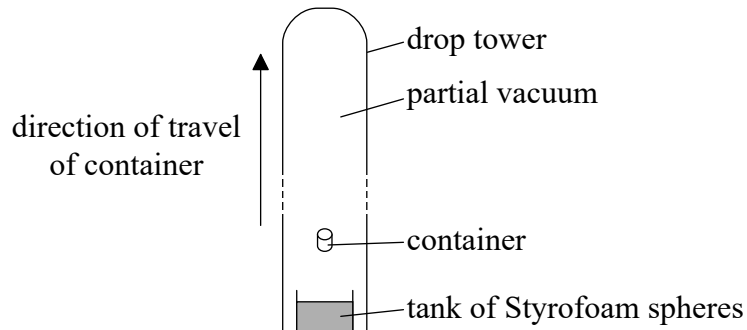*Answer **all** questions. Write your answers in the boxes provided.*

1.   In the drop tower shown, containers with experiments inside of them are fired upwards inside a vertical tower.

The container moves under the influence of gravity and eventually falls back to the bottom of the tower. Most of the air is removed from the tower so that air resistance is negligible. While in flight, the container and its contents are in free-fall.

(a)   The container is fired vertically upwards with initial speed $48\,\mathrm{m\,s^{-1}}$. Determine the time that the container is in flight.   *[2]*

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(This question continues on the following page)

(Question 1 continued)

(b) At the end of the flight, the container of total mass 480 kg falls into a tank of expanded Styrofoam (polystyrene) spheres to slow it. The container stops after moving a distance of 8.0 m in the Styrofoam. Calculate the average force that acts on the container due to the spheres. *[3]*

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(c) Outline why the experiments inside the container could be considered to be in "weightless" conditions. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(d) The tower is 120 m high with an internal diameter of 3.5 m. When most of the air has been removed, the pressure in the tower is 0.96 Pa.

(i) Determine the number of molecules of air in the tower when the temperature of the air is 300 K. *[3]*

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(ii) Outline whether the behaviour of the remaining air in the tower approximates to that of an ideal gas. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(e)   The container can also be released from rest at the top of the tower. The graph shows how the container velocity varies with time from release with the tower in a partial vacuum.
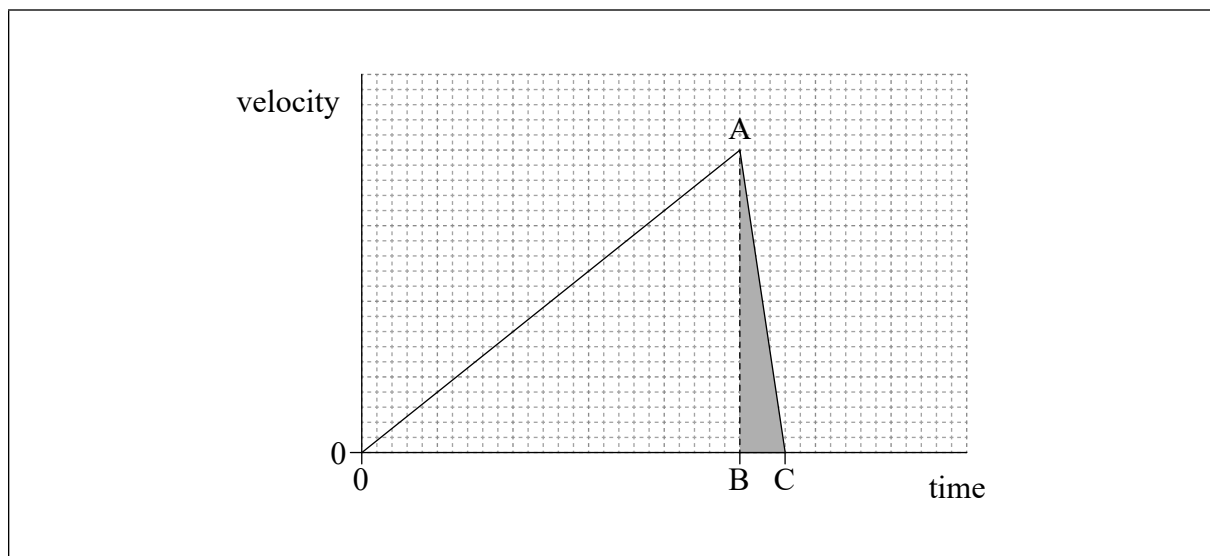

(i)   State the quantity that is represented by the shaded area ABC.   *[1]*

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(ii)   Air is introduced into the tower. The container is released from the top of the tower when the air in the tower is at atmospheric pressure. Using the axes in (e), sketch a graph to show how the container velocity varies with time from release when the air is at atmospheric pressure.   *[3]*

Turn over

2. The diagram shows an electrical circuit with the values of its components. The cells have a negligible internal resistance.
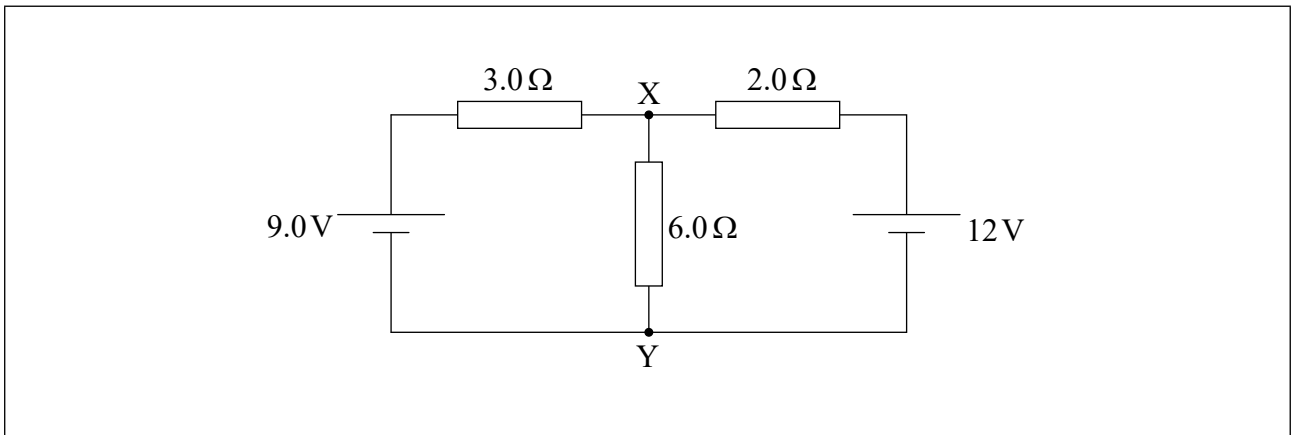
(a) Show, using Kirchhoff's laws, that the current in the $6.0\,\Omega$ resistor is 1.5 A. *[4]*

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(This question continues on the following page)

(Question 2 continued)

(b) (i) Calculate the potential difference between X and Y. *[1]*

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(ii) Outline whether X **or** Y is at higher potential. *[1]*

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Turn over

3. A circuit is designed to supply regular pulses of charge to a $3.3\,k\Omega$ resistor using an electronic switch S.
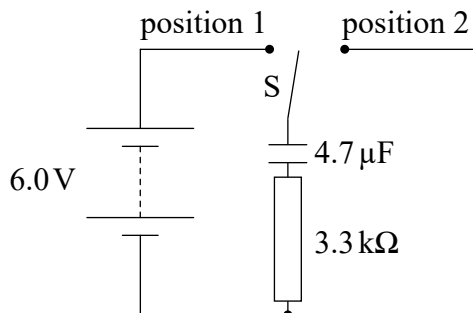
Initially the capacitor is uncharged. The battery has a negligible internal resistance. The capacitance of the capacitor is $4.7\,\mu F$.

(a) At time $t=0$ the switch is moved to position 1. Using the axes, draw a graph to show how the potential difference V across the capacitor varies with time t as it charges. A time scale is not required. *[2]*
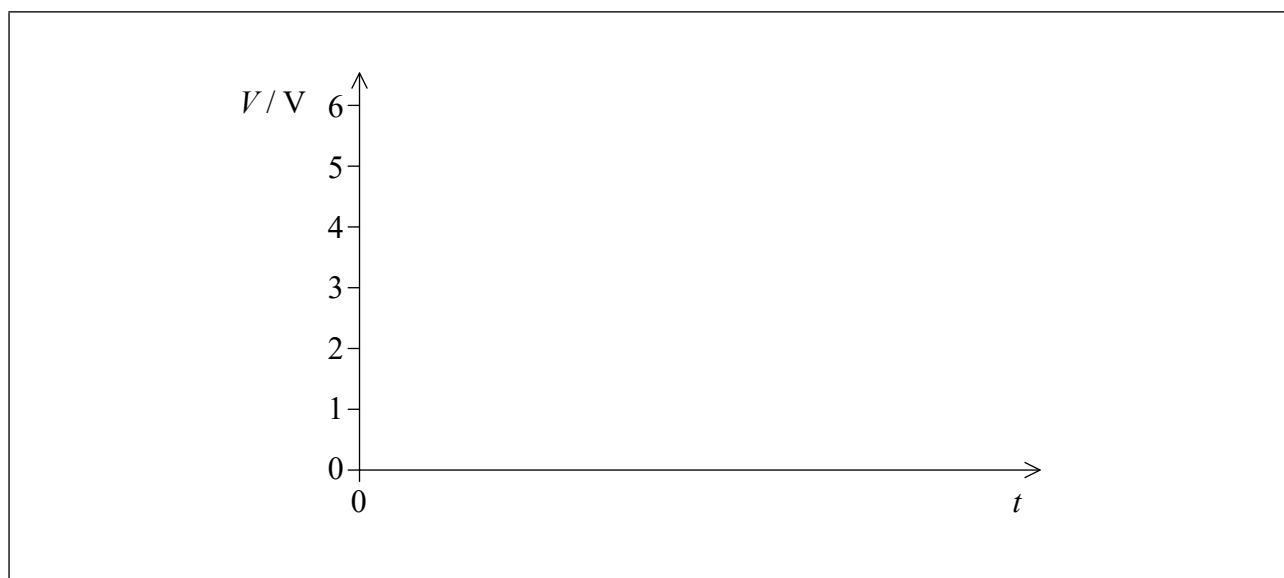
(This question continues on the following page)

(Question 3 continued)

(b)   A single pulse of charge is produced by moving the switch S to position 2 for 6.3 ms.

    (i)   Show that the potential difference across the capacitor falls by about 2 V during the duration of the pulse. *[3]*

    (ii)   Calculate the charge that flows through the circuit during the pulse. *[2]*

    (iii)   The battery has a charge capacity of 0.55 Ah and the circuit produces one pulse each second. Calculate the time, in years, for which the battery can operate the circuit. *[2]*

(This question continues on the following page)

Turn over

(Question 3 continued)

(iv) Two batteries in series, each of emf 6.0 V and having negligible internal resistance, replace the single battery. All other components in the circuit remain the same. Compare the energy transferred from the two batteries with the energy transferred from the single battery during one charge–discharge cycle. [2]
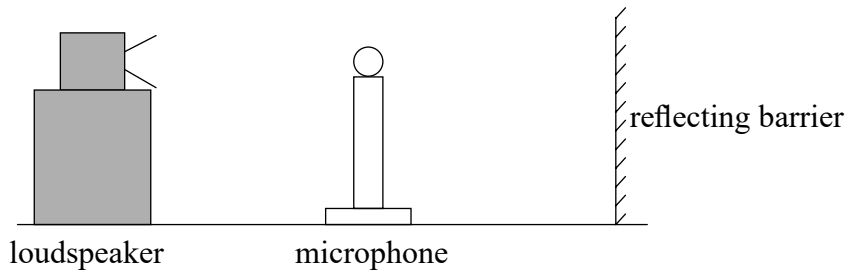
4. A loudspeaker emits sound waves of a single frequency towards a reflecting barrier.

loudspeaker   microphone

reflecting barrier

A microphone is moved along a straight line between the loudspeaker and the barrier. A sequence of equally spaced maxima and minima of sound wave intensity is detected.

(a) Explain how the maxima and minima are formed. [4]

(This question continues on the following page)

24EP10

(Question 4 continued)

(b)   The microphone is moved through 1.0 m from one point of minimum intensity to another point of minimum intensity. It passes through seven points of maximum intensity as it moves. The speed of sound is $340\,\text{m s}^{-1}$.

(i)   Calculate the wavelength of the sound waves.   *[2]*

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(ii)   Outline how you could use this arrangement to determine the speed of sound in air.   *[3]*

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Turn over

5. (a) A power station burns natural gas at a rate of $35\,\text{kg}\,\text{s}^{-1}$. The power output of the station is $750\,\text{MW}$ and the efficiency of the station is $38\,\%$.

(i) Calculate the energy provided by the natural gas each second. *[1]*

(ii) Calculate the specific energy of the natural gas. State appropriate units for your answer. *[3]*

(b) Outline why much of the world's energy is provided from fossil fuels. *[2]*

(This question continues on the following page)

(Question 5 continued)

(c)   There is a suggestion that the temperature of the Earth may increase if the use of fossil fuels is not reduced over the coming years.

(i)   Explain, with reference to the enhanced greenhouse effect, why this temperature increase may occur. *[3]*

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(ii)   Outline how scientists continue to attempt to resolve the climate change debate. *[1]*
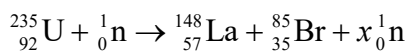
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(This question continues on the following page)

Turn over

(Question 5 continued)

(d)   Nuclear power stations are one way in which energy can be generated without the use of fossil fuels. One example of a nuclear fission reaction is as shown.

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{148}_{57}\text{La} + ^{85}_{35}\text{Br} + x\,^{1}_{0}\text{n}$$

(i)   Identify the value of x.   *[1]*

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(ii)   The following data are available.

Mass of U-235 $= 235.044\,\text{u}$
Mass of n $= 1.009\,\text{u}$
Mass of La-148 $= 147.932\,\text{u}$
Mass of Br-85 $= 84.910\,\text{u}$

Determine, in MeV, the energy released when one uranium nucleus undergoes nuclear fission in the reaction in (d).   *[3]*

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(iii)   Outline, with reference to the speed of the neutrons, the role of the moderator in a nuclear reactor.   *[3]*
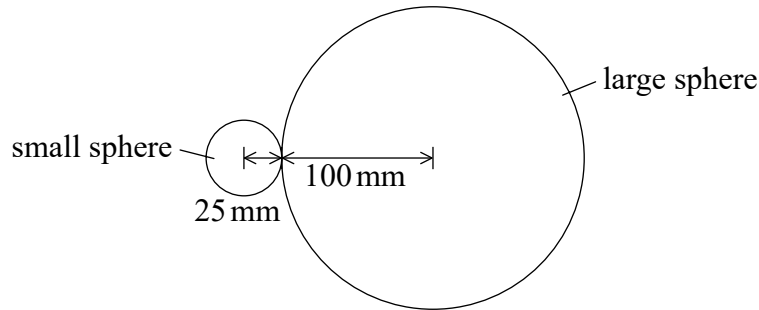
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6. In 1798, Cavendish investigated Newton's law of gravitation by measuring the gravitational force between two lead spheres.

A student repeats the experiment with modern apparatus that has lead spheres of unequal size.

(not to scale)

The large sphere had a radius of 100 mm and a mass of 47 kg. The small sphere had a radius of 25 mm and a mass of 0.73 kg.

(a) Estimate the gravitational force between the spheres when the spheres were in contact. *[2]*

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(b) The student repeats Cavendish's experiment using lead spheres with twice the radius. Discuss the effect on your calculation in (a) of doubling the radius of both spheres. *[4]*

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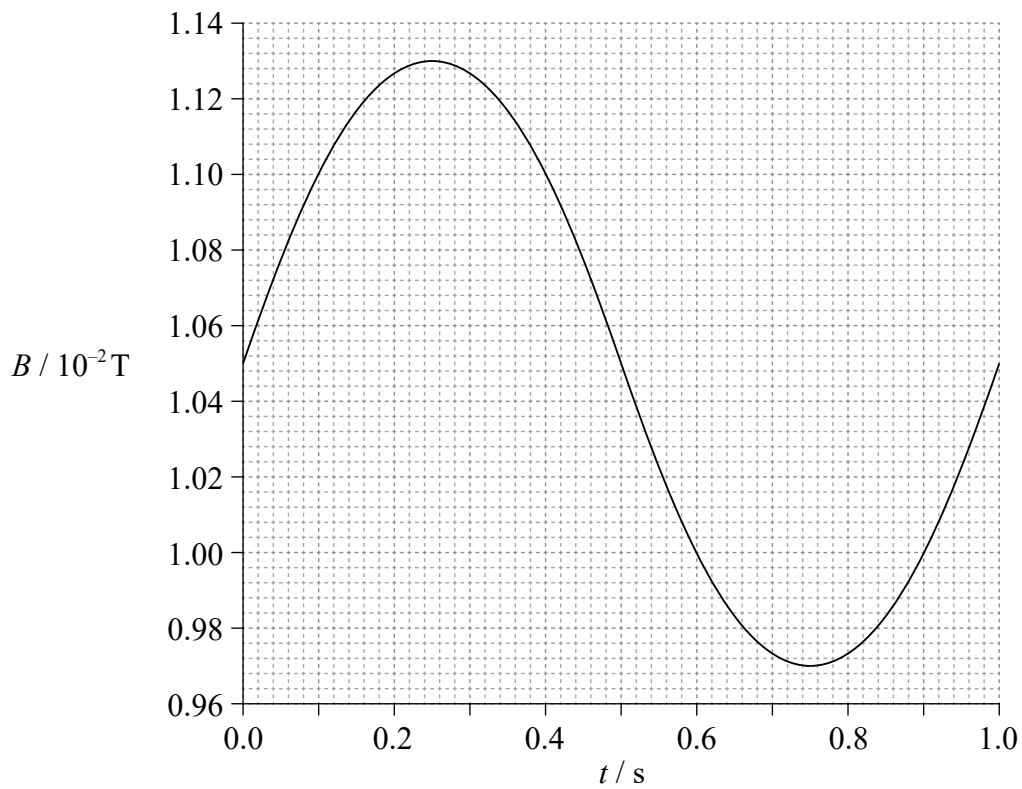
7.   A magnet is suspended on the end of a spring and oscillates vertically with a small amplitude
above a coil.
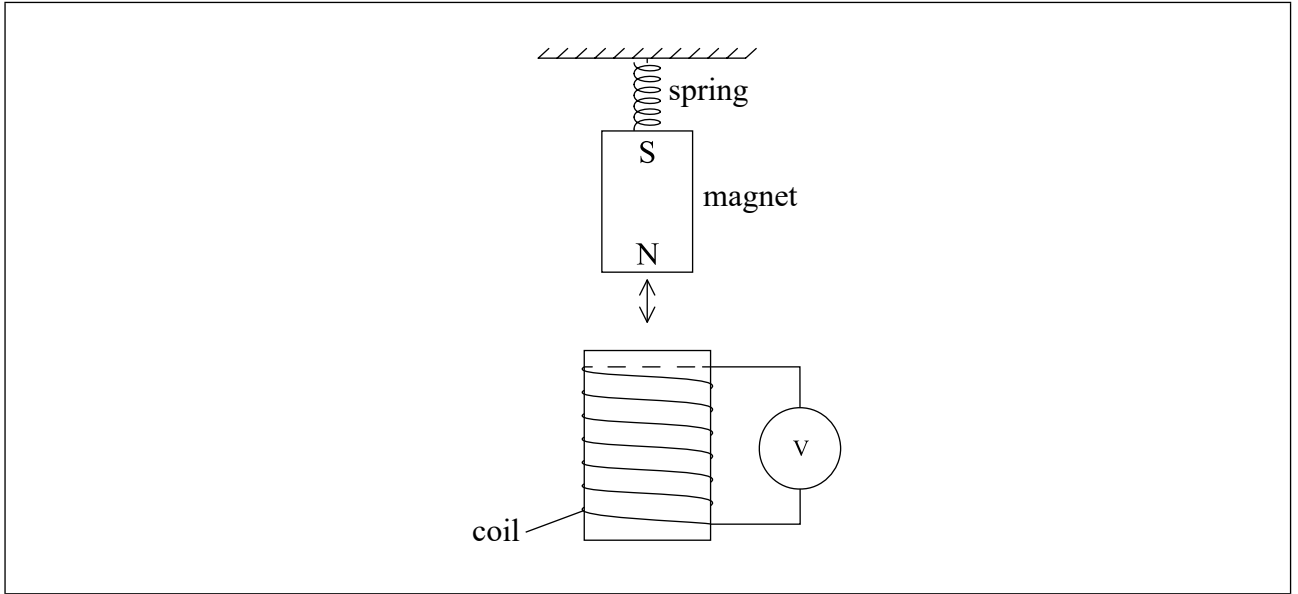
The coil has 240 turns each with a cross-sectional area of $2.5 \times 10^{-4}\,\text{m}^2$.

The graph shows how the magnetic flux density B through the coil varies with time t for
one complete oscillation of the magnet. The magnet is at its equilibrium position when $t=0$.

24EP16

(Question 7 continued)

(a)   Determine the maximum electromotive force (emf) induced in the coil.   *[4]*

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(b)   The spring is changed so that the frequency of oscillation of the magnet is doubled without changing the amplitude of oscillation. Using the axes, sketch a graph to show how the induced emf in the coil varies with time *t* when the frequency of oscillation has doubled. The coil is at its equilibrium position when *t*=0. You should give suitable values on the *y*-axis.   *[3]*

induced emf

0.0   0.2   0.4   0.6   0.8   1.0

t / s

(This question continues on the following page)

Turn over
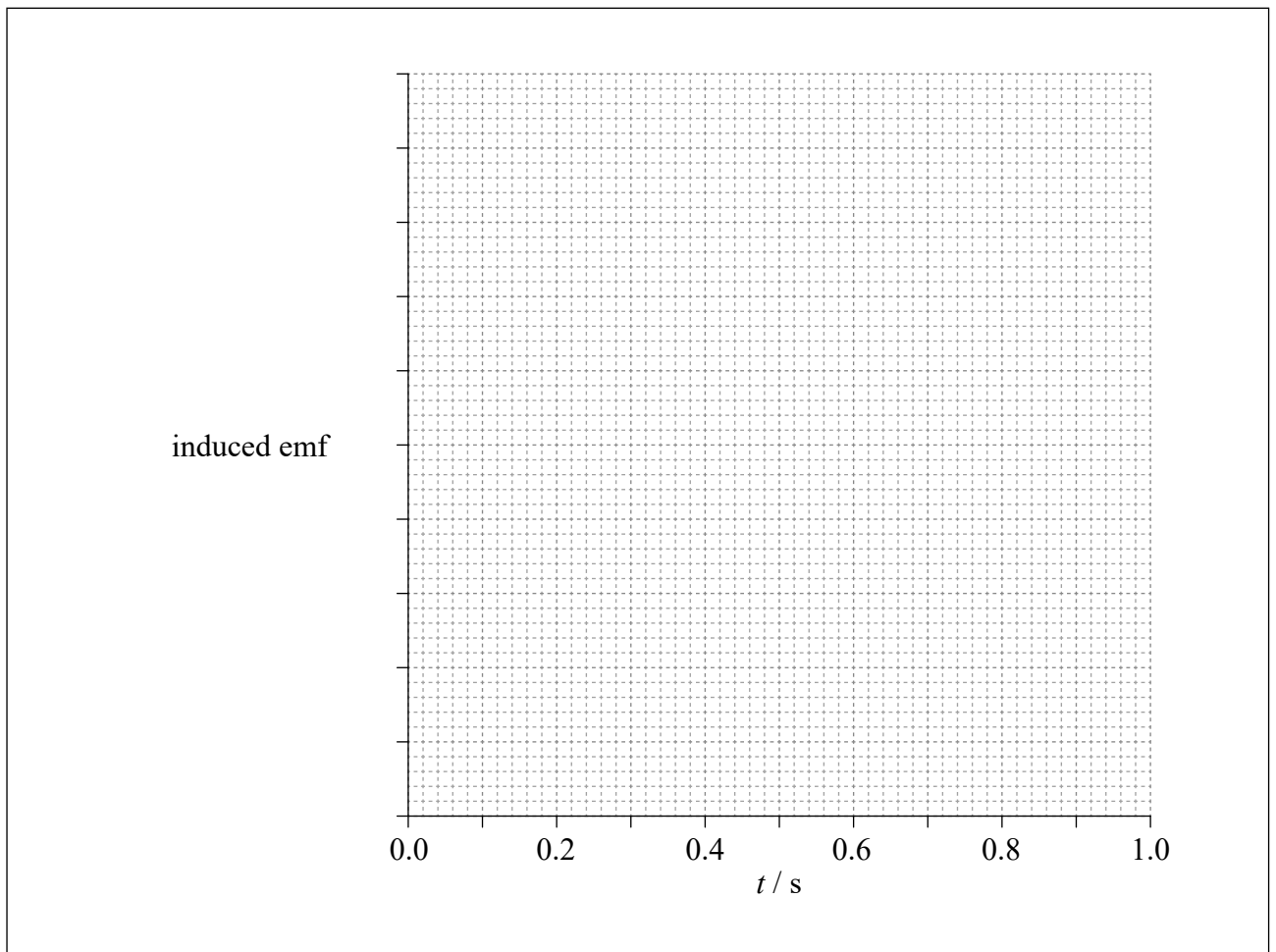
(Question 7 continued)

(c) (i) Label the diagram of the magnet and coil on page 18 with arrows to show the direction of the conventional current as the north pole of the magnet approaches the coil. *[1]*

(ii) Explain your answer to (c)(i). *[2]*

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