.

$Bqv = \frac{mv^2}{r}$ t for 1 turn $= \frac{2\pi r}{v} \Rightarrow v = \frac{2\pi r}{t}$.

$\Rightarrow Bq = \frac{mv}{r} = \frac{m\,2\pi \cancel{r}}{t\,\cancel{r}} \Rightarrow t = \frac{2\pi m}{Bq} \Rightarrow$ t in semi circle $= \frac{\pi m}{Bq}$

(3)

(c) The maximum radius of the path followed by the proton is 0.55 m and the magnetic flux density of the uniform field is 0.44 T.

Ignore any relativistic effects.

Calculate the maximum speed of a proton when it leaves the cyclotron.

$\frac{Bqr}{m} = v$ so $v = 2.3 \times 10^7$ m/s

r m_p

maximum speed = ____________________ m s^{-1}

(2)

(Total 6 marks)

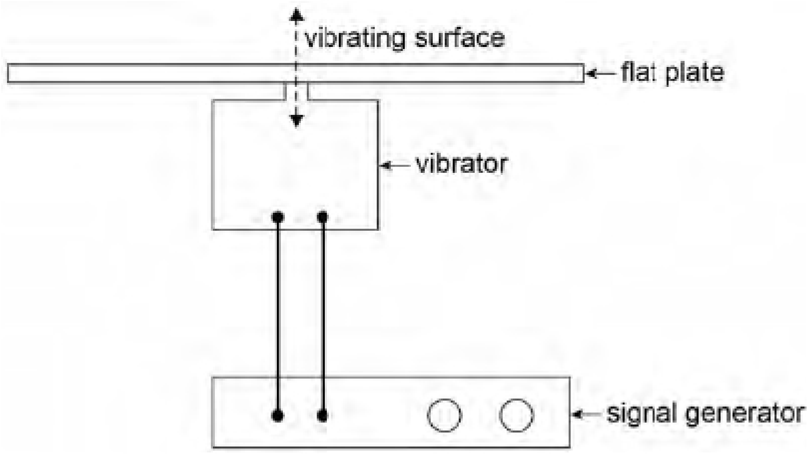
10 (a) State the conditions for simple harmonic motion.

Acceleration is proportional to displacement and is in the opposite direction

(2)

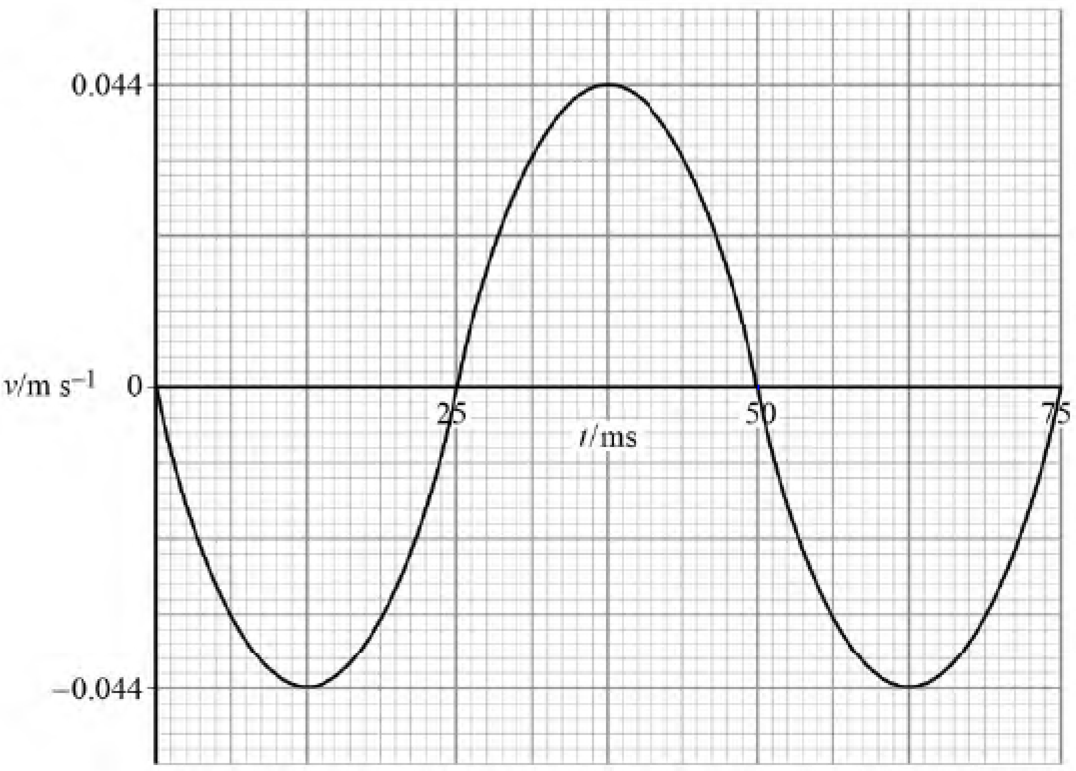
(b) A rigid flat plate is made to vibrate vertically with simple harmonic motion. The frequency of the vibration is controlled by a signal generator as shown in **Figure 1**.

Figure 1



The velocity−time (v−t) graph for the vibrating plate at one frequency is shown in **Figure 2**.

Figure 2



Show that the maximum displacement of the plate is 3.5×10^{-4} m.

$V_{max} = \omega A \leftarrow$ Amp = max displacement

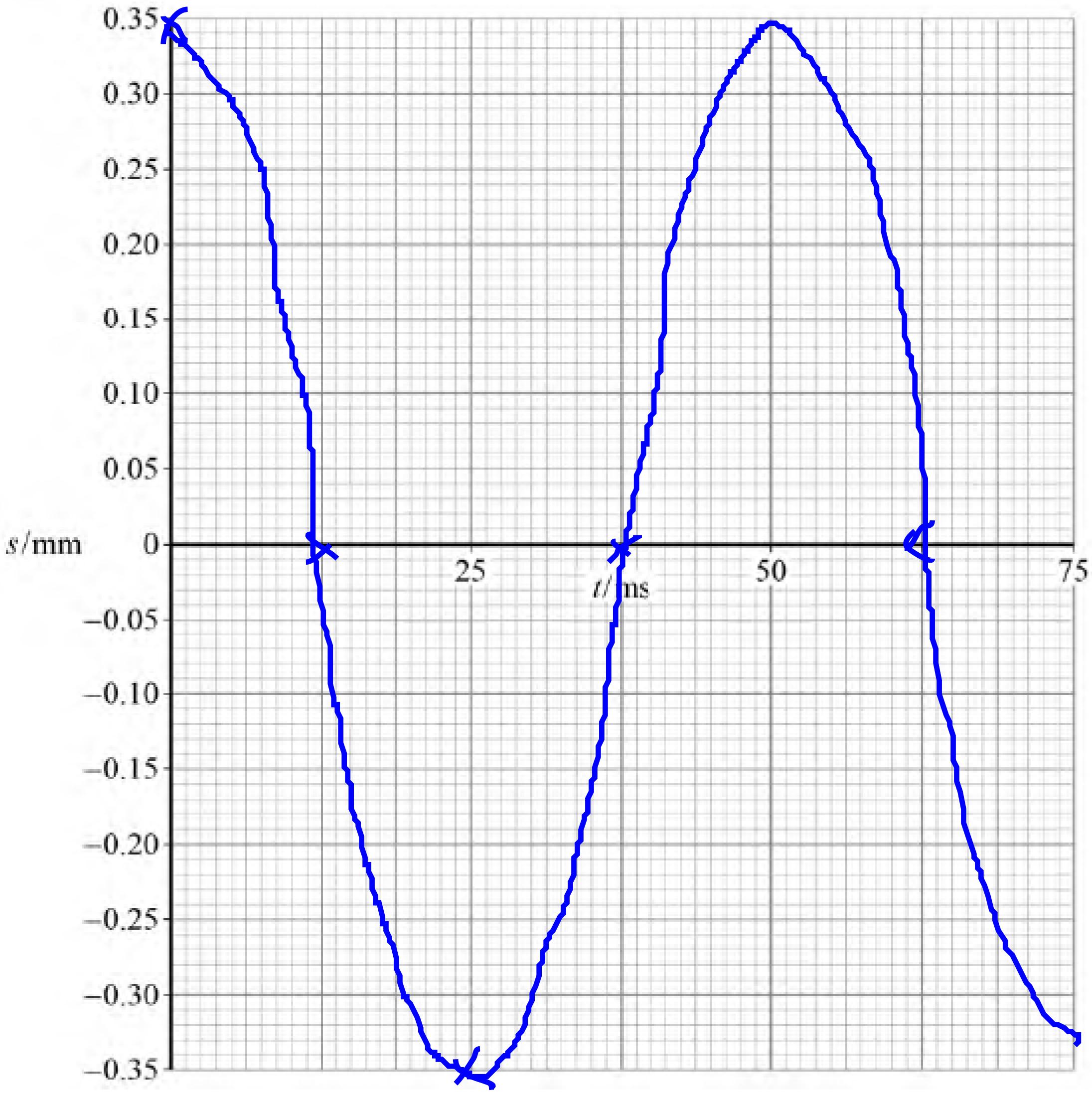
$T = 50\text{ms}$ & $\omega = \frac{2\pi}{T}$

$\therefore \frac{0.044 \times 50\text{ms}}{2\pi} = 3.5 \times 10^{-4}$ m

(2)

(c) Draw on **Figure 3** the displacement−time (*s*−*t*) graph between 0 and 75 ms.

Figure 3



(1)

(d) State **one** time at which the plate has maximum potential energy.

When $v = 0$, & $s = \max$

so 0, 25, 50, 75 ms

time = ______________________ s

(1)

(e) A small quantity of fine sand is placed onto the surface of the plate. Initially the sand grains stay in contact with the plate as it vibrates. The amplitude of the vibrating surface remains constant at 3.5×10^{-4} m over the full frequency range of the signal generator. Above a particular frequency the sand grains lose contact with the surface.

Explain how and why this happens.

the sand is falling at acceleration g

When the vibrating plate has a downwards a < g then the sand stays in contact

As f increases so does a and eventually a>g and so contact is lost as the plate is accelerating more than the sand.

(3)

(f) Calculate the lowest frequency at which the sand grains lose contact with the surface of the plate. - ie $a = g$

$\omega = 2\pi f$

$a = \omega^2 x$ ← will be at top displacement = A

$g = \omega^2 A$ $\Rightarrow \frac{g}{A} = 4\pi^2 f^2 \Rightarrow f = \sqrt{\left(\frac{g}{A 4\pi^2}\right)}$

9.81

3.5×10^{-4} m

frequency = 27 Hz

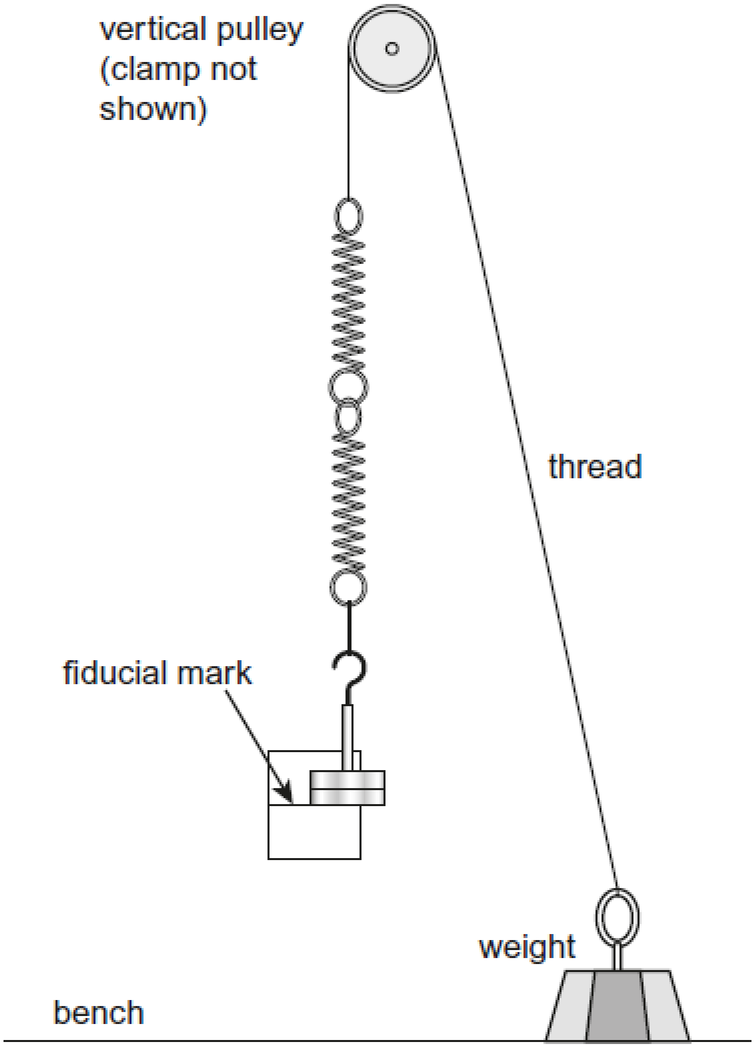
(258)

(2)

(Total 11 marks)

11 A student investigates the vertical oscillations of the mass–spring system shown in **Figure 1**.

Figure 1



The system is suspended from one end of a thread passing over a pulley.

The other end of the thread is tied to a weight.

The system is shown in **Figure 1** with the mass at the equilibrium position.

The spring constant (stiffness) is the same for each spring.

(a) Explain why the position of the fiducial mark shown in **Figure 1** is suitable for this experiment.

the mark is at where the midpoint of the oscillation will be, therefore at the place where speed it greatest

(1)

The table below shows the measurements recorded by the student.

Time for 20 oscillations of the mass-spring system/s				
22.9	22.3	22.8	22.9	22.6

$\frac{\text{range}}{2}$ ↓

(b) (i) Determine the percentage uncertainty in these data.

mean $= \frac{\Sigma}{N} = 22.7$ range $= 0.6$ $\therefore 22.7 \pm 0.3$

$\therefore$ % uncertainty $= \frac{0.3}{22.7} \times 100$

percentage uncertainty = 1.3 %

(3)

(ii) Determine the natural frequency of the mass-spring system.

$T = \frac{22.7}{20}$ $\therefore f = \frac{1}{T} =$

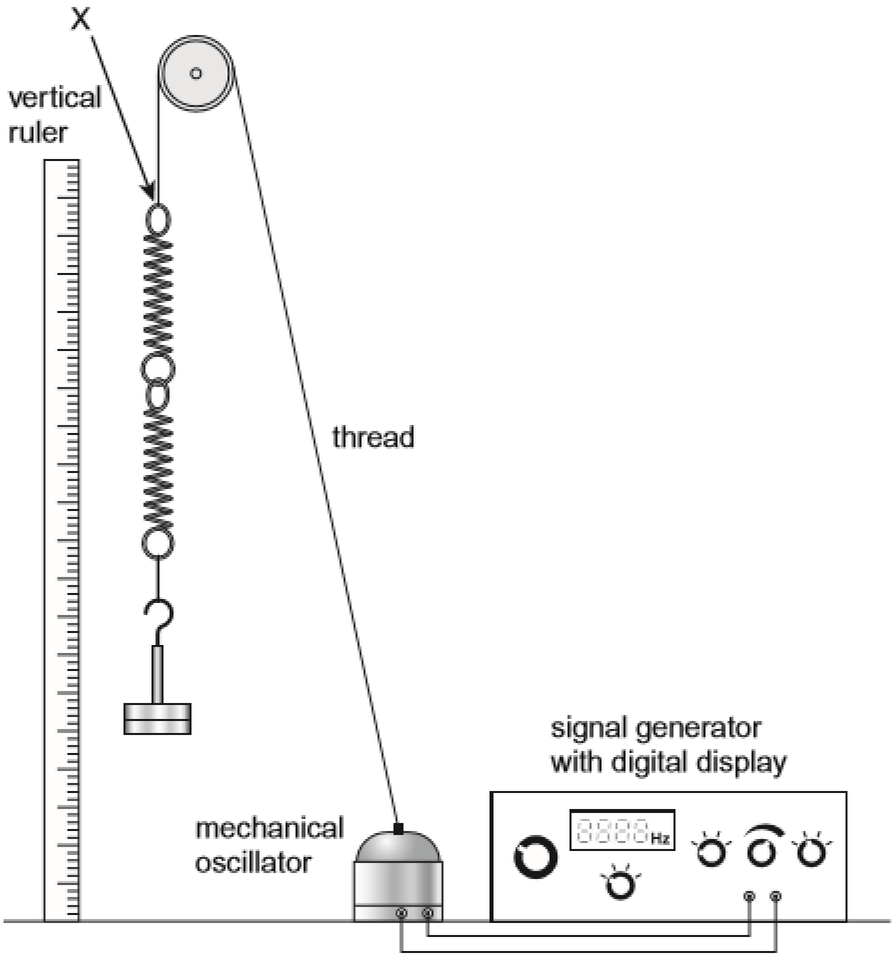
natural frequency = 0.88 Hz

(1)

(c) The student connects the thread to a mechanical oscillator. The oscillator is set in motion using a signal generator and this causes the mass–spring system to undergo forced oscillations.

A vertical ruler is set up alongside the mass–spring system as shown in **Figure 2**. The student measures values of *A*, the amplitude of the oscillations of the mass as *f*, the frequency of the forcing oscillations, is varied.

Figure 2



A graph for the student's experiment is shown in **Figure 3**.

(i) Add a suitable scale to the frequency axis.
You should refer to your answer in part **(b)(ii)** and note that the scale starts at 0 Hz.

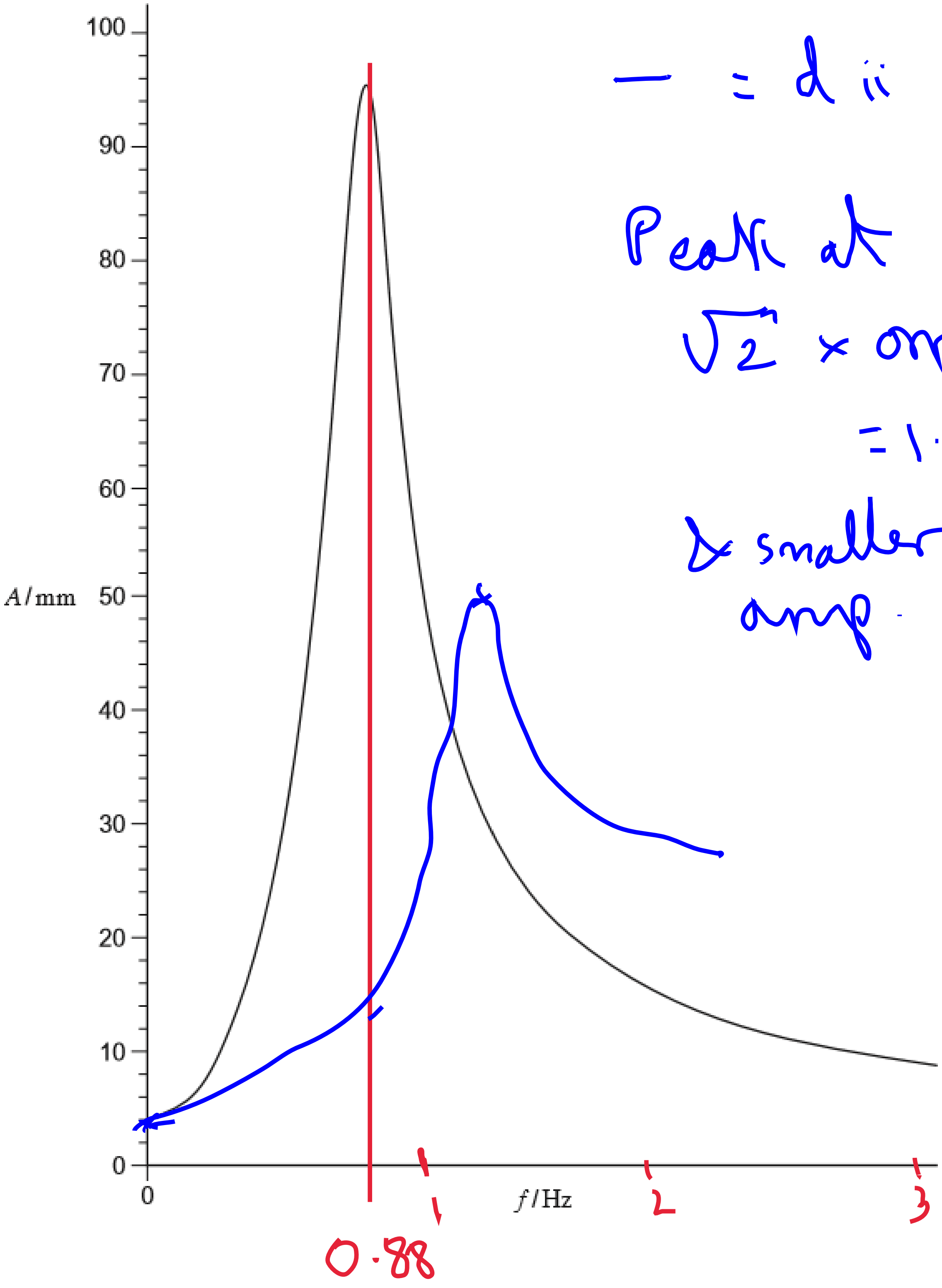
(1)

(ii) Deduce from **Figure 3** the amplitude of the oscillations of X, the point where the mass–spring system is joined to the thread.
You should assume that the length of the thread is constant.

amplitude of X = 4 mm ← point where there is no S.

(1)

Figure 3



— = d ii

Peak at f
√2 × original
= 1.25

& smaller
amp.

(d) (i) State and explain how the student was able to determine the accurate shape of the graph in the region where *A* is a maximum.

When the student saw that the amplitude was rapidly increasing they took more readings for amp vs f. In other words, they decrease the interval between readings for f.

(2)

(ii) The student removes one of the springs and then repeats the experiment.

Add a new line to **Figure 3** to show the graph the student obtains.

You may wish to use the equation $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

(2)

(Total 11 marks)

(1)