Name: ____

Topic 7: Electric and Magnetic Fields Part 3

Date:

Time:

Total marks available:

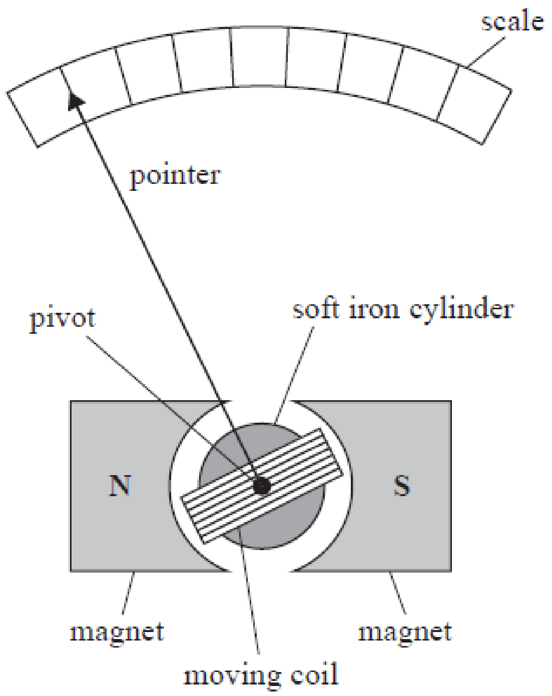
Total marks achieved: ______

Questions

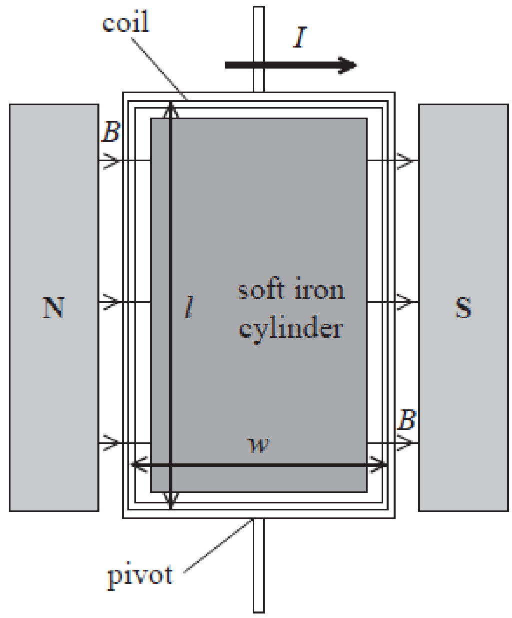
Q1.

The diagrams show the plan view and side view of a moving coil ammeter.

Plan view



Side view



The coil within a very sensitive moving coil ammeter can be damaged when the ammeter is transported. The two ends of the coil are connected together when the ammeter is transported. This reduces the movement of the coil and makes it less likely to be damaged.

A student suggests that this is due to Faraday's law and Lenz's law.

Explain how these laws apply to this situation.

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(Total for question = 4 marks)

Q2.

The force between two identical point charges, X and Y, is *F*.

Charge X is doubled; charge Y remains the same.

Which row of the table gives the force on each charge?

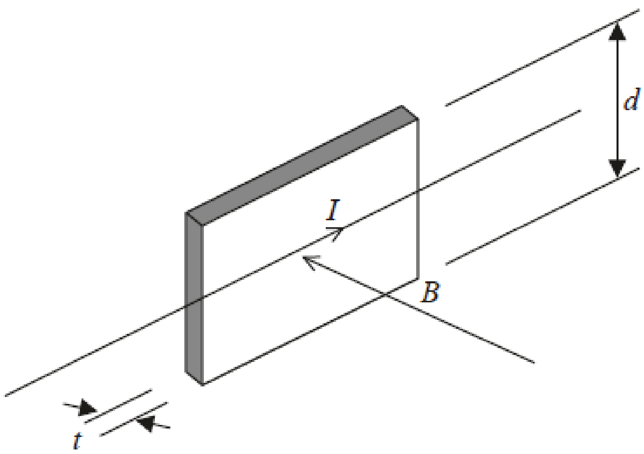
	X	Y
☐ **A**	*F*	*F*
☐ **B**	*F*	*2F*
☐ **C**	*2F*	*F*
☐ **D**	*2F*	*2F*

(Total for question = 1 mark)

Q3.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current *I* and a magnetic field of flux density *B* are applied to a slice of semiconductor as shown. The slice has thickness *t* and depth *d*.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Derive the following equation for V_{HALL}:

$$V_{HALL} = \frac{BI}{nte}$$

where n is the number of charge carriers per unit volume of the semiconductor.

(4)

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(Total for question = 4 marks)

Q4.

A simple model of the hydrogen atom consists of an electron moving in a circular path around a proton.

(i) In this simple model it is the electrostatic force, rather than the gravitational force, that is responsible for keeping the electron in a circular path.

By means of calculations justify this statement.

radius r of the hydrogen atom = 5.3×10^{-11} m

(4)

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(ii) Ignoring the gravitational force, calculate the velocity of the electron in this simple model of the hydrogen atom.

(3)

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Velocity = ...

(Total for question = 7 marks)

Q5.

An alpha particle and a beta particle both move into the same uniform magnetic field which is perpendicular to their direction of motion. The beta particle travels at 15 times the speed of the alpha particle.

The ratio of the force on the beta particle to the force on the alpha particle is

☐ **A** 3.7

☐ **B** 7.5

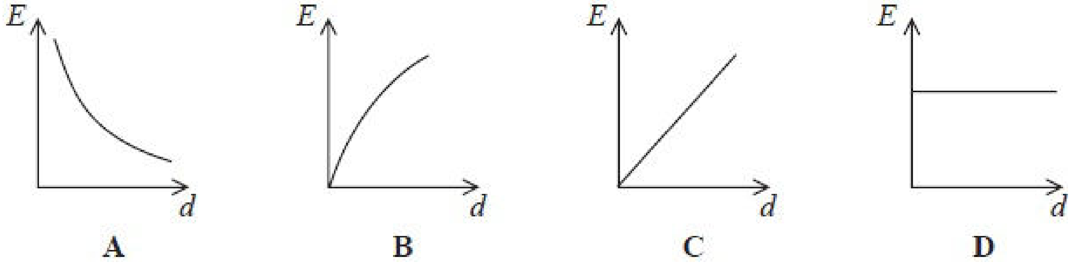
☐ **C** 30

☐ **D** 60

(Total for question = 1 mark)

Q6. Two parallel, conducting plates are connected to a battery. One plate is connected to the positive terminal and the other plate to the negative terminal. The plate separation *d* is gradually increased while the plates stay connected to the battery.

Select the graph that shows how the electric field strength *E* between the plates varies with separation *d*.



☒ **A**

☒ **B**

☒ **C**

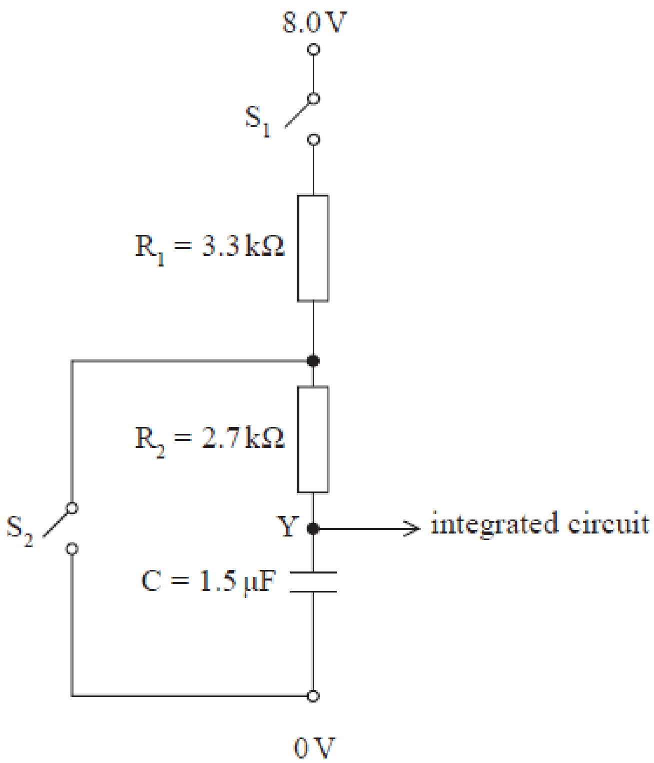
☒ **D**

(Total for Question = 1 mark)

Q7.

The properties of capacitors make them useful in timing circuits.

The following circuit is used to provide an input Y to an integrated circuit.



Initially the capacitor is uncharged. The switch S_1 is closed.

Sketch a graph to show how the potential at point Y varies with time.

(3)

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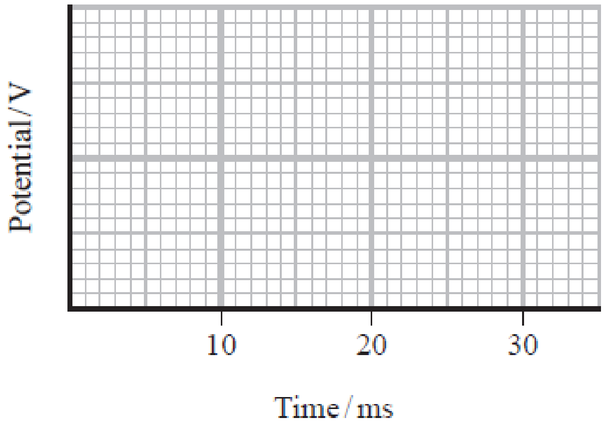
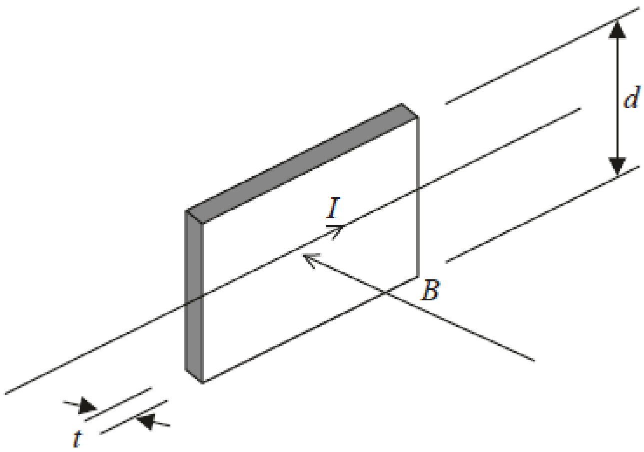


(Total for question = 3 marks)

Q8.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current *I* and a magnetic field of flux density *B* are applied to a slice of semiconductor as shown. The slice has thickness *t* and depth *d*.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

Show that the units are the same on each side of the equation

$$V_{HALL} = \frac{BI}{nte}$$

(3)

(Total for question = 3 marks)

Q9.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

A bee has short hairs which are thought to carry charge.

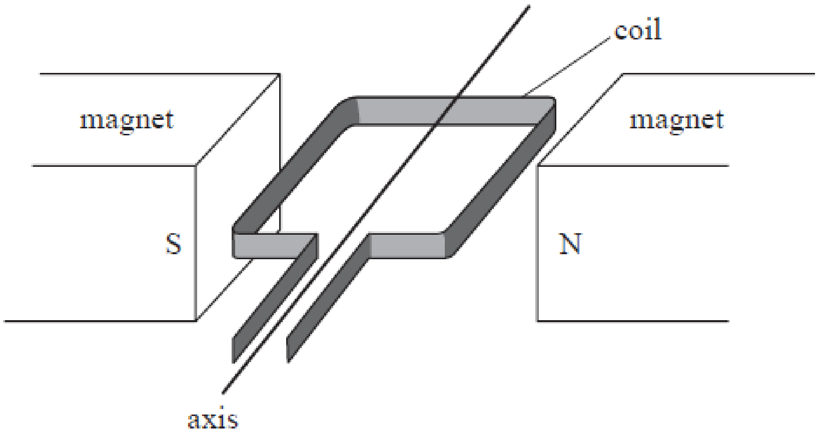
State how the bee might use this to detect the electric field of a flower.

(1)

(Total for question = 1 mark)

Q10.

*****Hybrid electric vehicles (HEV) use the same device both as a generator to charge the car battery and as an electric motor to support the propulsion system. A simplified diagram of the device is shown. The coil can rotate freely around the axis.



Describe how the device can be used as both a generator and an electric motor.

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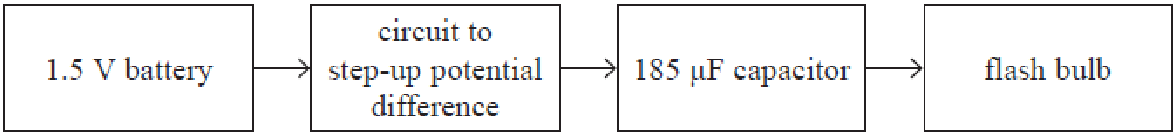
(Total for question = 6 marks)

Q11.

* Cameras usually have an inbuilt flash bulb that can be used to take photographs in poor light conditions. As a photograph is taken, the bulb should be able to produce a bright flash of light for up to 4 ms.

A capacitor can be used along with a battery as a power supply for the flash bulb. The flow diagram shows a possible arrangement.



Comment on the suitability of using this capacitor arrangement as a power supply rather than connecting the bulb directly to the battery.

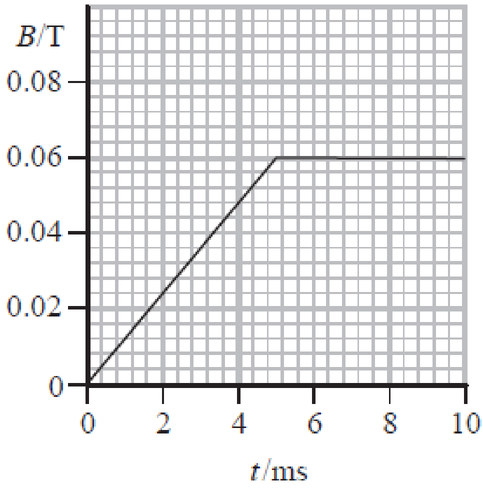
A typical flash bulb has a resistance of 6 Ω.

(6)

(Total for question = 6 marks)

Q12.

A coil of 300 turns each of area 1.5×10^{-4} m^2 is placed in a magnetic field with its plane at right angles to the field. The graph shows how the magnetic flux density *B* of the field varies with time *t*.



The e.m.f. induced in the coil during the first 5 ms is

☒ **A** 5.4×10^{-1} V

☒ **B** 4.5×10^{-2} V

☒ **C** 1.8×10^{-3} V

☒ **D** 5.4×10^{-4} V

(Total for question = 1 mark)

Q13.

(a) A magnetic field can be measured with a device called a Hall probe. The probe is connected to a voltmeter. When the probe is placed at right angles to a magnetic field, a potential difference is recorded on the voltmeter. The potential difference increases with increasing magnetic flux density.

A wire carries a constant current. A Hall probe is used to investigate how the magnetic flux density produced by the wire varies with distance from the wire.

The potential difference *V* was recorded for a range of distances *r*.

r/cm	V/V
1.0	0.725
1.5	0.483
2.0	0.363
2.5	0.29
3.0	0.242
3.5	0.21

(i) Criticise these results.

(2)

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(ii) It is suggested that *V* and *r* are related by the equation

$$V = \frac{k}{r}$$

where *k* is a constant.

(1) Determine by calculation whether this suggestion is valid.

(2)

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(2) A graph of $\frac{1}{V}$ is plotted against r.

State how the graph would indicate that the equation is correct.

(1)

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(b) The Hall probe can be replaced with a small coil of wire which is connected to a sensitive voltmeter. The plane of the coil is at right angles to the magnetic field produced by the current-carrying wire.

(i) Explain, with reference to Faraday's law, why the voltmeter reading would be zero.

(2)

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(ii) State **three** different ways in which an e.m.f. could be induced in this coil.

(3)

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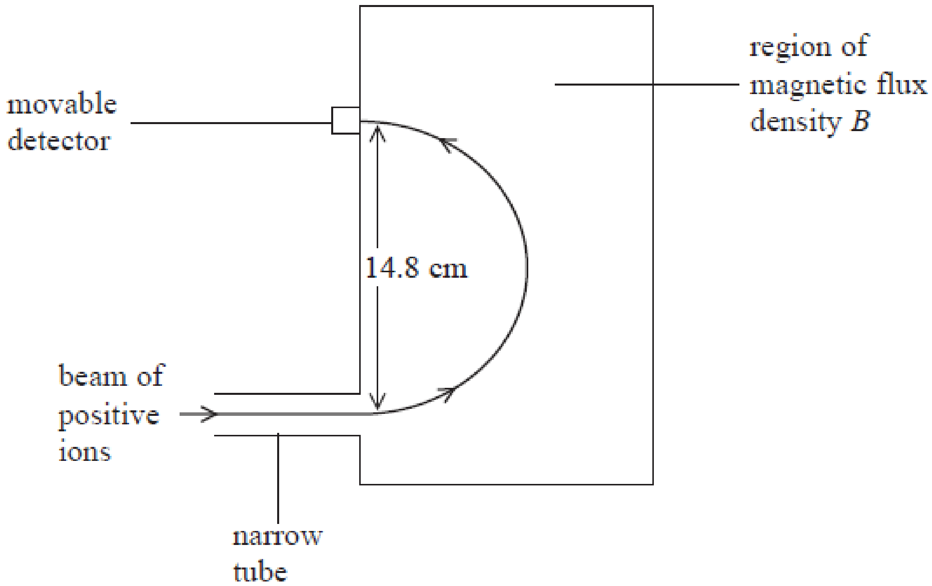
(Total for question = 10 marks)

Q14.

A mass-spectrometer is an instrument that is used to measure the masses of molecules. Molecules of a gas are ionised and travel through a vacuum in a narrow tube. The ions enter a region of uniform magnetic flux density *B* where they are deflected in a semicircular path as shown.



(a) State why it is necessary for the molecules to be ionised.

(1)

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(b) State the direction of the magnetic field.

(1)

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(c) The ions have a charge of +*e* and a speed of 1.20×10^5 m s^{-1}. When *B* has a value of 0.673 T, the ions are detected at a point where the diameter of the arc is 14.8 cm.

Calculate the mass of an ion.

(3)

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Mass of an ion = ...

(d) Ions with a smaller mass but the same charge and speed are also present in the beam.
On the diagram sketch the path of these ions.

(1)

(Total for question = 6 marks)

Q15.

The photograph is an image of the paths of particles obtained from an early particle detector, the cloud chamber.

Modern particle detectors such as the ones at CERN still work on the basic principle that charged particles cause ionisation of the material through which they pass. These ionisations can be tracked and recorded. Magnetic fields are used to deflect the particles so that their properties can be investigated.

(a) State what is meant by ionisation in this context.

(1)

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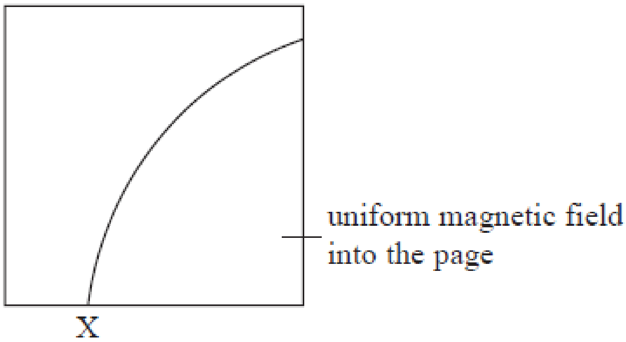
(b) The diagram below shows the ionisation path of a particle when it is in the region of a uniform magnetic field. The particle enters the field at X.



State how we know that the particle is negatively charged.

(1)

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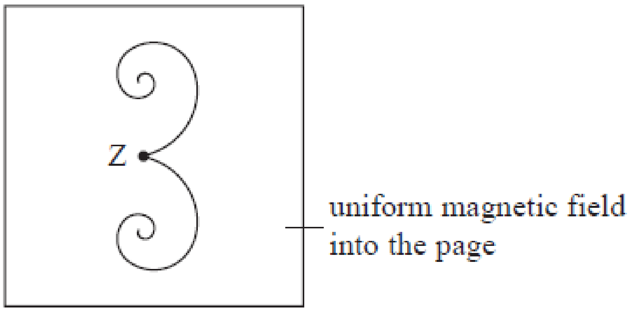
(c) The diagram below shows an event occurring in the same magnetic field.



Point Z is where a high energy photon interaction occurs which causes two particles to be formed.

Describe, with reasons, what can be deduced about the photon and the two particles that are formed in this interaction.

(5)

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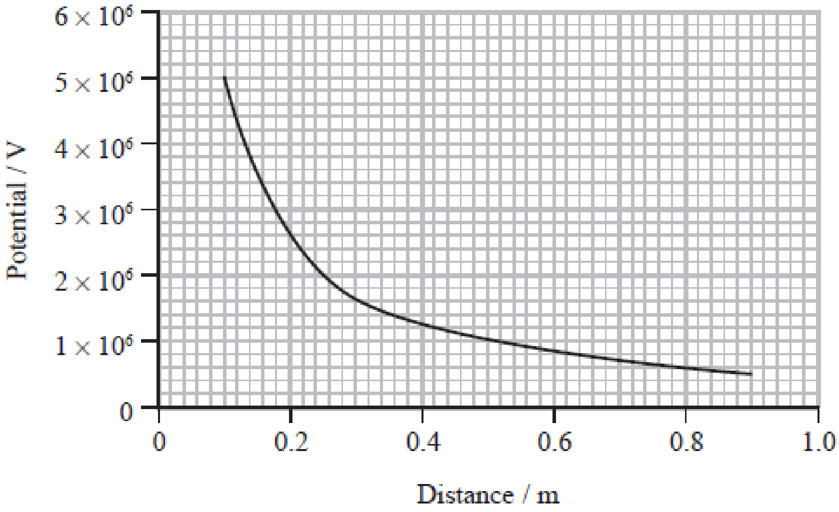
(Total for question = 7 marks)

Q16.

The graph shows how potential varies with distance from the centre of a charged sphere.



Air molecules will be ionised if the electric field strength exceeds 3×10^6 V m^{-1}.

Deduce whether air molecules will be ionised at a distance of 30 cm from the centre of this sphere.

(4)

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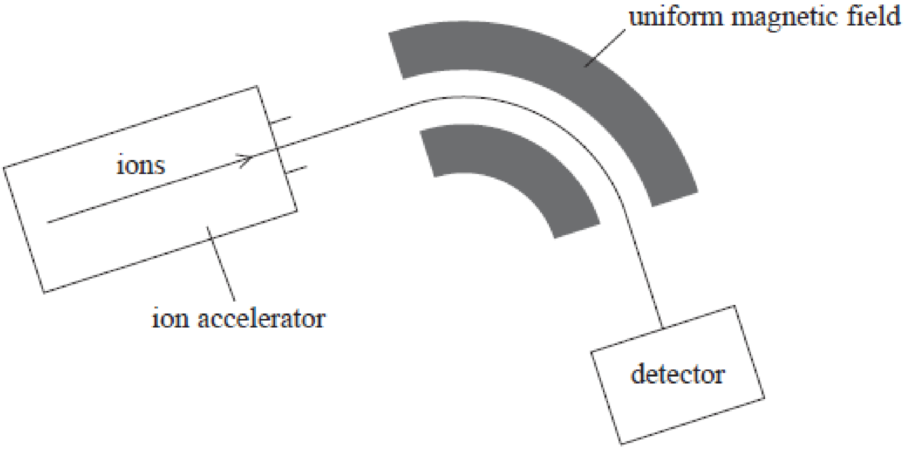
(Total for question = 4 marks)

Q17.

Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam.
This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

After passing through the velocity selector the ion beam enters a region of uniform magnetic flux density 0.35 T with the ions travelling at right angles to the field direction.

(i) Explain why the ions travel in a circular path.

(2)

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(ii) Calculate the radius of the circular path.

(2)

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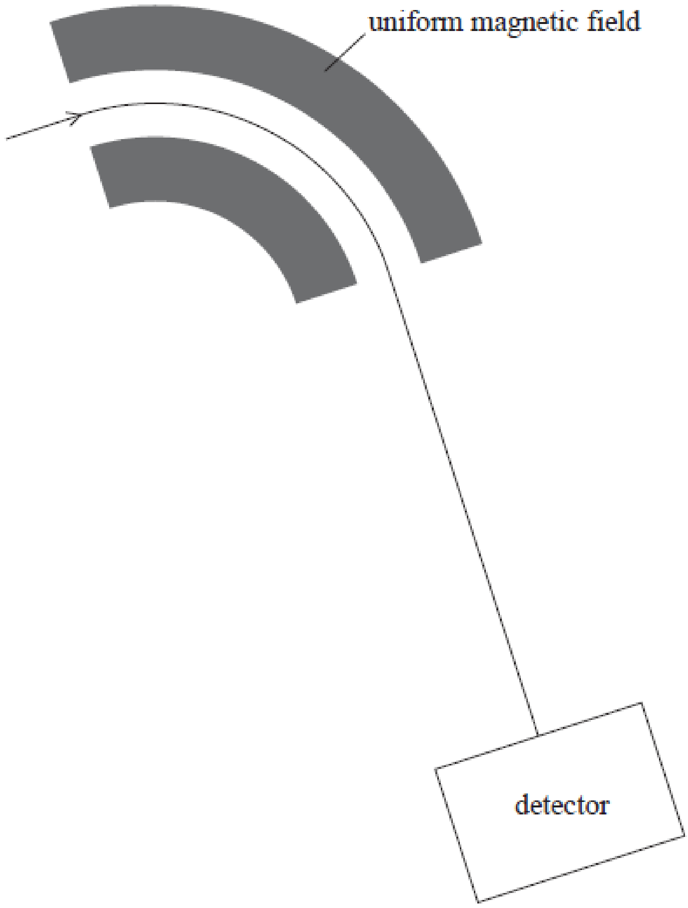
Radius = ...

(iii) The diagram shows the path of the chlorine-35 ions in the field. Chlorine-37 ions enter the magnetic field with the same velocity.



1. Add another line to the diagram to show the path of these chlorine-37 ions.

(1)

2. Explain any differences in the paths.

(2)

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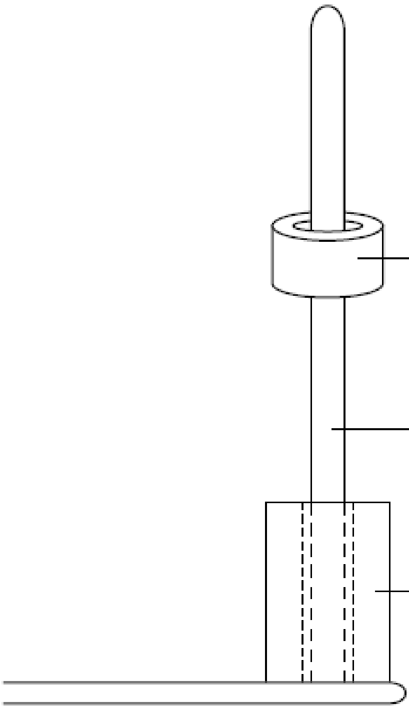
(Total for question = 7 marks)

Q18.

A coil of wire is placed around the lower end of an iron rod. The coil is supplied with an alternating current.

A thick aluminium ring is placed around the iron rod above the coil. The coil remains in the position shown.



An alternating current is induced in the aluminium ring.

Explain, using Lenz's law, why the aluminium ring remains in the position shown.

(4)

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(Total for question = 4 marks)

Q19.

The photograph shows a statue of Buddha in Sri Lanka, which is protected by a lightning conductor.

© Valery Shanin/123RF

Give a reason why the lightning conductor should be taller than the statue.

(1)

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(Total for question = 1 mark)

Q20.

A standard candle, within a nearby star cluster, is a distance *D* from the Earth. It produces a radiation flux *F* at the surface of the Earth.

The flux at the surface of the Earth, for a standard candle of the same luminosity in a second star cluster, is 4*F*.

The distance of the second star cluster from the Earth is

☒ **A** $4D$

☒ **B** $2D$

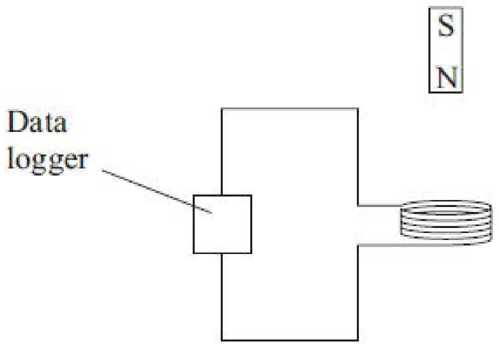
☒ **C** $\frac{D}{2}$

☒ **D** $\frac{D}{4}$

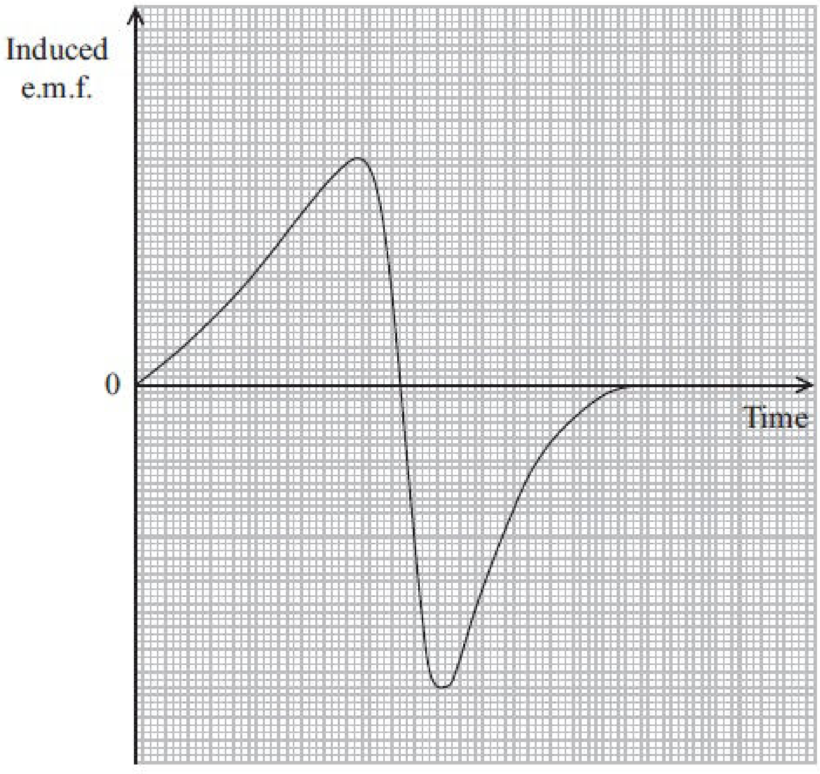
(Total for question = 1 mark)

Q21.

A teacher demonstrates electromagnetic induction by dropping a bar magnet through a flat coil of wire connected to a data logger.



The data from the data logger is used to produce a graph of induced e.m.f. across the coil against time.



*(a) Explain the shape of the graph and the relative values on both axes.

(6)

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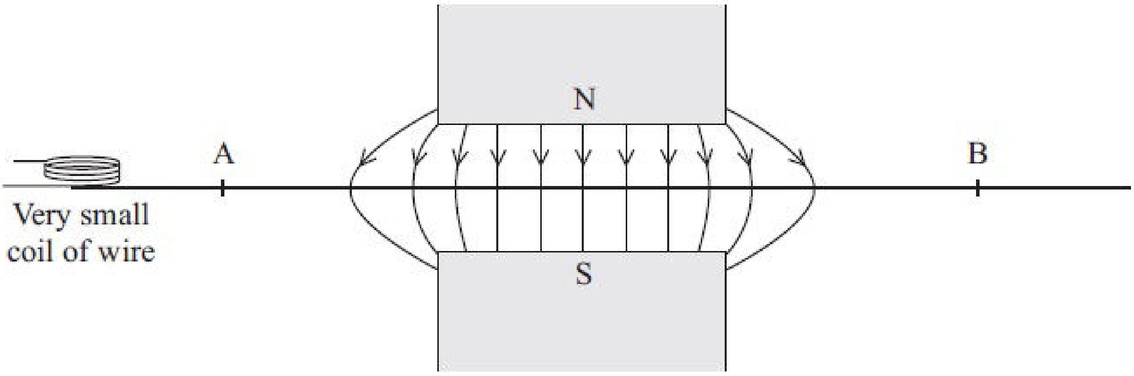
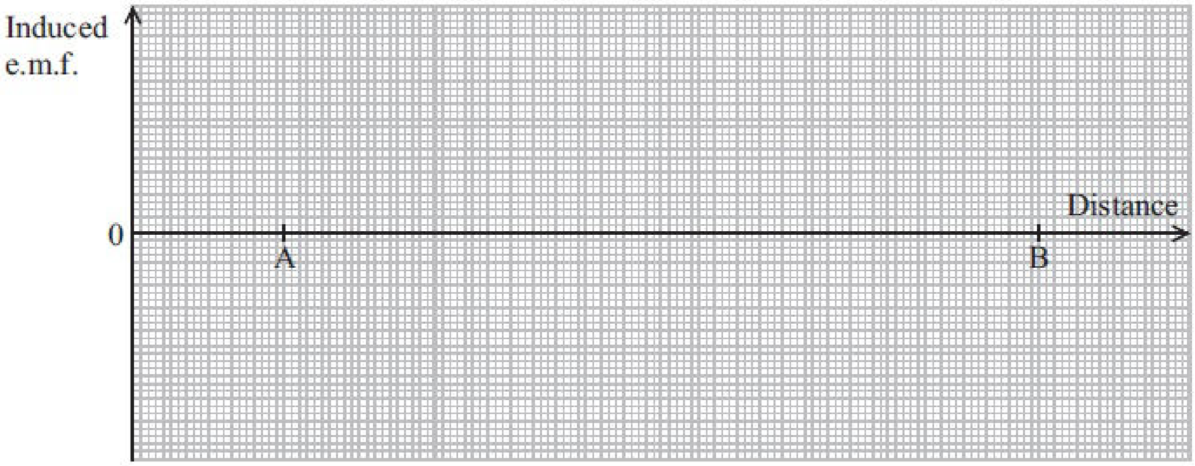
*(b) The teacher then sets up another demonstration using a large U-shaped magnet and a very small coil of wire which is again connected to a data logger.

The north pole is vertically above the south pole and the coil is moved along the line AB which is midway between the poles. The magnetic field due to the U-shaped magnet has been drawn. The plane of the coil is horizontal.



Sketch a graph to show how the e.m.f. induced across the coil varies as the coil moves from A to B at a constant speed.

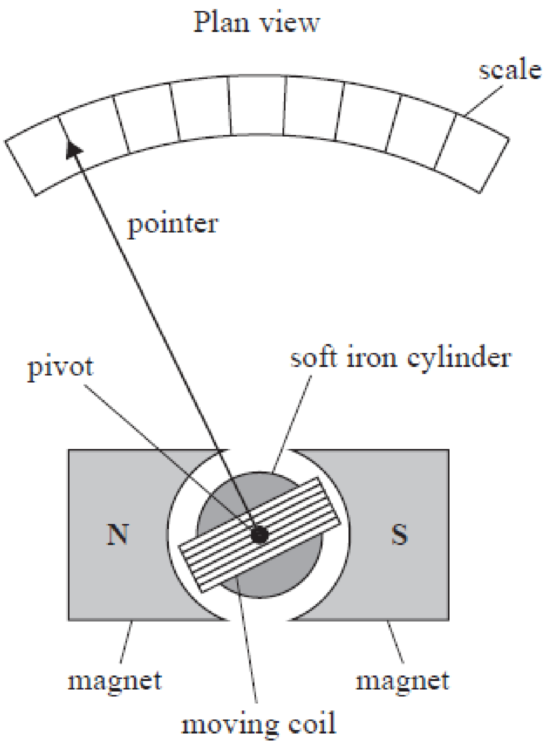
(4)

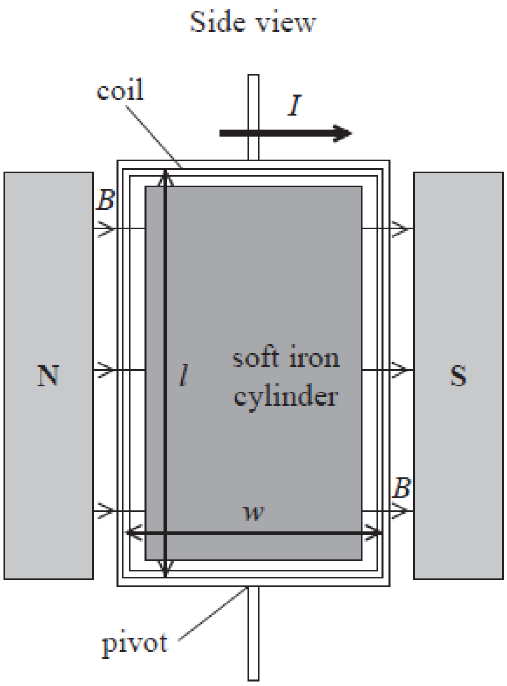


(Total for question = 10 marks)

Q22.

The diagrams show the plan view and side view of a moving coil ammeter.





The fixed soft iron cylinder and magnets produce a uniform magnetic field of magnetic flux density B. The coil is able to rotate within this magnetic field. The coil has width w and length l. There is a current I in the coil in the direction shown in the side view diagram.

(i) Explain which way the coil will rotate.

(2)

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(ii) Show that the moment M on the coil about the pivot, due to the magnetic field, is given by

$$M = BAIN$$

where
A is the cross-sectional area of the coil
N is the number of turns of wire on the coil.

(4)

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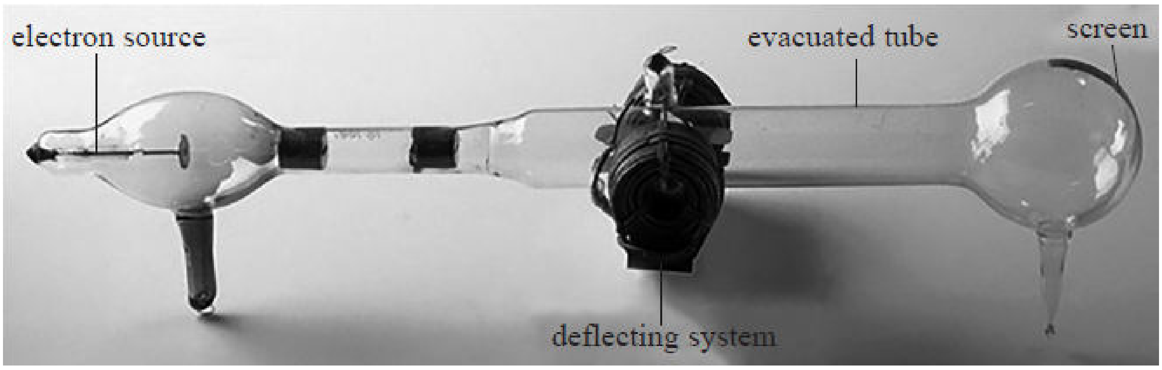
(Total for question = 6 marks)

Q23.

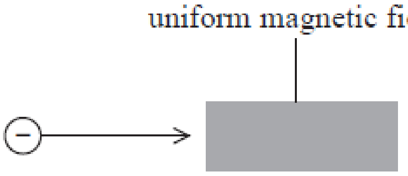
At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

An electron is travelling left to right and enters a region of uniform magnetic field as shown below. The direction of the magnetic field is perpendicular to the direction of travel of the electron.



(i) The magnetic field deflects the electron in the direction up the page.

Explain the direction of the magnetic field that would produce this deflection.

(2)

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(ii) Explain why the electron would travel in a circular path if no other forces acted on it.

(2)

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(Total for question = 4 marks)

Q24.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of the following is a unit of magnetic flux?

☐ **A** $N\ C^{-1}$

☐ **B** $T\ m^{-2}$

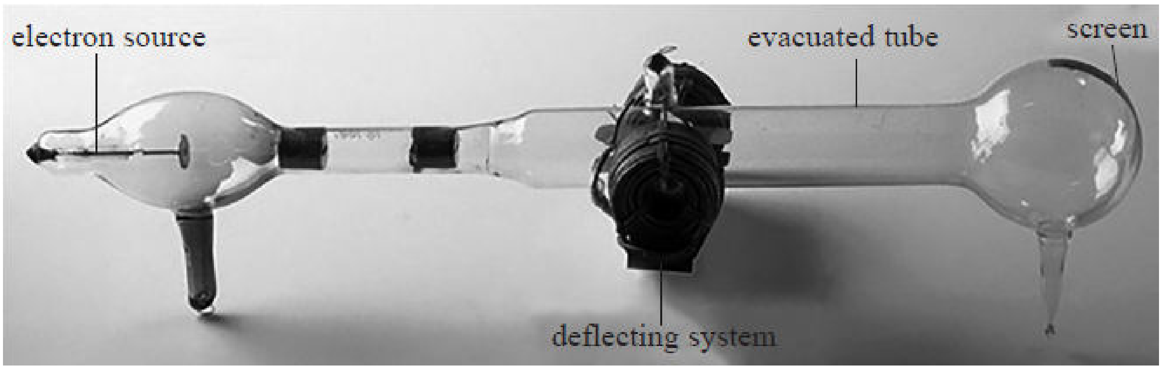
☐ **C** V s

☐ **D** $Wb\ m^{2}$

(Total for question = 1 mark)

Q25.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

In a modern version of Thompson's experiment, a uniform electric field of electric field strength E is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where B is the magnetic flux density of the magnetic field.

(2)

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(ii) The beam is produced by accelerating electrons through a potential difference of 250 V.

The electric field strength is $1.4 \times 10^4\ \text{V m}^{-1}$. The magnetic flux density is 1.5×10^{-3} T.

Calculate the value of the specific charge e/m for the electron using this data.

(3)

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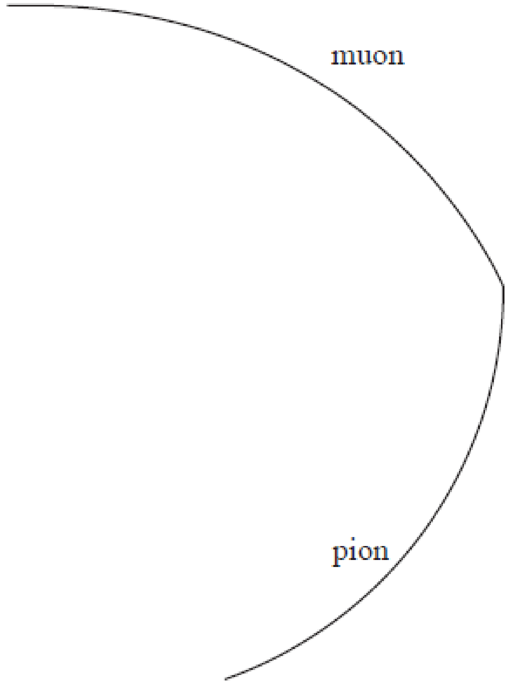
e/m = ...

(Total for question = 5 marks)

Q26.

A negatively charged pion decays into a muon and an antineutrino. The diagram shows tracks in a particle detector formed in such an event.



The momentum of the pion just before it decays is 9.1×10^{-20} N s.

Determine the magnetic flux density of the magnetic field which acts in the detector and state its direction.

Scale of diagram 1 cm represents 10 cm

pion charge = -1.6×10^{-19} C

(4)

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Magnetic flux density = ...

Direction of magnetic field = ...

(Total for question = 4 marks)

Q27.

A current of 1.50 A flows in a straight wire of length 0.450 m. The wire is placed in a uniform magnetic field of flux density 2.00×10^{-3} T which acts perpendicular to the wire.
Under these conditions the magnetic force balances the weight of the wire.

Calculate the mass of the wire.

- ☒ **A** 1.32×10^{-2} kg
- ☒ **B** 1.35×10^{-3} kg
- ☒ **C** 1.38×10^{-4} kg
- ☒ **D** 1.35×10^{-4} kg

(Total for question = 1 mark)

Q28. The magnetic force F that acts on a current-carrying conductor in a magnetic field is given by the equation

$$F = BIl.$$

(a) State the condition under which this equation applies.

(1)

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(b) The unit for magnetic flux density B is the tesla.

Express the tesla in base units.

(2)

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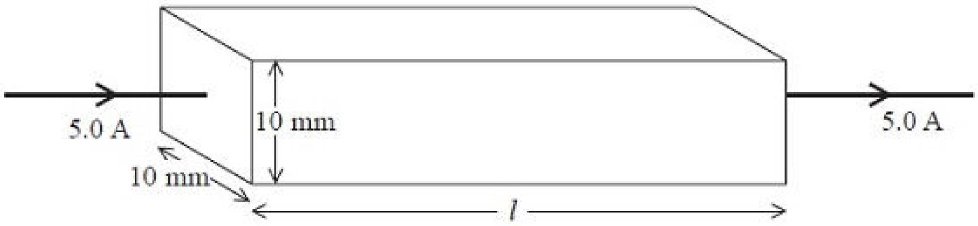
(c) The diagram shows a rectangular bar of aluminium which has a current of 5.0 A through it.



The bar is placed in a magnetic field so that its weight is supported by the magnetic field.

Calculate the minimum value of the magnetic flux density B needed for this to occur.

density of aluminium = 2.7×10^3 kg m^{-3}

(3)

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....

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Minimum B = ...

(d) State the direction of the magnetic field.

(1)

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(Total for Question = 7 marks)

Q29. A charged, non-magnetic particle is moving in a magnetic field.

Which of the following would **not** affect the magnetic force acting on the particle

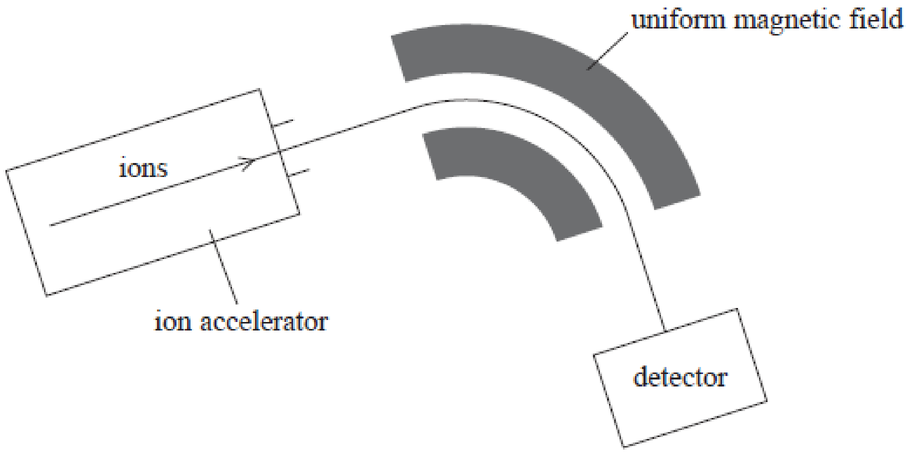
- ☒ **A** the magnitude of the charge on the particle
- ☒ **B** the strength of the magnetic field
- ☒ **C** the velocity component parallel to the magnetic field direction
- ☒ **D** the velocity component perpendicular to the magnetic field direction

(Total for Question = 1 mark)

Q30.

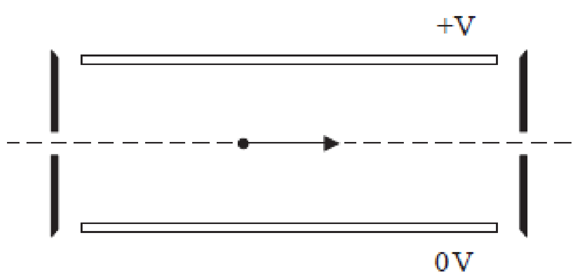
Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam. This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

In most mass spectrometers the ions are passed through a velocity selector, after being accelerated, to produce a beam of ions of a particular velocity.
The velocity selector consists of a pair of parallel plates, across which a potential difference (p.d.) is applied to create an electric field.



In one mass spectrometer the plates are 2.5 cm apart and a p.d. of 135 V is applied.

A magnetic field is also applied to produce a force on the ions in the opposite direction to the force from the electric field. For one particular speed the ions travel in a straight line and emerge from the selector.

(i) Add to the diagram to indicate the directions of the electric field and the magnetic field.

(2)

(ii) The magnetic flux density applied to the velocity selector is 24.5 mT.

Deduce whether this magnetic flux density is suitable to produce a beam of chlorine-35 ions of speed 2.2×10^5 m s^{-1}.

(4)

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(Total for question = 6 marks)

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • This is because there is a change of flux (linkage) as the meter is moved (1) • An emf is induced which will produce a current in the coil (as both ends of the coil are connected) (1) • Current-carrying conductor within a magnetic field experiences a force (1) • These forces oppose the coil's motion (reducing it) (1)		4

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	D		1

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equates $F=Bev$ and $F=eE$ (1) • Substitutes $E = V/d$ **Or** $F = eV/d$ seen (1) • Replaces v with I/neA (1) • Substitute $A = d \times t$ and leads to given equation (1) Alternative: • Equates $F = BIl$ and $F = QE$ with Q identified as total charge (1) • Substitutes $E = V/d$ **Or** $F = QV/d$ seen • Substitutes $Q = neAl$ and cancels l • Substitute $A = d \times t$ and leads to given equation	Example of derivation: $Bev = eE$ $Bev = eV/d$ $\frac{BI}{neA} = \frac{V_H}{d}$ $V_H = \frac{BI}{net}$ Alternative: $BIl = QE$ Total charge $Q = neAl$ $BIl = neAlE$ $BI = neAV_H/d$ $V_H = BI/net$	(4)

Q4.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• use of $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • use of $F = Gm_1m_2/r^2$ **(1)** • Expresses forces as a ratio **(1)** **OR** calculates the individual forces F_e=8.1 x 10^{-8} N F_g = • 3.6 x 10^{-47} N **(1)** • Ratio = 2 x 10^{39} or 5 x 10^{-40} and identifies gravitational force as insignificant **(1)**		**4**
(ii)	• use of $F = mv^2/r$ and $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • to derive $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ **(1)** • velocity = 2.2× 10^6 m s^{-1} **(1)**	Example of calculation: $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ $v = \sqrt{\frac{1.6\times10^{-19}\text{ C}\times1.6\times10^{-19}\text{ C}}{4\pi\times8.85^{-12}\text{ Fm}^{-1}\times5.3\times10^{-11}\text{m}\times9.1\times10^{-31}\text{ kg}}}$ $v = 2.185 \times 10^6$ m s^{-1}	**3**

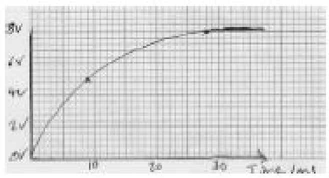
Q5.

Question Number	Answer	Mark
	B	1

Q6.

Question Number	Answer	Mark
	A	1

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• line approximately exponential curve starting at 0 and increasing potential **(1)** • beginning to flatten off at a maximum of 8 V (at 30 ms above 7.5 V) **(1)** • Use of time constant *RC* **(1)**	 This can be evidenced with an exponential curve passing through about 5 V at 9 ms **Or** approximately 2/3 of their maximum	3

Q8.

Question Number	Acceptable answers		Additional guidance	Mark
	• Uses V = J/C **Or** V = Nm/C **Or** V = Wb s^{-1} • Use of T = N/Cms^{-1} **Or** T = N/Am **Or** T = Wb m^{-2} **Or** Sub of $B=F/IL$ and cancels I's • Uses units of n = m^{-3} and completes agreement Alternative with base units: • Uses base unit of force = kg m s^{-2} **Or** base unit of energy = kg m^2 s^{-2} • Uses base unit of charge = A s **Or** uses A = Cs^{-1} **Or** Sub of $B=F/IL$ and cancel I's or A's • Uses base units of n = m^{-3} and completes agreement	(1) (1) (1) (1) (1) (1)	Example of unit simplification: J/C should equal $\frac{N}{Am} \times A \div m^{-3}Cm$ $= \frac{Nm}{C} = \frac{J}{C}$	(3)

Q9.

Question Number	Acceptable answers		Additional guidance	Mark
	• Charged particle/hair attracts/repels **Or** charged/hair experiences a force	(1)		(1)

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Indicative content: Generator: • coil has to be rotated • cuts magnetic flux **Or** rate of change of flux linkage • induces an emf Motor: • current provided to coil • Force on sides of coil that are perpendicular to magnetic field • rotate coil as forces provide a moment	(see table below)	6

IC points	IC mark	Max linkage mark available	Max final mark
6	4	2	**6**
5	3	2	**5**
4	3	1	**4**
3	2	1	**3**
2	2	0	**2**
1	1	0	**1**
0	0	0	**0**

Q11.

Question Number	Acceptable Answers	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer → Number of marks awarded for indicative marking points: 6 → 4 5 - 4 → 3 3 - 2 → 2 1 → 1 0 → 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5 - 4	3
3 - 2	2
1	1
0	0

	The following table shows how the marks should be awarded for structure and lines of reasoning. <table><tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>			**(6)**
	Indicative content • the capacitor can be charged to a higher p.d. than that of the battery • storing larger amount of energy on capacitor as predicted by $E = ½ CV^2$ • with a low resistance in the bulb the capacitor discharges rapidly • this produces enough power, $P = W/t$ to produce the flash • use of $T = RC$ to estimate a value for T (1 ms) • comparison of time constant with 4 ms	<u>Example of calculation:</u> $T = 6\ \Omega \times 185\ \mu F = 1.1$ ms Accept $5T > 4$ ms		

Q12.

Question Number	Answer	Mark
	A	1

Q13.

Question Number	Answer		Mark
(a)(i)	**Max 2** Inconsistent number of significant figures or decimal places **Or** results recorded to different precision /resolution No repeat readings More readings needed up to <u>1.5</u> cm	 (1) (1) (1)	2
(a)(ii)(1)	Attempt to use *Vr* = constant Correctly finds two values of *Vr* from values in table **and** makes comment **Or** uses *Vr* value with another *r* or *V* to confirm corresponding value **and** makes comment <u>Example of calculation</u> *r*/cm — *V*/V — *rV*/ cmV 1.0 — 0.725 — 0.725 1.5 — 0.483 — 0.725 2.0 — 0.363 — 0.726 2.5 — 0.29 — 0.725 3.0 — 0.242 — 0.726 3.5 — 0.21 — 0.735	(1) (1)	2
(a)(ii)(2)	The graph would be a straight line graph through the origin. (accept a sketch of a straight line graph going through the origin graph)	(1)	1
(b)(i)	An e.m.f. is (induced) when there is a changing (magnetic) field/flux. Because the <u>current</u> is constant there is a constant magnetic field. **Or** Because the <u>current</u> is constant there isn't a changing magnetic field.	(1) (1)	2
(b)(ii)	Movement of either the coil or the wire Use an alternating current/signal/supply/AC Switch the current on/off **Or** change current e.g. use of variable resistor	(1) (1) (1)	3
	Total for question		**10**

Q14.

Question Number	Answer		Mark
(a)	Only (moving) charged particles are deflected by a magnetic field **Or** Only charged particles can be accelerated to produce a beam	(1) (1)	1
(b)	Into the page	(1)	1
(c)	Use of $F = mv^2/r$ **Or** use of $r = p/BQ$ Use of $F = Bqv$ **Or** use of $p = mv$ $m = 6.64 \times 10^{-26}$ kg <u>Example of calculation</u> $mv^2/r = Bqv$ $m = Bqr/v$ =(0.673 T × 1.6 × 10^{-19} C × 7.40 × 10^{-2} m) / 1.20 × 10^5 m s^{-1} $m = 6.64 \times 10^{-26}$ kg	(1) (1) (1)	3
(d)	Semicircle drawn starting from same initial point <u>and</u> a smaller radius	(1)	1
	Total for question		6

Q15.

Question Number	Answer		Mark
(a)	The idea that electron(s) have been removed/added from an atom/molecule/particle.	(1)	1
(b)	Flemings left hand (rule) **Or** FLHR	(1)	1
(c)	**Max 5** Only charged particles leave a trail so photon is neutral **Or** the two particles produced are charged because they leave a track Particles are oppositely charged because they curve/spiral in opposite directions **Or** Particles are oppositely charged to conserve charge (Applying FLHR) , top particle is positive and bottom one negative. Because they have the same curvature/radius on the spirals **Or** because the paths have identical shape Particles have the same momentum The photon enters from the left because the (resultant) momentum afterwards is to the right.	(1) (1) (1) (1) (1) (1)	5
	Total for question		7

Q16.

Question Number	Acceptable Answers		Additional guidance	Mark
	• tangent at correct point	(1)	Example of calculation:	4
	• triangle with base at least 0.4 m	(1)	Gradient = 3200000 / 0.6	
	• 5.3×10^6 (Vm^{-1}) (range 4.9×10^6 to 6.1×10^6)	(1)	$E = 5.3 \times 10^6$ V m^{-1}	
	• So would ionise as value greater than 3×10^6	(1)	MP4 to be consistent with calculated value	
	Alternative:		$V = 1.6 \times 10^6$ V m^{-1}	
	• Correct value of V at 30 cm	(1)		
	• Use of $E = k\frac{Q}{r^2}$ and $V = k\frac{Q}{r}$	(1)		
	• 5.3×10^6 (Vm^{-1})	(1)		
	• So would ionise as value greater than 3×10^6	(1)		

Q17.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• The ions experience a force perpendicular to their velocity (and the magnetic field)	(1)	For velocity accept direction of motion or direction of travel	
	• The (resultant) force on the ions causes an acceleration at right angles to their velocity **Or** There is a magnetic force acting towards the centre of the path	(1)		2

Question Number	Acceptable Answer		Additional Guidance	Mark
(ii)	• Use of $r = \dfrac{mv}{BQ}$	(1)	Example of calculation: $r = \dfrac{mv}{BQ}$	
	• $r = 0.23$ m	(1)	$= \dfrac{(34.97 \times 1.66 \times 10^{-27})\,\text{kg} \times 2.2 \times 10^5\,\text{m s}^{-1}}{0.35\,\text{T} \times 1.6 \times 10^{-19}\,\text{C}} = 0.228\,\text{m}$	2

Question Number	Acceptable Answer		Additional Guidance	Mark
(iii) 1	• path drawn with less curvature (less overall deflection)	(1)	MP1 awarded for path in the magnetic field	1

Question Number	Acceptable Answer	Additional Guidance	Mark
2 (iii)	• ions are more massive (1) • ions have the same charge so the radius of the path would be greater (1)		2

Q18.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • The current produces a magnetic field around the aluminium ring **(1)** • The direction of the ring field opposes the change producing it **(1)** • The fields repel, producing a force **(1)** • The electromagnetic force is equal and opposite to the weight of the ring so it remains in position shown **(1)**		**4**

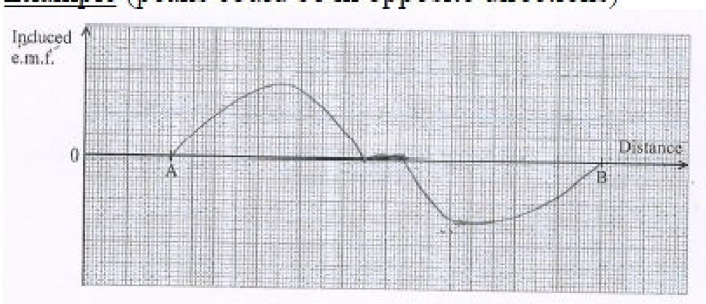
Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• So that the lightning makes contact with the conductor rather than the statue (1)		1

Q20.

Question Number	Answer	Mark
	C	1

Q21.

Question Number	Answer		Mark
*(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Max 6 from** Reference to changing/cutting of field/flux	(1)	
	Induced e.m.f. proportional to rate of change/cutting of flux (linkage) (accept equation)	(1)	
	Initial increase in e.m.f. as the magnet gets closer to the coil	(1)	
	Identifies region of negative gradient with magnet going through the coil	(1)	
	Indication that magnet's speed increases as it falls	(1)	
	Negative (max) value › positive (max) value (this mark is dependent on awarding marking point 5)	(1)	
	Time for second pulse shorter (this mark is dependent on awarding marking point 5)	(1)	
	The areas of the two parts of the graph will be the same (since Nφ constant)	(1)	6
(b)	Two sequential pulses (if **not** two sequential pulses, scores zero) Pulses same height (+/- 3 mm squares) and width (by eye) Pulses in opposite directions Region of zero e.m.f. in the middle	(1) (1) (1) (1)	4
	Example (peaks could be in opposite directions) 		

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	An explanation that makes reference to the following points: • Fleming left hand rule force will cause force on left hand side of coil into page **Or** right hand side of coil out of page (1) • The coil will turn clockwise as shown in the plan view (MP2 dependent on MP1) (1)	allow 1 mark for statement "rotates clockwise because of FLHR"	2
(ii)	• Moment of F around pivot = $F \times w/2$ (1) • Use of $F = BIl$ (1) • Moment due to F on both sides = $2 \times BIl \times w/2$ (1) • As N turns and $l \times w = A$; Total moment = $BAIN$ (1)	alt: Use of Torque of a couple = $F \times w$ then MP1 and 3 This equation should be substituted into a product with a "distance" to be awarded 'use of'	4

Q23.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• (Perpendicularly) out of the page (1) • The force is perpendicular to the magnetic field and the direction of (conventional) current **Or** an application of Fleming's Left-Hand Rule (1)	Accept movement of electrons for current	2
(ii)	An explanation that makes reference to the following points: • There would be a force (of constant magnitude) on the electron perpendicular to its direction of motion (1) • Causing an acceleration towards the centre of a circle (1)	Accept reference to centripetal force for MP1	2

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not correct as this is a unit of electric field strength B is not correct as units T m^2 could be used as a unit of flux D is not correct as Wb is a unit of flux		1

Q25.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = BQv$ and $F = EQ$ (1) • Algebra to show $v = \frac{E}{B}$ (1)		2
(ii)	• Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ (1) • Use of $v = \frac{E}{B}$ (1) • $\frac{e}{m} = 1.7 \times 10^{11}\ \mathrm{C\ kg^{-1}}$ (1)	Example of calculation: $v = \frac{E}{B} = \frac{1.4 \times 10^4\ \mathrm{V\ m^{-1}}}{1.5 \times 10^{-3}\ \mathrm{T}}$ $\frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{(9.33 \times 10^6\ \mathrm{m\ s^{-1}})^2}{2 \times 250\ \mathrm{V}} = 1.74 \times 10^{11}\ \mathrm{C\ kg^{-1}}$	3

Q26.

Question Number	Acceptable answers	Additional guidance	Mark
	• measures radius (allow between 4 cm and 6 cm) (1) • Use of $p = Bqr$ (1) • $B = 1.1$ T (range 0.95 T – 1.42 T) (1) • direction: out of page (1)	Allow use of their measured radius in MP2 Example of calculation: $9.1 \times 10^{-20}\ \mathrm{N\ s} = B \times 1.6 \times 10^{-19}\ \mathrm{C} \times 0.52\ \mathrm{m}$ $B = 1.09$ T	4

Q27.

Question Number	Answer	Mark
	C	1

Q28.

Question Number	Answer		Mark
(a)	The <u>magnetic</u> field (must be) at right angles to the current	**(1)**	**1**
(b)	All three units for force, length and current clearly identified (The unit of force is kg m s^{-2} , the unit of current is A, the unit of length is m) T = kg A^{-1} s^{-2}	**(1)** **(1)**	**2**
(c)	*Use of* $\rho = m/V$ Use of $mg = BIl$ B = 0.53 (T) (no u.e. as given in question for part (b)) <u>Example of calculation</u> $m = 2.7 \times 10^3$ kg $m^{-3} \times 10\times 10^{-3}$ m $\times 10\times 10^{-3}$ m $\times l$ $m = 0.27 \times l$ $B = (0.27 \times l \times 9.81$ m $s^{-2})/(5$ A $\times l)$ B = 0.53 T	**(1)** **(1)** **(1)**	**3**
(d)	(Magnetic field is) into paper/page	**(1)**	**1**
	Total for question		**7**

Q29.

Question Number	Answer	Mark
	C	1

Q30.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• Electric field vertically downwards (from top plate to bottom plate) • Magnetic field into paper	(1) (1)		2

Question Number	Acceptable Answer		Additional Guidance	Mark
(ii)	• Use of $E = \frac{V}{d}$ • Use of $F_E = EQ$ • Use of $F_M = BQv$ • Show that these forces are equal (if v is 2.2 x 10^5 m s^{-1}) and hence state that B is suitable	(1) (1) (1) (1)	Do not award MP4 if incorrect ion charge used Example of calculation: $E = \frac{V}{d} = \frac{135\,V}{2.5 \times 10^{-2}\,m} = 5400\,V\,m^{-1}$ $F = EQ = 5400\,V\,m^{-1} \times 1.6 \times 10^{-19}\,C = 8.6 \times 10^{-16}\,N$ $F = BQv = 24.5 \times 10^{-3}\,T \times 1.6 \times 10^{-19}\,C \times 2.2 \times 10^{5}\,m\,s^{-1}$ $= 8.6 \times 10^{-16}\,N$	4