8 A student attempts to create his own loudspeaker by attaching a paper cone to a magnet, which is connected to a spring vertically as shown in Fig 8.1.

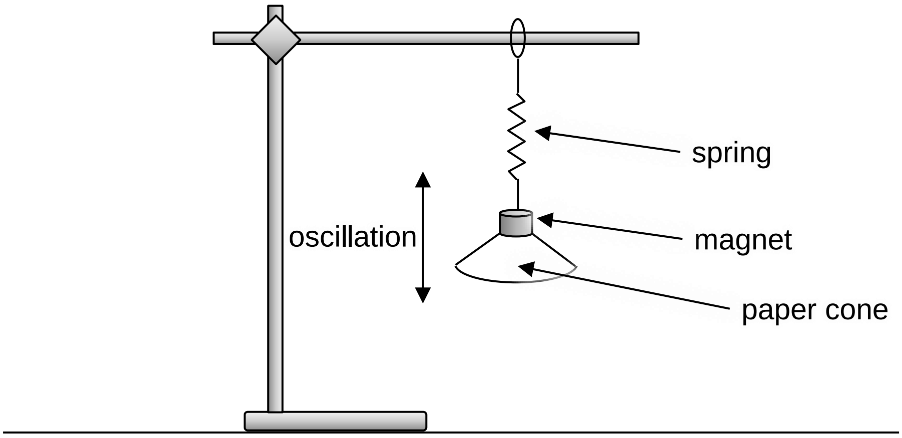

Fig 8.1

When the magnet is displaced a small distance and released, it oscillates up and down.

The vertical displacement of the magnet from its equilibrium position is x. The acceleration of the magnet is given by the expression

$$a = -\frac{k}{m}x$$

where k is the force constant of the spring and m is the mass of the magnet and paper cone.

(a) Explain, with reference to the acceleration of the magnet and paper cone, why the oscillation of the magnet is simple harmonic.

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…………………………………………………………………………………………… [2]

(b) The force constant of the spring is 35 kN m^{-1} and the mass of the magnet and paper cone is 20 g.

(i) Show that the frequency of oscillation of the magnet and paper cone is 210 Hz.

[2]

(ii) The amplitude of oscillation of the magnet, x_0 is 0.20 mm.
Calculate the maximum resultant force on the magnet and paper cone.

maximum resultant force = ………………………….. N [2]

(iii) Hence, calculate the maximum tension in the spring.

maximum tension = ………………………….. N [2]

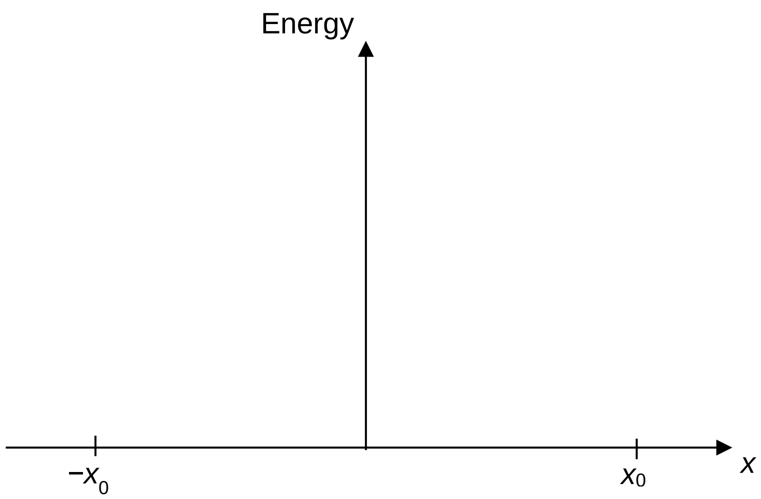
(iv) Calculate the maximum kinetic energy of the oscillation.

maximum kinetic energy = ………………………….. J [2]

(v) As the magnet oscillates, the spring remains extended throughout the oscillation. On the axes below, sketch graphs to show the variation with vertical displacement from the equilibrium position, *x* of:

1. the kinetic energy of the magnet and paper cone, E_k
2. the elastic potential energy in the spring, E_s
3. the gravitational potential energy of the magnet and paper cone, E_g

Take displacement downwards as positive.



[3]

(c) The student now assembles a solenoid coil near the magnet and paper cone, as shown in Fig 8.2.

He then passes a sinusoidal alternating current through the solenoid and this causes the magnet and paper cone to oscillate and make a sound.

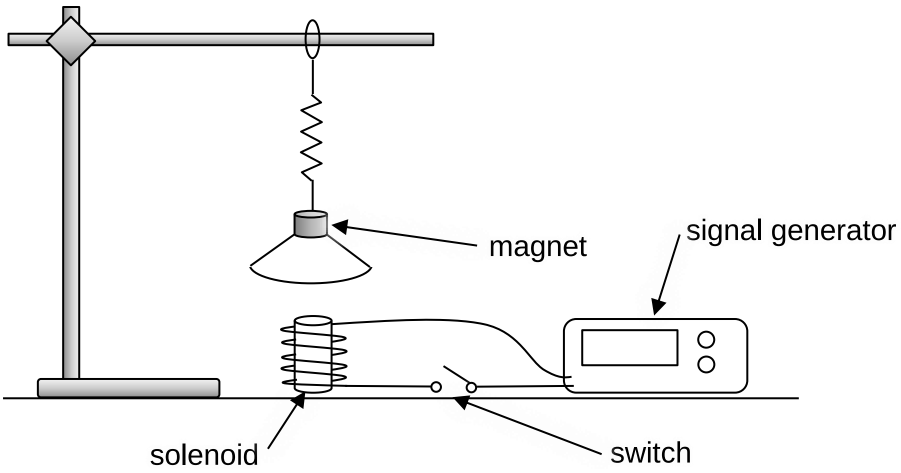


Fig 8.2

(i) State and explain the frequency of the alternating current that produces the loudest sound.

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……………………………………………………………………………………… [2]

(ii) The switch is then opened.

Explain why the oscillations of the magnet and paper cone eventually come to a stop.

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……………………………………………………………………………………… [2]

(iii) The student then modifies the loudspeaker by adding a small mass to the magnet and paper cone.

Explain the effect of this change on the frequency of the alternating current that causes the speaker to generate the loudest sound in **(c)(i)**.

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…………………………………………………………………………………… [2]

(iv) Loudspeakers that are produced commercially are often found to consist of several speakers of different masses, as shown in Fig 8.3.

Fig 8.3

Suggest why this might be so.

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End of Section B