1 A transformer is required to produce an r.m.s. output of 2.0×10^3 V when it is connected to the 230 V r.m.s. mains supply. The primary coil has 800 turns.

(a) Calculate the number of turns required on the secondary coil, assuming the transformer is ideal.

(2)

(b) The transformer suffers from *eddy current* losses.

(i) Explain how *eddy currents* arise.

___

___

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___

___

(4)

(ii) State the feature of transformers designed to minimise eddy currents.

___

(1)
(Total 7 marks)

2 **Figure 1** shows the plan view of a cyclotron in which protons are emitted in between the dees. The protons are deflected into a circular path by the application of a magnetic field. **Figure 2** shows a view from in front of the cyclotron.

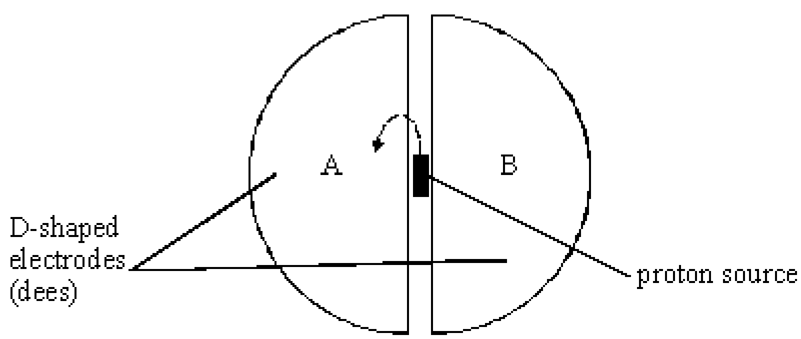


Figure 1

Figure 2

(a) (i) Mark on **Figure 2** the direction of the magnetic field in the region of the dees such that it will deflect the proton beam in the direction shown in **Figure 1**.

(2)

(ii) Show that the velocity of the proton, v, at some instant is given by:

$$v = \frac{Ber}{m}$$

where m is the proton mass, r the radius of its circular path, B the magnetic flux density acting on the proton and $+e$ the proton charge.

(2)

(iii) Write down an equation for the time T for a proton to make a complete circular path in this magnetic field.

(2)

(iv) Explain how your equation leads to the conclusion that T is independent of the speed with which the proton is moving.

____

____

____

(1)

(b) In addition to this magnetic field there is an electric field provided between the dees. This accelerates the proton towards whichever dee is negatively charged. An alternating potential difference causes each dee to become alternately negative and then positive. This causes the proton to accelerate each time it crosses the gap between the dees.

(i) Describe and explain the effect the acceleration has on the path in which the proton moves.

____

____

____

(2)

(ii) In terms of T, write down the frequency with which the p.d. must alternate to match the period of motion of the proton.

(1)

(c) (i) Calculate the velocity of a proton of energy 0.12 keV.

the proton mass, $m = 1.7 \times 10^{-27}$ kg
the magnitude of the electronic charge, $e = 1.6 \times 10^{-19}$ C

(3)

(ii) Calculate the de Broglie wavelength of the 0.12 keV proton.

the Planck constant, $h = 6.6 \times 10^{-34}$ J s

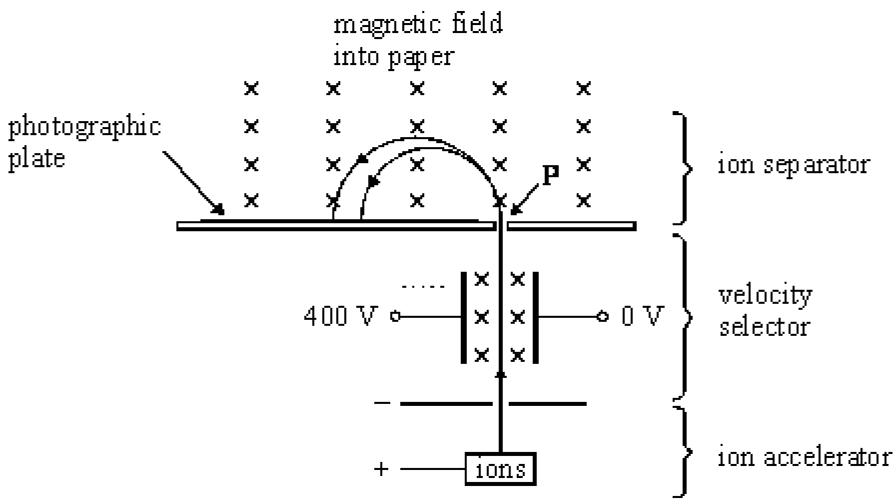
(3)

(iii) Name the region of the electromagnetic spectrum which has an equivalent wavelength to that of the proton.

____

(1)
(Total 17 marks)

3 The diagram below shows a diagram of a mass spectrometer.



(a) The magnetic field strength in the velocity selector is 0.14 T and the electric field strength is 20 000 V m^{-1}.

(i) Define the unit for magnetic flux density, the tesla.

____

____

(2)

(ii) Show that the velocity selected is independent of the charge on an ion.

(2)

(iii) Show that the velocity selected is about 140 km s^{-1}.

(1)

(b) A sample of nickel is analysed in the spectrometer. The two most abundant isotopes of nickel are $^{58}_{28}Ni$ and $^{60}_{28}Ni$. Each ion carries a single charge of $+1.6 \times 10^{-19}$ C.

mass of a proton or neutron = 1.7×10^{-27} kg

The $^{58}_{28}Ni$ ion strikes the photographic plate 0.28 m from the point **P** at which the ion beam enters the ion separator.

Calculate:

(i) the magnetic flux density of the field in the ion separator;

(3)

(ii) the separation of the positions where the two isotopes hit the photographic plate.

(2)

(Total 10 marks)

4 (a) Explain what is meant by the term *magnetic flux linkage*. State its unit.

(2)

(b) Explain, in terms of electromagnetic induction, how a transformer may be used to step down voltage.

(4)

(c) A minidisc player is provided with a mains adapter. The adapter uses a transformer with a turns ratio of 15:1 to step down the mains voltage from 230 V.

(i) Calculate the output voltage of the transformer.

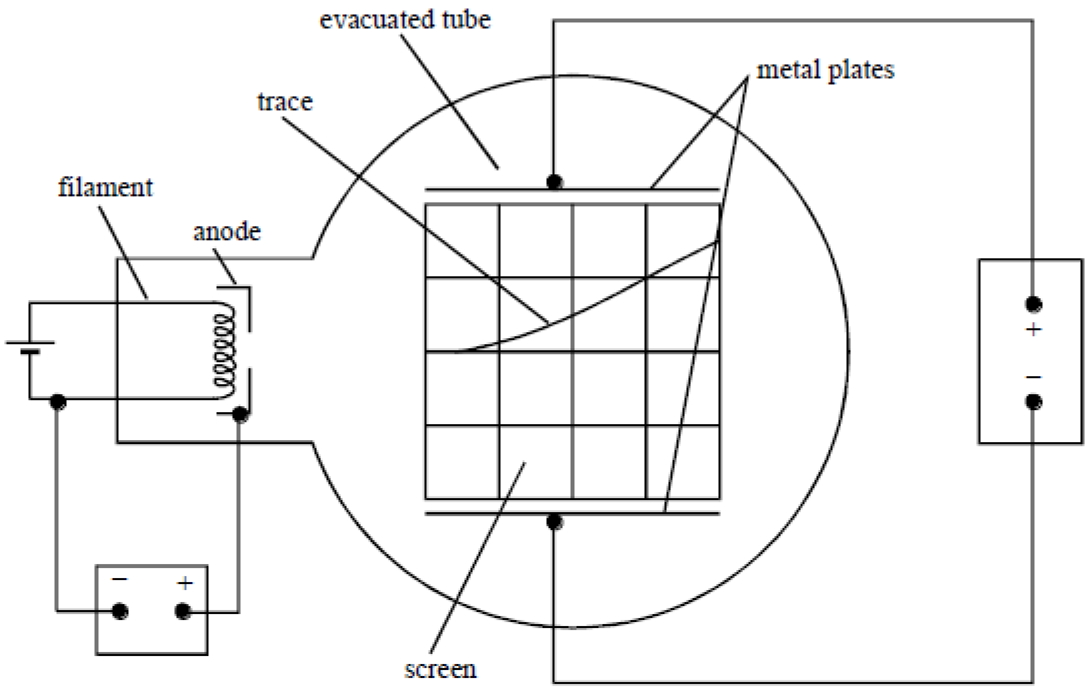
(2)

(ii) State **two** reasons why the transformer may be less than 100% efficient.

(2)

(Total 10 marks)

5 A narrow beam of electrons is directed into a uniform electric field created by two oppositely-charged parallel metal plates at right angles to the field lines. A fluorescent screen is used to make the beam give a visible trace.



(a) (i) Explain why the beam curves towards the positive plate.

___

___

(ii) How does the trace show that, on entry to the electric field, all the electrons have the same speed?

___

___

___

(3)

(b) The beam is produced as a result of accelerating electrons between the filament and a metal anode.

(i) Explain why the wire filament must be hot.

___

___

___

(ii) Write down an equation relating the speed of the electrons, v, to the potential difference, V_A, between the anode and the filament.

____

____

(2)

(c) The deflection of the beam due to the electric field can be cancelled by applying a suitable uniform magnetic field *in* the same region as the electric field.

(i) What direction should the magnetic field be in to do this?

____

____

(ii) Write down an equation relating the speed of the electrons v to the plate voltage V_p, the plate separation d, and the magnetic flux density B necessary to make the beam pass undeflected between the plates.

____

____

(iii) The following measurements were made when the beam was undeflected.

V_A = 3700 V V_p = 4500 V d = 50 mm B = 2.5 mT

Use the two equations you have written down and the given data to calculate the specific charge, e/m, of the electron.

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____

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(5)

(Total 10 marks)

6 (a) (i) State **two** differences between a proton and a positron.

difference 1 ____

____

difference 2 ____

____

(ii) A narrow beam of protons and positrons travelling at the same speed enters a uniform magnetic field. The path of the positrons through the field is shown in **Figure 1**.

Sketch on **Figure 1** the path you would expect the protons to take.

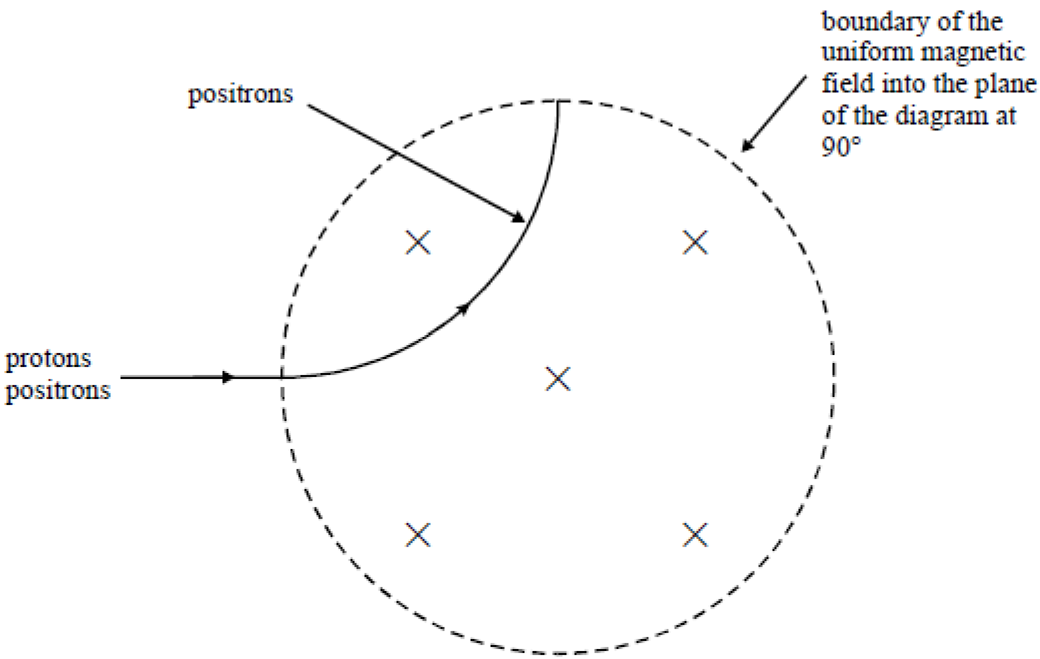

Figure 1

(iii) Explain why protons take a different path to that of the positrons.

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____

____

____

(5)

(b) **Figure 2** shows five isotopes of carbon plotted on a grid in which the vertical axis represents the neutron number N and the horizontal axis represents the proton number Z. Two of the isotopes are stable, one is a beta minus emitter and two are positron emitters.

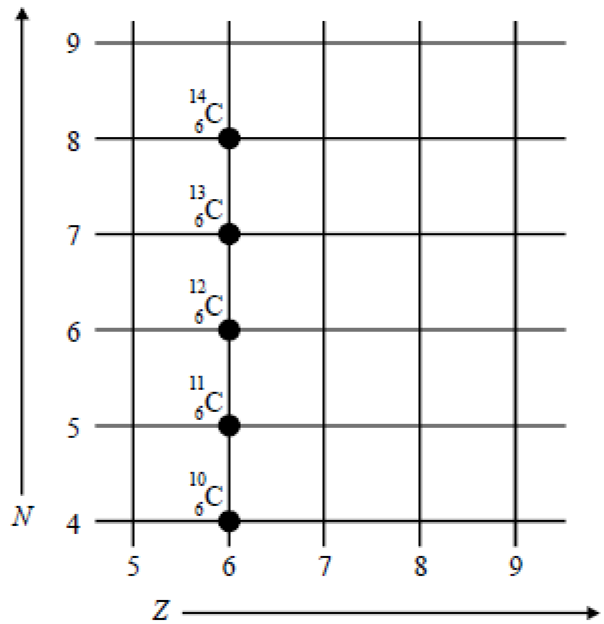


Figure 2

(i) Which isotope is a beta minus emitter?

___

(ii) Which of the two positron emitters has the shorter half-life? Give a reason for your choice.

___

___

___

(3)

(c) A positron with kinetic energy 2.2 MeV and an electron at rest annihilate each other. Calculate the average energy of each of the two gamma photons produced as a result of this annihilation.

___

___

___

___

(2)

(Total 10 marks)

7 (a) A satellite moves in a circular orbit at constant speed. Explain why its speed does not change even though it is acted on by a force.

____

____

____

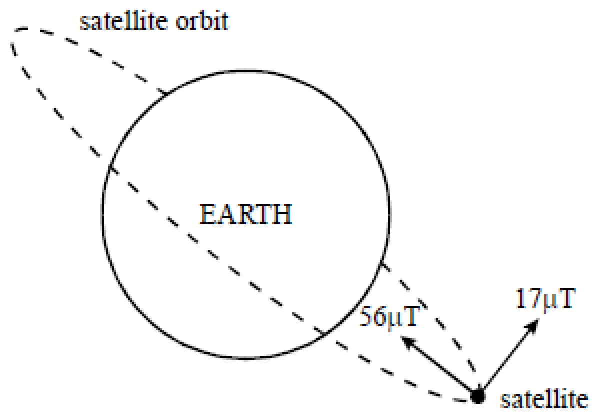
____

____

____

(3)

(b) At a certain point along the orbit of a satellite in uniform circular motion, the Earth's magnetic flux density has a component of 56 μT towards the centre of the Earth and a component of 17 μT in a direction perpendicular to the plane of the orbit.



(i) Calculate the magnitude of the resultant magnetic flux density at this point.

____

____

(ii) The satellite has an external metal rod pointing towards the centre of the Earth. Calculate the angle between the direction of the resultant magnetic field and the rod.

____

____

____

____

____

(iii) Explain why an emf is induced in the rod in this position.

(4)

(Total 7 marks)

8 A metal aircraft with a wing span of 42 m flies horizontally with a speed of 1000 km h^{-1} in a direction due east in a region where the vertical component of the flux density of the Earth's magnetic field is 4.5×10^{-5} T.

(a) Calculate the flux cut per second by the wings of the aircraft.

(b) Determine the magnitude of the potential difference between the wing tips, stating the law which you are applying in this calculation.

(c) What would be the change in the potential difference, if any, if the aircraft flew due west?

(Total 6 marks)

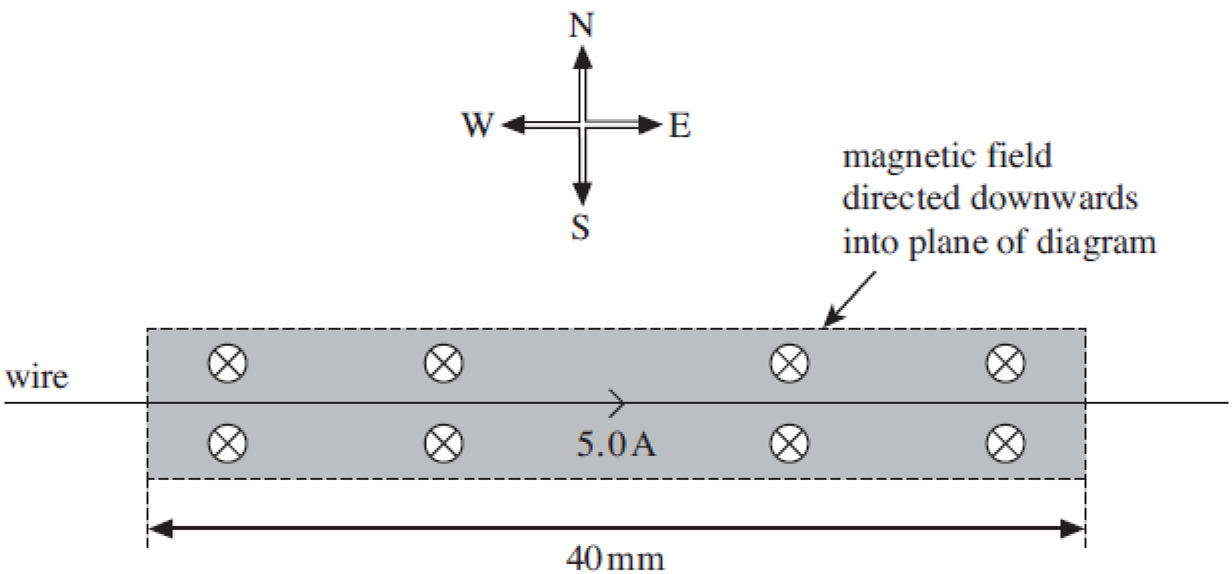
9 A transformer, which is not perfectly efficient, is connected to a 230 V rms mains supply and is used to operate a 12 V rms, 60 W lamp at normal brightness. The secondary coil of the transformer has 24 turns.

Which line, **A** to **D**, in the table is correct?

	number of turns on primary coil	**rms current in primary coil**
A	92	less than 0.26 A
B	92	more than 0.26 A
C	460	less than 0.26 A
D	460	more than 0.26 A

(Total 1 mark)

10 A horizontal straight wire of length 40 mm is in an east-west direction as shown in the diagram. A uniform magnetic field of flux density 50 mT is directed downwards into the plane of the diagram.



When a current of 5.0 A passes through the wire from west to east, a horizontal force acts on the wire. Which line, **A** to **D**, in the table gives the magnitude and direction of this force?

	magnitude / mN	**direction**
A	2.0	north
B	10.0	north
C	2.0	south
D	10.0	south

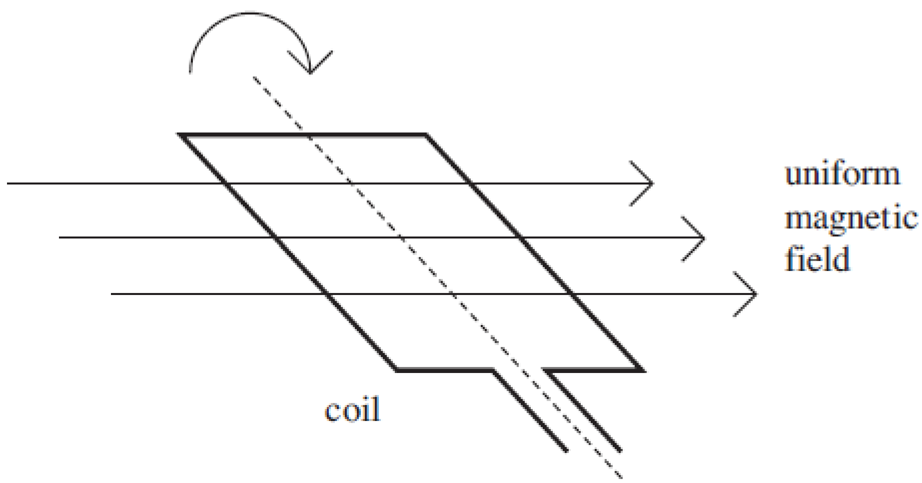
(Total 1 mark)

11 Which line, **A** to **D**, in the table correctly describes the trajectory of charged particles which enter separately, at right angles, a uniform electric field, and a uniform magnetic field?

	uniform electric field	**uniform magnetic field**
A	parabolic	circular
B	circular	parabolic
C	circular	circular
D	parabolic	parabolic

(Total 1 mark)

12 A rectangular coil is rotated in a uniform magnetic field.



When the coil is rotated at a constant rate, an alternating emf ε is induced in it. The variation of emf ε, in volts, with time t, in seconds, is given by

$$\varepsilon = 20 \sin (100\, \pi t)$$

Which line, **A** to **D**, in the table gives the peak value ε_0 and the frequency f of the induced emf?

	ε_0 / V	**f / Hz**
A	10	50
B	10	100
C	20	50
D	20	100

(Total 1 mark)

13 The magnetic flux through a coil of 5 turns changes uniformly from 15×10^{-3} Wb to 7.0×10^{-3} Wb in 0.50 s. What is the magnitude of the emf induced in the coil due to this change in flux?

A 14 m V

B 16 m V

C 30 m V

D 80 m V

(Total 1 mark)

14 Which one of the following statements concerning power losses in a transformer is **incorrect**?

Power losses can be reduced by

A laminating the core.

B using high resistance windings.

C using thick wire.

D using a core made of special iron alloys which are easily magnetised.

(Total 1 mark)

15 A section of current-carrying wire is placed at right angles to a uniform magnetic field of flux density *B*. When the current in the wire is I, the magnetic force that acts on this section is *F*.

What force acts when the same section of wire is placed at right angles to a uniform magnetic field of flux density 2*B* when the current is 0.25 I?

A $\frac{F}{4}$

B $\frac{F}{2}$

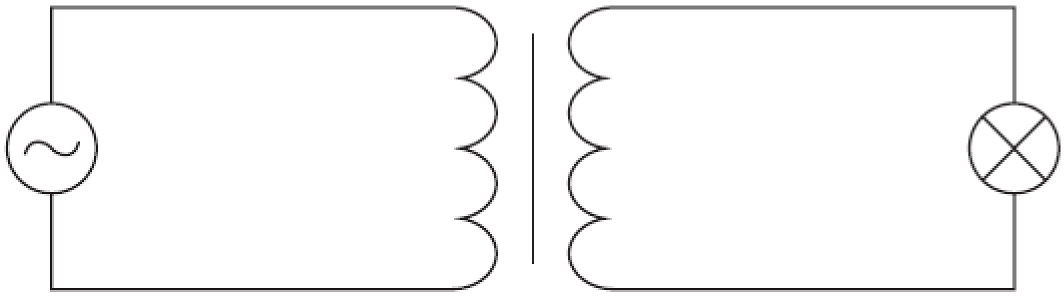
C *F*

D *2F*

(Total 1 mark)

16 A transformer with 3000 turns in its primary coil is used to change an alternating pd from an rms value of 240 V to an rms value of 12 V.

When a 60 W, 12 V lamp is connected to the secondary coil, the lamp lights at normal brightness and a rms current of 0.26 A passes through the primary coil.

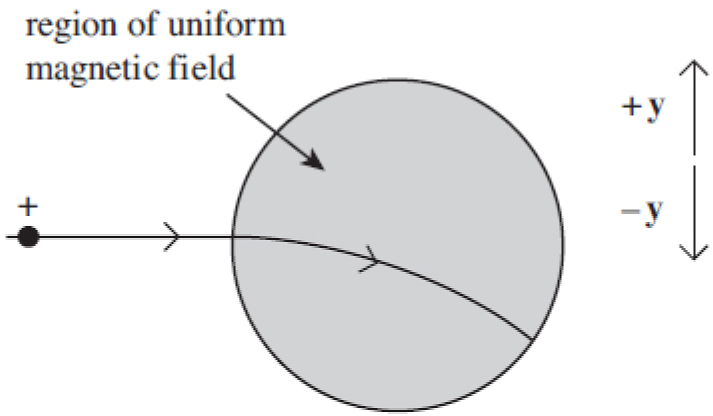


Which line, **A** to **D**, in the table gives correct values for the number of turns on the secondary coil and for the transformer efficiency?

	number of turns on the secondary coil	**efficiency**
A	150	96%
B	60 000	96%
C	150	90%
D	60 000	90%

(Total 1 mark)

17 A beam of positive ions enters a region of uniform magnetic field, causing the beam to change direction as shown in the diagram.



What is the direction of the magnetic field?

A out of the page and perpendicular to it

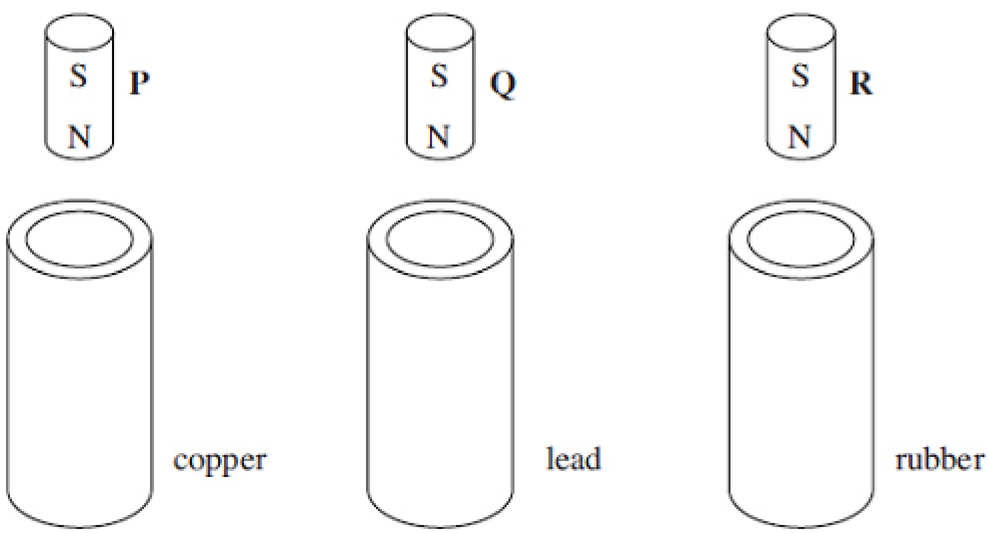
B into the page and perpendicular to it

C in the direction indicated by +*y*

D in the direction indicated by -*y*

(Total 1 mark)

18 Three vertical tubes, made from copper, lead and rubber respectively, have identical dimensions. Identical, strong, cylindrical magnets **P**, **Q** and **R** are released simultaneously from the same distance above each tube. Because of electromagnetic effects, the magnets emerge from the bottom of the tubes at different times.



Which line, **A** to **D**, in the table shows the correct order in which they will emerge?

resistivity of copper $= 1.7 \times 10^{-8}\ \Omega\text{m}$

resistivity of lead $= 22 \times 10^{-8}\ \Omega\text{m}$

resistivity of rubber $= 50 \times 10^{13}\ \Omega\text{m}$

	emerges first	**emerges second**	**emerges third**
A	**P**	**Q**	**R**
B	**R**	**P**	**Q**
C	**P**	**R**	**Q**
D	**R**	**Q**	**P**

(Total 1 mark)

19 When a mobile phone is being recharged, the charger heats up. The efficiency of the transformer in the charger can be as low as 15% when drawing a current of 50 mA from a 230 V mains supply. If the charging current required is 350 mA, what is the approximate output voltage at this efficiency?

A 4.9 V

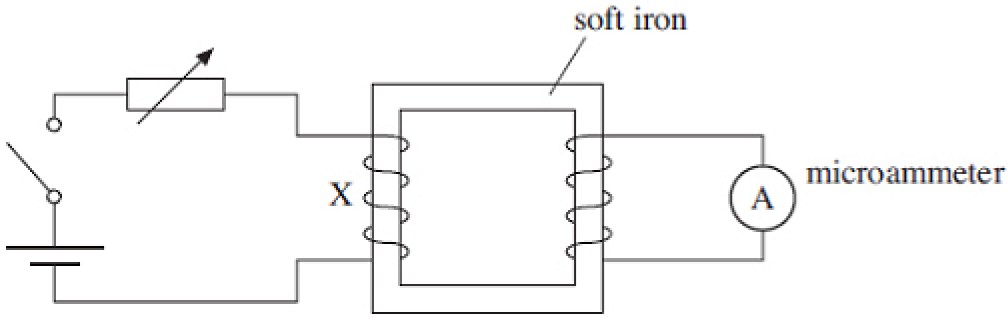
B 11 V

C 28 V

D 33 V

(Total 1 mark)

20 Using the circuit shown, and with the switch closed, a small current was passed through the coil X. The current was slowly increased using the variable resistor. The current reached a maximum value and was then switched off.



The maximum reading on the microammeter occurred when

A the small current flowed at the start.

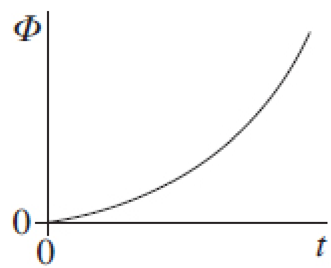
B the current was being increased.

C the current was being switched off.

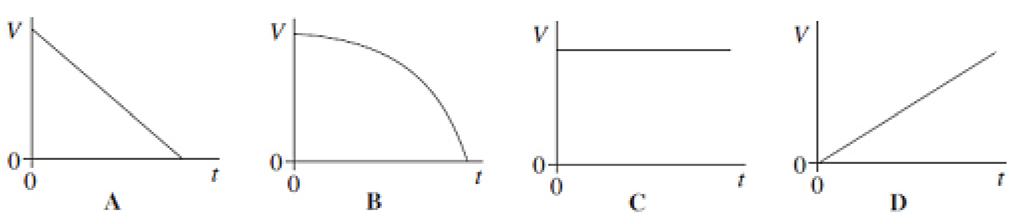
D the current in X was zero.

(Total 1 mark)

21 The graph shows how the magnetic flux, Φ, passing through a coil changes with time, t.



Which one of the following graphs could show how the magnitude of the emf, V, induced in the coil varies with t?



(Total 1 mark)

Mark schemes

1

(a) $\frac{N_S}{N_P} = \frac{V_S}{V_P}$ **C1**

7000 (6960) **A1**

(2)

(b) (i) changing magnetic field **B1**

emf or changing magnetic field is in the core **B1**

e.m.f. induced (due to changing magnetic field) not back emf **B1**

current flows as core is made from a conducting material **B1**

(4)

(ii) laminated core **B1**

(1)

[7]

2

(a) (i) vertical field line(s) B1

directed downwards B1

2

(ii) mv^2/r and Bev seen M1

equated and correctly rearranged A1

2

(iii) $v = \frac{2\pi r}{T}$ or equivalent

M1

$T = \frac{2\pi m}{Be}$

A1

2

(iv) no v in the equation for T (m, B and e all independent of v)

B1

1

(b) (i) proton spirals outwards/suitable diagram B1

as v ↑ r ↑

B1

2

(ii) $f = 1/T$

B1

1

(c) (i) conversion of keV to J (1.92×10^{-17})

C1

use of ½ mv^2

1.50×10^5 ms^{-1}

A1

3

(ii) $\lambda = \frac{h}{p}$

$p = mv$ or substituted values

C1

2.6×10^{-12} m

A1

3

(iii) *y*-rays or X-rays or answer consistent with candidate's λ

B1

1

[17]

3 (a) (i) 1 N per A per m
or 1 Wb m^{-2}
or quotes: $B = F/IL$ with terms defined
or induced $EMF = \Delta BAN/t$ with terms defined
or a slightly flawed attempt at the definition in statement form

C1

It is the flux density (perpendicular to a wire) that produces a force of 1N per m on the wire when the current is 1A
or
$B = F/IL$ **and** 1 T is flux density when F = 1N; I = 1A and L = 1 m
or induced $EMF = \Delta BAN/t$ and 1 T is the flux change when emf = 1V for A=1 N =1 and t =1 or similar

A1

2

(ii) force on charge due to E field , $F_E = Eq$ **or** Vq/d
and
force due to B field, $F_B = Bqv$
or $Eq=Bqv$

B1

$= Bqv$; cancels q **and states explicitly** $v = \frac{E}{B}$

or $v = \frac{V}{dB}$

B1

2

(iii) v = 20000/0.14 (seen) **or** 143×10^3 m s^{-1}

B1

1

(b) (i) $Bqv = mv^2/r$ or $r = mv/Bq$ (allow e instead of q)
mass of ion = $1.7 \times 10^{-27} \times 58$ (may be in equation)
or (9.86×10^{-26} kg seen)

C1

or
radius = 0.14 m (may be in equation)

C1

Substitutes and arrives at 0.62 to 0.63 T

A1

3

(ii) Calculates new radius (0.145 m) or diameter (0.288 m)
using $r \propto m$ or otherwise **allowing ecf**

C1

0.010 m (condone 0.01 m) or 0.0096 – 0.0097 m
(Allow 0.0079 m or 0.008 m due to use of different
sfs for B and v)

A1

2

[10]

4 (a) product of flux and number of turns

B1

Wb or equivalent

C1

(2)

(b) changing primary magnetic field due to alternating voltage **B1**

(applied to primary)
varying flux links with secondary **B1**

induced emf ∑ rate of change of flux linkage **B1**

$N_S < N_P$ so less voltage on secondary **C1**

(4)

(c) (i) equation or correct substitution **C1**

15.3 V **A1**

(2)

(ii) <100% flux linkage / flux leakage / copper losses / iron losses / hysterysis losses **not** just "heating" or "heat loss" **B2**

(2)

[10]

5 (a) (i) electrons are negatively charged so beam is attracted to positive plate [or repelled by negative plate or electron experiences force towards positive plate] **(1)**

(ii) beam does not spread out **(1)**
if speeds varied, faster electrons would be deflected less than slower electrons **(1)**

3

(b) (i) to give conduction electrons sufficient k.e. to leave metal [or to cause thermionic emission or electrons have insufficient ke. in a cold filament to leave filament] **(1)**

(ii) $\frac{1}{2}mv^2 = eV_A$ [or $v = \sqrt{\frac{2eV_A}{m}}$] **(1)**

2

(c) (i) into the plane of the diagram **(1)**
perpendicular to the diagram [or the electric field] **(1)**

(ii) $Bev = \frac{eV_p}{d}$ **(1)**

(iii) combine the two equations to give $\frac{e}{m} = \frac{V_p^2}{2V_A B^2 d^2}$ **(1)**

$$\frac{e}{m} = \frac{4500^2}{2 \times 3700 \times (2.5 \times 10^{-3})^2 \times (50 \times 10^{-3})^2}$$ **(1)**

1.75×10^{11} Ckg^{-1} **(1)**

max 5

[10]

6 (a) (i) *including, for example:*
positron is an antimatter particle; proton is a matter particle (*)
positron is a lepton; proton is a hadron (*)
positron has a smaller rest mass than a proton (*)
positron is not composed of other particles; proton is made up of quarks (*)
(*) any two **[1] [1]**

(ii) proton path has greater radius of curvature than positron **(1)**

(iii) radius of curvature $r = \frac{mv}{Be}$ and v, B and e are constants **(1)**

therefore r proportional to m **(1)**
mass of proton is (much) greater than mass
of positron (at same speed) **(1)**

5

(b) (i) C - 14 **(1)**

(ii) C - 10 **(1)**
as this is furthest from stability **(1)**

3

(c) rest mass of electron = 0.51 MeV therefore total energy available
= (2.2 +2 × 0.51)= 3.22 (MeV) **(1)**

gamma photons produced have average energy = $\frac{3.22}{2}$ = 1.6 MeV**(1)**

2

[10]

7 (a) gravity or force acts towards centre **(1)**
force acts at right angles to velocity or direction of motion
[or velocity is tangential] **(1)**
no movement in direction of force **(1)**
no work done so no change of kinetic energy so no change in speed **(1)**

3

(b) (i) $B = (56^2 + 17^2)^{½} = 59\ \mu T$ **(1)**

(ii) $\tan\theta = \frac{17}{56}$ **(1)**

$\theta = 17°$ **(1)** ($\pm$ 1°)

(iii) rod sweeps out or cuts (magnetic) flux
[or rod cuts field] **(1)**

4

[7]

8 (a) $1000\ \text{km hr}^{-1} = \frac{1000 \times 10^3}{3600}\ \text{m s}^{-1}$

flux cut per second = B × area swept out per second $\left[\text{or } 4.5 \times 10^{-5} \times 42 \times \frac{10^4}{36}\right]$ **(1)**

= 0.52Wb **(1)**

(b) induced e.m.f. equals flux cut per second [or equation and symbols defined] **(1)**
$\therefore E$ = 0.52V **(1)**

(c) direction of p.d. reversed **(1)**

[6]

9 D

[1]

10 B

[1]

11 A

[1]

12 C

[1]

13 D

[1]

14 B

[1]

15 B

[1]

16 A

[1]

17 A

[1]

18 D

[1]

19 A

[1]

20 C

[1]

21 D

[1]

Examiner reports

1 (a) Most candidates used the correct equation but a surprisingly large number rearranged it incorrectly and gave an answer indicating that there would be fewer turns on the secondary coil than on the primary coil. Significant figure penalties were common here.

(b) (i) This explanation was not well done. Few candidates made it clear that the induction was taking place in the core and very few mentioned that the core was an electrical conductor. Many candidates made weak references to back e.m.f's and a large number seemed to be trying to explain what happened in the secondary coil. Questions of this type are often asked and candidates would be well advised to practice making sequential explanations.

(ii) Many candidates knew about laminations. A few forgot to specify that it was the core that should be laminated. Some wanted to laminate the coils.

2 (a) (i) Surprisingly, several candidates failed to answer this part. Of those who did most recognised that the magnetic field would be vertically downwards.

(ii) Most candidates were able to complete this part successfully.

(iii) This was found to be more difficult and only the best candidates were able to arrive at the expected equation.

(iv) Of those arriving at an appropriate equation in (iii) most recognised that all the quantities were independent of v.

(b) (i) Few candidates recognised that the proton would spiral outwards as its speed increases. Several candidates did discuss an increase in the radius of the proton path.

(ii) Most candidates correctly recognised the relationship between f and T.

(c) (i) Weaker candidates had difficulty in converting the energy from keV into J but otherwise this part was well answered.

(ii) The de Broglie relationship was well known although, even with error carried forwards from (i), several candidates had difficulty in calculating a consistent wavelength.

(iii) Few candidates could relate the wavelength calculated in (ii) to its appropriate area in the electromagnetic spectrum.

3 (a) (i) Only a small proportion of the candidates was able to provide a correct definition of the telsa. Most gave another form of the unit Wb m^{-2} or less commonly N A^{-1} m^{-1}.

(ii) It would have been useful to see some words to support the algebraic argument but this was very rare. Responses were usually a number of formulae with cancellations (including some irrelevant formulae amongst the relevant ones in the poorest answers). In view of the poor explanations candidates were at least expected to make *v* the subject of the final formula to gain both marks.

(iii) This was often correct but whether the answers were based on an understanding of the physics or just number crunching was often difficult to follow. Candidates were given the benefit of the doubt.

(b) (i) Many knew the equation $r = mv/Bq$ or were able to derive it from first principles. A common error was to use the diameter instead of the radius so arriving at half the answer. Some did not calculate the mass of the ion and others used $28 \times 1.6 \times 10^{-19}$ C for the charge on the ion.

(ii) Many were able to gain credit in this part using the error carried forward for an incorrect flux density. However, the majority subtracted the given diameter from their new radius so losing the second mark.

4

(a) Few of the candidates were able to give a good explanation of magnetic flux linkage. several confusing the term with *flux density*. Few correctly identified the Weber as the correct unit.

(b) Most candidates were unable to give a coherent explanation of how electromagnetic induction underpinned the working of the step down transformer. The most common observation gaining credit was that there are more turns on the primary than the secondary coil.

(c) (i) Most candidates calculated the output voltage correctly.

(ii) Few candidates' answers gained credit for this part. It was common for candidates to cite *heating* or *eddy currents* as the reason for less than 100% efficiency. Although these answers are not incorrect they are too vague to allow credit at this level.

5

Most candidates explained correctly in part (a) why the beam bends towards the positive plate and why the trace shows that the electrons have the same speed. Relatively few candidates went on to state that faster-moving electrons would deflect less and slower electrons more.

Many candidates scored both marks in part (b), often with a good account of thermionic emission which indicated clear understanding of the process involved.

Few candidates scored both marks in part (c)(i), although many did know that the magnetic field direction needs to be into the plane of the diagram. Weaker candidates generally failed to score here, often confusing the force direction and the field direction, Most candidates knew the correct equation in part (c)(ii) and many realised that the equation was to be used in part (c)(iii), although some lost a mark through failure to state the correct unit.

6

Parts (a)(i) and (a)(ii) were found to be straightforward by most candidates, but only the best explained the ideas behind the trajectory with any rigour. This required the essential statement that B, v, and e are constants in the equation $R = mv / Be$.

Part (b) discriminated well at the bottom end of the ability range.

Many more candidates than expected failed to include the rest mass of both particles in the total energy calculation in part (c).

7 In part (a) the large majority of candidates knew that the force on the satellite acted towards the centre of the Earth and that the direction of motion or velocity of the satellite was at right angles to the force. However, few of them were able to use these facts to explain adequately why the speed remained constant. Little or no reference was made to the absence of work done or zero change in potential or kinetic energy.

There were many correct calculations in parts (b)(i) and (ii), but some candidates did confuse the two components when calculating the angle in part (ii). In the final part, correct explanations for the induced emf were usually given in terms of the rod cutting the non-radial component of the Earth's magnetic field.

8 All but the below average candidates could calculate the flux cut per second in part (a). The commonest errors arose in changing km h^{-1} to m s^{-1} and in the final unit.

Many candidates went astray in part (b), not realising that the e.m.f. in V equalled the flux cut per second. Some candidates started again with Blv, others referred to the Hall effect or even gravitational potential. Correct statements of Faraday.s law in words were fairly common, although a number of candidates thought that an equation like $E = -N\phi / dt$, or even the name of the law , was enough. The equation was accepted only if the symbols were defined. The majority of candidates said that the only change in the p.d. would be a reversal in polarity. Some candidates, not always those who scored high marks, carefully pointed out that relative to an observer in the aircraft, there would be no change. Both answers were obviously accepted, but references to charges and currents were not.

9 The question showed that most of the candidates were able to apply the turns ratio equation correctly, because over 80% of them selected $N_p = 460$. A simple conservation of power calculation would also show them that the primary current would be 0.26 A if the transformer was perfectly efficient. Since this transformer has an efficiency of less than 100%, the better candidates (51%) realised that the primary current had to be greater than 0.26 A.

10 This question dealt with various aspects of electromagnetism. The question required the application of $F = B\ I\ L$ together with Fleming's left hand rule. The facility was 75% and the most common incorrect response was distractor D – from those who could not decide the correct direction.

11 This question had appeared in an examination previously; it tested the fairly familiar knowledge of the trajectory of charged particles in electric and magnetic fields and this time had a facility of 71%.

12 This question tested the candidates' understanding of the peak voltage and frequency terms in the equation $\varepsilon = \varepsilon_0 \sin (2\pi f\ t)$ for a coil rotating at constant speed in a uniform magnetic field. This equation was not understood as well as might have been expected, because the facility was less than 60%. Common misapprehensions seem to have been that ε_0 represents the peak-to-peak voltage (because distractors A and B each attracted more than 10% of the responses) and that $2f$ represents the frequency (because distractor D attracted 17% of responses).

13 This question, which involved the direct application of $\varepsilon = \Delta N\Phi / \Delta t$, probably required less thought before committing a response. The facility of the question was 74%, an improvement of 10% over the last occasion when it appeared in an examination. Thinking that the induced emf is equal to the rate of change of *flux*, instead of *flux linkage*, probably caused 16% of the candidates to select distractor B.

14 This qestion was about transformers. Causes of power loss were well known in this question, where three quarters of the candidates evidently saw that using windings with higher resistance would have a detrimental effect.

15 This question was a test of $F = BIl$ that, with a facility of 86%, proved to be the least demanding question in this Section A. When the question was pre-tested just over half of the students selected the correct response.Fleming's left hand rule, as applied to a beam of positive ions

16 This question tested both the turns ratio equation and efficiency; again there were few problems and the facility was 72%.

17 This question 61% of the students could apply the rule correctly, but almost one quarter of them chose distractor B, where the magnetic field would have acted "down" into the page instead of "up" out of it.

18 This question on the emf generated by a moving magnet and the consequences of Lenz's law, had been used in a previous examination. The facility of 67% this time was slightly better than when it was last used. Curiously, the most common incorrect response was distractor A (chosen by 18%), where the order in which the magnet would emerge is the exact opposite of the correct order.

19 This question amounted to a traditional transformer efficiency question, but it was set in the context of a mobile phone charger circuit with low efficiency. The facility of the question was 71%. There was no strong distractor, and the question discriminated much better than it had done when pre-tested.

20 This question needed students to spot that the most rapid change of flux in a transformer circuit occurs when a current is suddenly interrupted, leading to a maximum emf and (in this case) the largest current in the secondary circuit. A conventional car ignition system, now increasingly rare, illustrates this principle most effectively. The facility of the question was 43%, with 25% of the students opting for distractor B (when the primary current is steadily increased).

21 This question was a graphical test of the relationship between an induced emf and the rate of change of magnetic flux causing it. 59% of the students saw that the increasing gradient of the original graph had to imply that the emf would increase, and that therefore only graph D *could* be correct. 24% of the responses were for distractor B, where the emf is shown to decrease at an increasing rate.