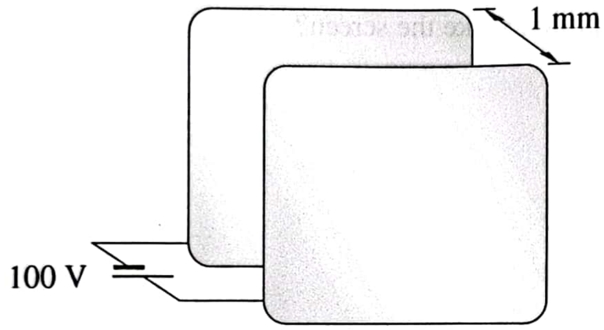
Questions

Module 6: Electromagnetism

6.1 Charged Particles, Conductors and Electric and Magnetic Fields

Multiple-choice questions: 1 mark each

1. Two parallel metal plates are 1 mm apart. A potential difference of 100 V is applied as shown.



What is the magnitude of the uniform electric field between the plates?

(A) 10^{-3} V m^{-1}

(B) 10^{-1} V m^{-1}

(C) 10^{2} V m^{-1}

(D) 10^{5} V m^{-1}

2007 HSC Q11

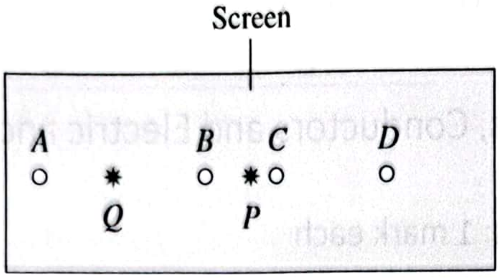
2. A potential difference of 50 V is applied between two identical, parallel aluminium plates which are separated by a distance of 10 mm.

In order to double this electric field strength, which new arrangement should be used?

	Separation (mm)	*Potential difference* (V)	*Plates*
(A)	20	100	Aluminium
(B)	5	50	Perspex
(C)	10	100	Copper
(D)	20	50	Aluminium

2006 HSC Q14

3. An electron is fired in a vacuum towards a screen. With no electric field being applied, the electron hits the screen at P. A uniform electric field is turned on and another electron is fired towards the screen from the same location, at the same velocity, striking the screen at point Q.



With the electric field still turned on, a proton is fired towards the screen from the same starting point as the electrons and with the same velocity.

At what point does the proton strike the screen?

A. A

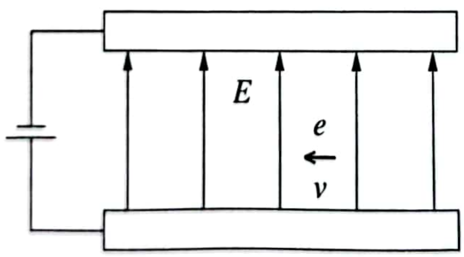
B. B

C. C

D. D

2017 HSC Q8

4. An electron, e, travelling with a velocity, v, passes through an electric field, E, between two parallel plates.



What is the direction of the force that this electric field exerts on the electron?

(A) ↑

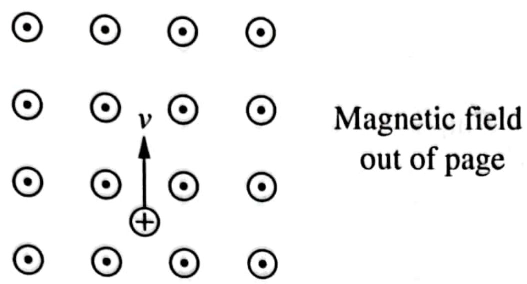
(B) ↖

(C) ↙

(D) ↓

2011 HSC Q19

5. At a particular moment, a positively charged particle is moving with velocity v in a magnetic field as shown.



At this moment, what is the direction of the force on the positively charged particle?

(A) To the right

(B) To the left

(C) Into the page

(D) Out of the page

2001 HSC Q2

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

What would NOT affect the magnetic force on the particle?

(A) The strength of the magnetic field

(B) The magnitude of the charge on the particle

(C) The velocity component parallel to the magnetic field direction

(D) The velocity component perpendicular to the magnetic field direction

2006 HSC Q12

7. An electron is moving near a long straight wire. When a current is applied to the wire the electron experiences a force in the same direction as the current flow in the wire.

What was the electron's initial direction of motion?

(A) Parallel to the current direction

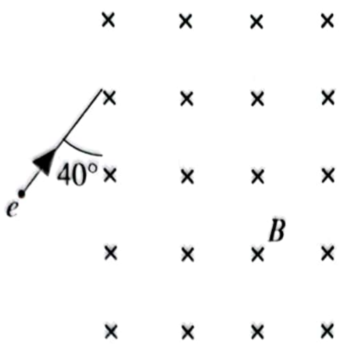
(B) Opposite to the current direction

(C) Towards the wire and perpendicular to it

(D) Away from the wire and perpendicular to it

2007 HSC Q13

8. An electron, e, moving with a velocity of 8.0×10^6 m s^{-1} enters a uniform magnetic field, B, of strength 2.1×10^{-2} T as shown.



The electron experiences a force which causes it to move along a circular path.

What is the radius of the path followed by the electron?

(A) 1.1×10^{-3} m

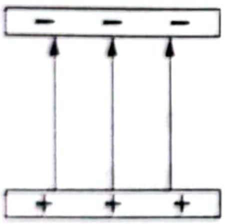
(B) 1.4×10^{-3} m

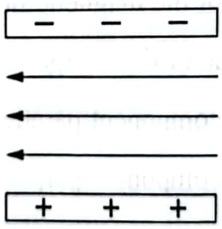
(C) 1.7×10^{-3} m

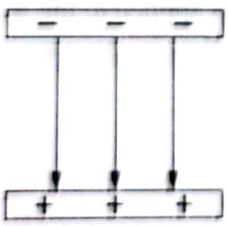
(D) 2.2×10^{-3} m

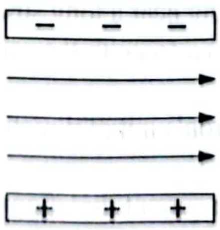
2008 HSC Q11

9. Which of the following correctly shows the electric field between two parallel, charged plates?

A. 

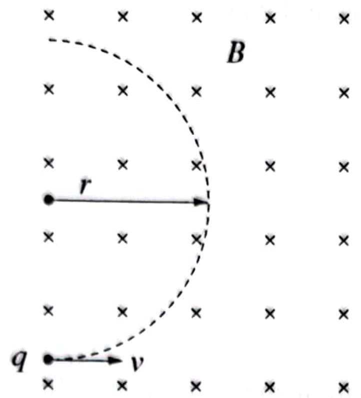
B. 

C. 

D. 

2017 HSC Q3

10. A charged particle, q, enters a uniform magnetic field B at velocity v. The particle follows a circular path of radius r as shown.



If the magnitude of the magnetic field were doubled and the other variables were kept constant, what would the new radius be?

(A) $\frac{r}{4}$

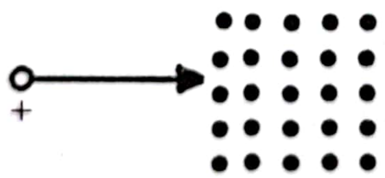
(B) $\frac{r}{2}$

(C) $2r$

(D) $4r$

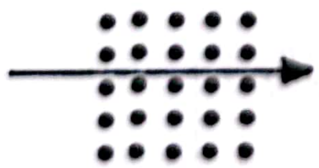
2010 HSC Q15

11. A positively charged particle enters the uniform magnetic field illustrated below. It initially travels perpendicularly to the field from the left.

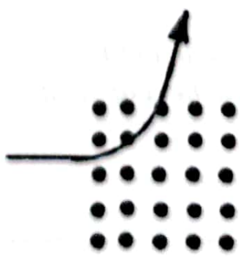


Which of the following diagrams best indicted the path of the particle through the region of the field?

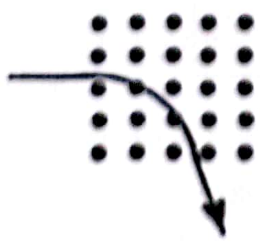
(A)



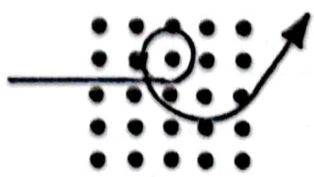
(B)



(C)



(D)



1982 HSC Q10

12. An electron, under the influence of a uniform magnetic field of strength 2.1×10^{-2} T, moves in a circular path with a speed of 4.9×10^{6} m s^{-1}. After one orbit under the influence of this magnetic field, how much energy does the electron gain?

(A) 0 J

(B) 1.2×10^{-17} J

(C) 1.56×10^{-14} J

(D) 7.84×10^{13} J

1988 HSC Q9

13. An electron passes through a uniform magnetic field at right angles to the direction of the field at a speed of 4.0×10^{6} m s^{-1}. The intensity of the field is 0.50 T.

What is the magnitude of the force acting on the electron?

(A) zero

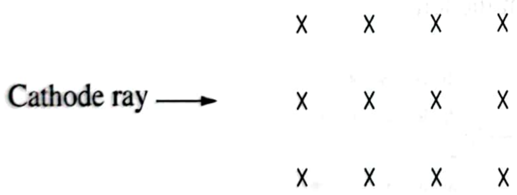
(B) 2.0×10^{-6} N

(C) 3.2×10^{-13} N

(D) 6.4×10^{13} N

1990 HSC Q9 (adapted)

14. The diagram shows a cathode ray entering a magnetic field.



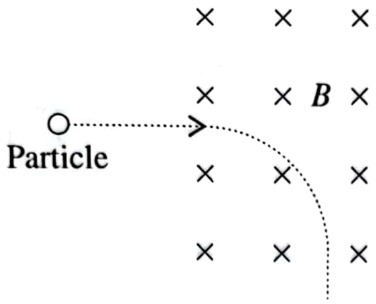
An electric field is applied to cancel the effect of the magnetic field on the cathode ray.

Which row of the table correctly describes the direction of the applied electric field, and the direction of the force acting on the cathode ray as a result of the magnetic field?

	Direction of the electric field applied	*Direction of force as result of the magnetic field*
(A)	↑	↑
(B)	↓	↑
(C)	↑	↓
(D)	↓	↓

2014 HSC Q18

15. A particle of mass m and charge q travelling at velocity v enters a magnetic field of magnitude B and follows the path shown.



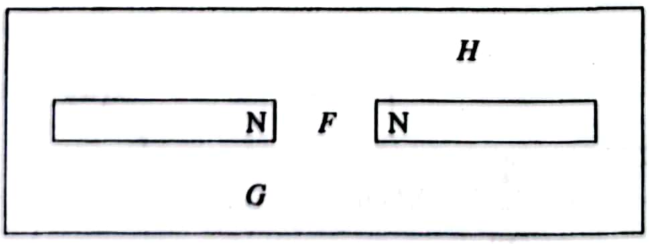
A second particle enters a magnetic field of magnitude $2B$ with a velocity of $\frac{1}{2}v$ and follows an identical path.

What is the mass and charge of the second particle?

	Mass	*Charge*
A.	m	q
B.	$\frac{1}{2}m$	$2q$
C.	$4m$	q
D.	m	$\frac{1}{2}q$

2017 HSC Q18

16. The diagram below shows the view from above of two identical permanent bar magnets. Their north ends are positioned close to each other. Points F, G and H are in the same plane as the magnets. F is midway between the ends of the magnets.



Which of the following is a true statement?

(A) A negatively charged particle moving to the right at G would experience a force upwards out of the page.

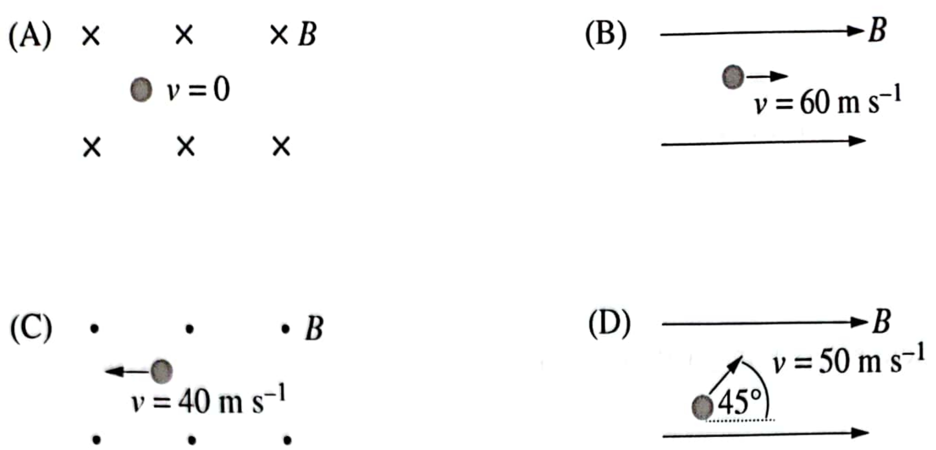
(B) A negatively particle moving to the left at F would experience a force upwards out of the page.

(C) A positively charged particle that is stationery at H would experience a force to the right.

(D) A positively charged particle moving to the right at F would experience a force upwards out of the page.

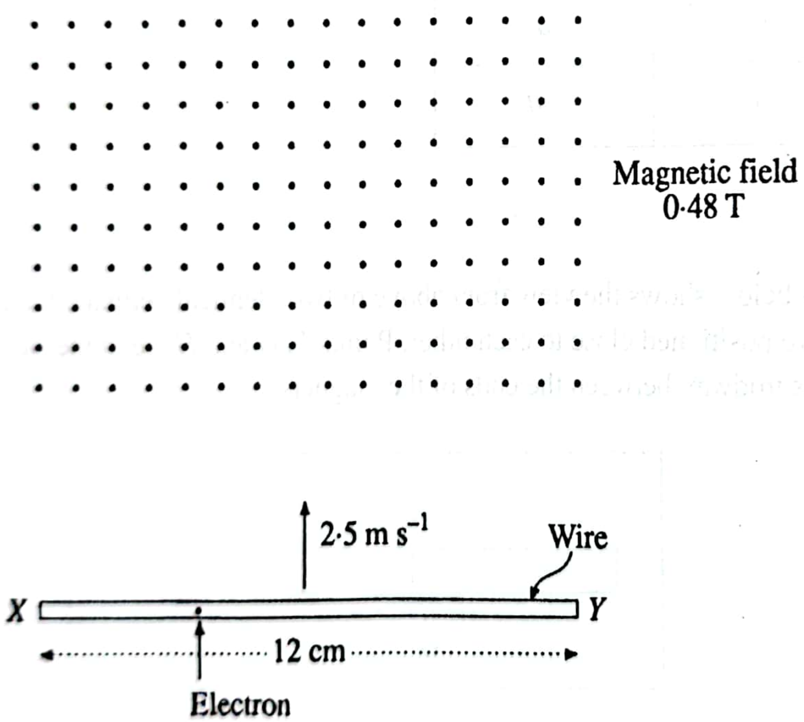
1995 HSC Q11 (adapted)

17. the proton (●), given that all of the fields are of equal magnitude.



2015 HSC Q8

18. A horizontal wire, *XY*, is moving into a magnetic field in a direction perpendicular to its length, as shown below. The speed of the wire is $2{\cdot}5\ \text{m s}^{-1}$. The magnetic field points directly out of the paper and its flux density is 0.48 T.



The magnitude and direction of the magnetic force on an electron in the wire when it first enters the magnetic field is

(A) $1{\cdot}9 \times 10^{-19}$ N towards the left.

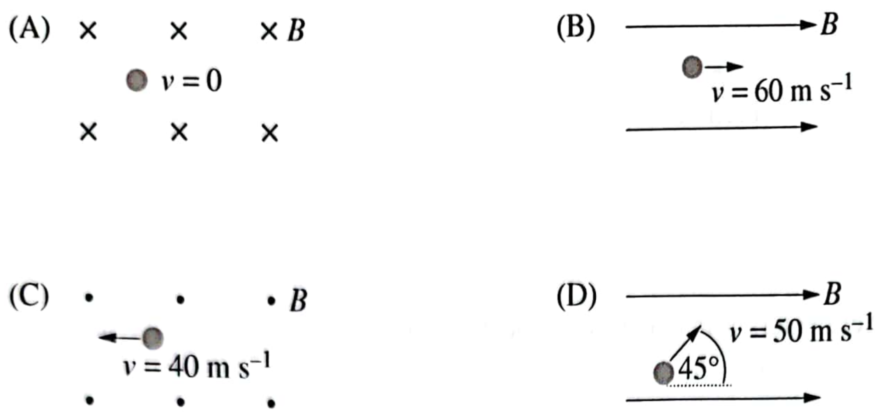
(B) $1{\cdot}9 \times 10^{-19}$ N towards the right.

(C) $9{\cdot}2 \times 10^{-22}$ N towards the left.

(D) $9{\cdot}2 \times 10^{-22}$ N towards the right.

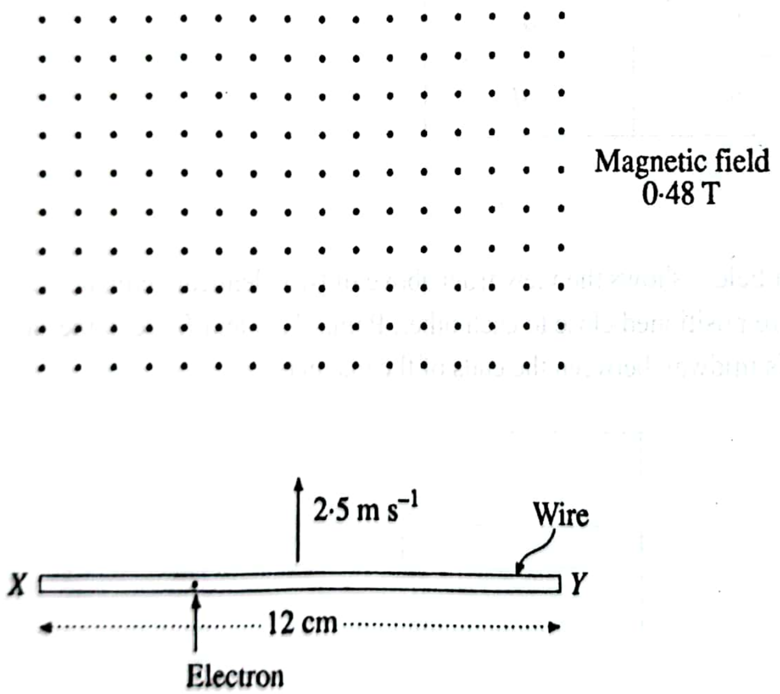
1996 HSC Q13

17. In which of the following situations does the magnetic field exert the greatest force on the proton (●), given that all of the fields are of equal magnitude?



2015 HSC Q8

18. A horizontal wire, XY, is moving into a magnetic field in a direction perpendicular to its length, as shown below. The speed of the wire is $2{\cdot}5\ \text{m s}^{-1}$. The magnetic field points directly out of the paper and its flux density is 0.48 T.



The magnitude and direction of the magnetic force on an electron in the wire when it first enters the magnetic field is

(A) $1{\cdot}9 \times 10^{-19}$ N towards the left.

(B) $1{\cdot}9 \times 10^{-19}$ N towards the right.

(C) $9{\cdot}2 \times 10^{-22}$ N towards the left.

(D) $9{\cdot}2 \times 10^{-22}$ N towards the right.

1996 HSC Q13

19. A region of space contains a constant magnetic field and a constant electric field.

How will these fields affect an electron that is stationary in this region?

(A) Both fields will exert a force.

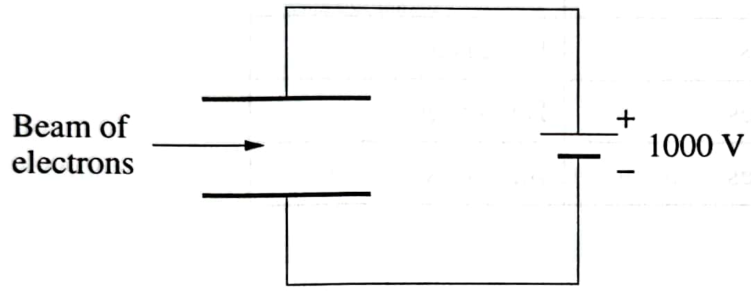
(B) Neither field will exert a force.

(C) Only the electric field will exert a force.

(D) Only the magnetic field will exert a force.

2016 HSC Q3

20. The diagram shows electrons travelling in a vacuum at 2×10^6 m s^{-1} between two charged metal plates 1×10^{-3} m apart.



A magnetic field is to be applied to make the electrons continue to travel in a straight line.

What is the magnitude and direction of the magnetic field that is to be applied?

A. 5×10^{-1} T into the page

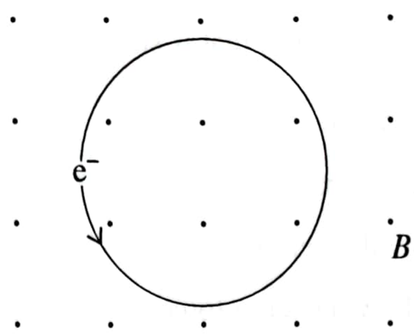
B. 5×10^{-1} T out of the page

C. 1×10^6 T into the page

D. 1×10^6 T out of the page

2018 HSC Q12

21. An electron moves in a circular path with radius r in a magnetic field as shown.

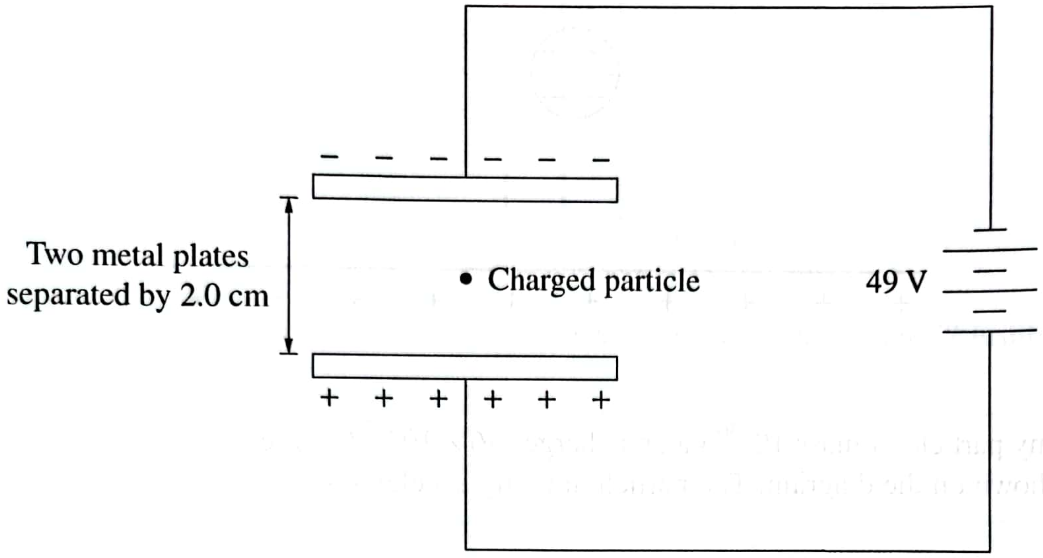


If the speed of the electron is increased, which row of the table correctly shows the effects of this change?

	Force on electron	*Radius of path*
A.	Increases	Decreases
B.	Increases	Increases
C.	Decreases	Decreases
D.	Decreases	Increases

2018 HSC Q13

22. The diagram shows two parallel horizontal metal plates connected to a DC source of electricity. Suspended between the plates is a charged particle of mass 9.6×10^{-6} kg.



(a) Using conventional symbols, draw the electric field between the metal plates on the diagram above. **1**

(b) Determine the magnitude of the electric field between the plates. **1**

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(c) Determine the sign and magnitude of the charge on the particle if it is suspended motionless between the plates. **3**

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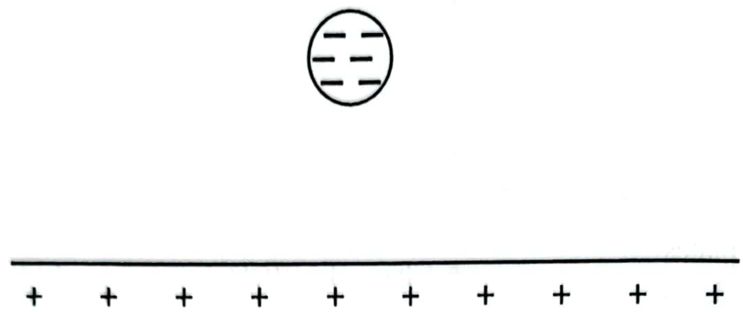
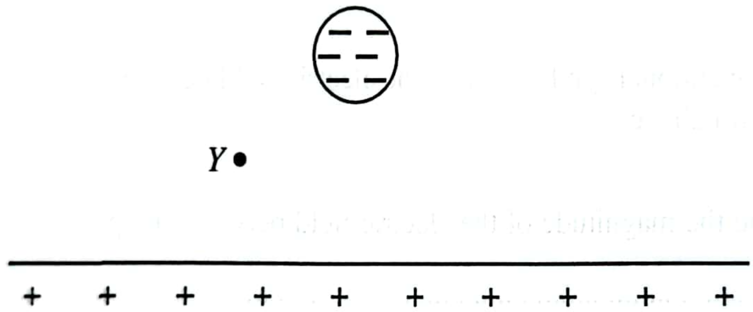
2005 HSC Q26 – 5 marks

23. (a) A negatively charged cylinder is fixed in position near a positively charged plate as shown in the cross-section.

Sketch the electric field lines between the cylinder and the plate on the cross-section diagram.



(b) A tiny particle of mass 10^{-30} kg and charge $+6 \times 10^{-12}$ C is released at point Y as shown on the diagram. The particle initially accelerates at 7.0×10^{21} m s^{-2}. **2**



Calculate the electric field intensity at Y.

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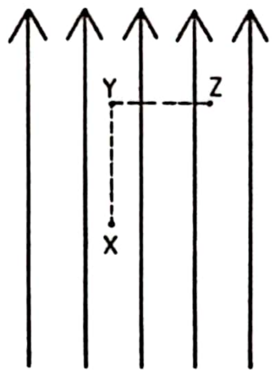
2007 HSC Q24 – 3 marks

24. This question refers to the diagram in which a uniform electric field is directed up the page.



(a) The line XY is parallel to the field. Is X at a higher potential than Y? Justify your answer.

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(b) The line YZ is perpendicular to the field. Is Z at a higher potential than Y? Justify your answer.

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(c) In moving from X to Y, the potential energy of an electron (charge -1.6×10^{-19} C) is increased. Explain why.

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1983 HSC Q16 – 3 marks

25. An electron is projected at 90° into a magnetic field of 9×10^{-4} T, at a speed of 1×10^{7} m s^{-1}. This causes the electron to undergo uniform circular motion.

Calculate the radius of the electron's path.

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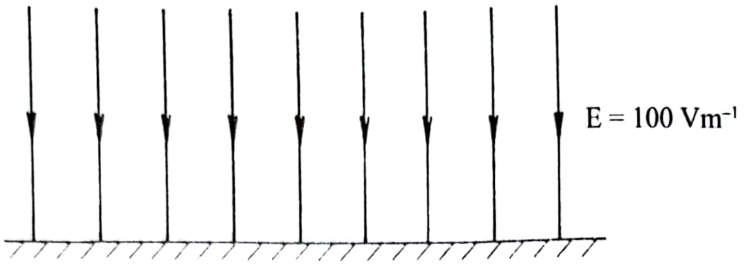
2014 HSC Q28(b) – 3 marks

26. The electric field near the Earth's surface may be taken to have a magnitude of 100 V m^{-1} and is directed downwards (see diagram below).



(a) Determine the potential difference between ground level and a point 2.0 m above the ground in this field.

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(b) A dust particle, mass 1.0×10^{-8} kg, carrying a charge of -1.0×10^{-9} C. is placed near the Earth's surface. Calculate the ratio of the electrical to the gravitational force acting on this particle.

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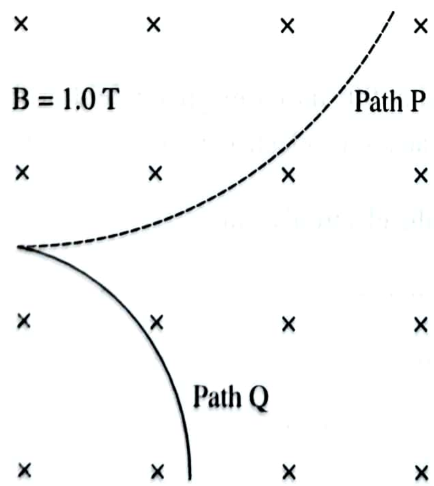
1990 HSC Q16 – 3 marks

27. The diagram shows the paths taken by two moving charged particles when they enter a region of uniform magnetic field.



(a) Why do the paths curve in different directions? **1**

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Question 27 continues

Question 27 (continued)

(b) Why are the paths circular? **2**

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(c) How do the properties of a particle affect the radius of curvature of its path in a uniform magnetic field? **2**

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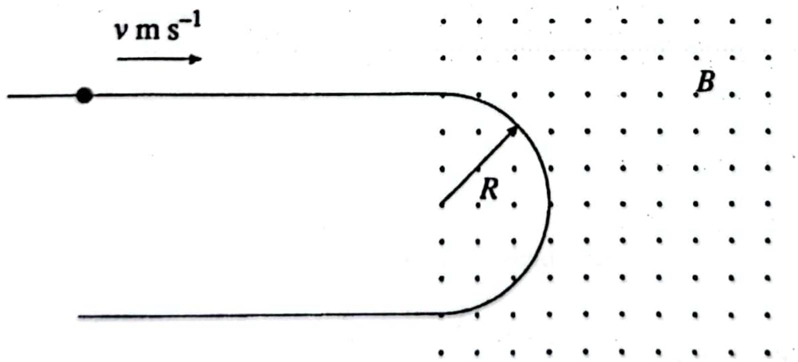
End of Question 27

2012 HSC Q30 – 5 marks

28. A proton is projected with a velocity of v m s^{-1} into a uniform magnetic field of flux density B tesla. The field is directed out of the page as shown.



The proton travels along a semicircular path and then leaves the region of the magnetic field.

(a) Explain why the path in the magnetic field has the shape shown.

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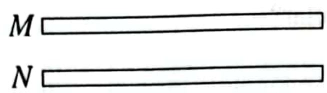
(b) The magnetic flux density is now halved, without reducing the region or space covered.

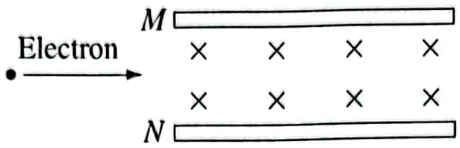
Sketch the path of the proton on the diagram above.

1996 HSC Q24 (adapted) – 3 marks

29. An electric field is produced between two charged parallel plates, M and N.



The potential difference is now changed and a magnetic field of 0.5 T is placed perpendicular to the plates, as shown in the diagram below.



Determine the magnitude and direction of the electric field required to allow the electron to travel through undeflected, if the electron is moving at 1×10^4 m s^{-1}.

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2013 HSC Q26(b) – 3 marks

Answers

Module 6: Electromagnetism

6.1 Charged Particles, Conductors and Electric and Magnetic Fields

Multiple choice: 1 mark each

1. D	**2.** C	**3.** C	**4.** D	**5.** A	**6.** C	**7.** C	**8.** D
9. A	**10.** B	**11.** C	**12.** A	**13.** C	**14.** D	**15.** C	**16.** A
17. C	**18.** A	**19.** C	**20.** A	**21.** B			

Explanations:

1. **D** $E = \frac{V}{d} = \frac{100\text{ V}}{1 \times 10^{-3}\text{ m}} = 10^5\text{ V m}^{-1}$ … as in (D).

2. **C** Field strength, $E = \frac{V}{d} = \frac{50\ V}{0.01\ m} = 5000\text{ V m}^{-1}$
If the field strength is doubled, $E = 10{,}000\text{ V m}^{-1}$
Only the values in (C) and (B) give this value for when E is doubled.
However, perspex is not a conductor. So (B) is incorrect and (C) is the answer.

3. **C** Force on a charged particle moving in an electric field is given by: $F = qE$. The charge (q) on an electron and that on a proton are the same in magnitude, but opposite in sign. The same electric field strength (E) will result in an equal force causing deflection of electrons towards the left and protons towards the right. However, the mass of a proton is around $\times 2000$ the mass of an electron, and since the acceleration, $a = \frac{F}{m}$, therefore the deflection will be much less. So the proton will hit the screen closest to (C). A positron, not a proton, would hit at (D). Positive particles will hit to the right of P. So (A) and (B) are incorrect.

4. **D** The electric field is defined in terms of the direction of the force on a positive particle. Since the electric field is upward, the force on a positive particle would be upward. So an electron, having a negative charge, would experience a downward force, as in (D).

5. **A** The direction of the force is given by using either the Right Hand Palm Rule or Fleming's Left Hand Rule or the Right Hand Motor Rule. All these rules give the direction of force to the right, as in (A).

[Note: The direction of conventional current is the motion of a positive charge – up the page in this case. The direction of the force must be perpendicular to both the magnetic field and the direction of motion of the charged object.]

6. **C** Force in a magnetic field, $F = qvB \sin\theta$. So F is affected by both the strength of the magnetic field, B, and the magnitude of the charge on the particle, q, so (A) and (B) are incorrect. A velocity component that is perpendicular to the magnetic field results in $\sin\theta = 1$ and so affects the magnetic field, whereas one that is parallel does not affect the magnetic field as it results in $\sin\theta = 0$. So (D) is incorrect and (C) is the answer.

7. **C** Were the electron to be moving either parallel to the electric current or opposite to it, the electron would not be crossing the magnetic field – so it would experience no force. So (A) and (B) are incorrect. For the electron to experience a force parallel to the wire, its motion must be perpendicular to both the magnetic field and to the wire, as in both (C) and (D). Using the RH palm rule (and remembering that the electron is a *negative* particle so its motion is opposite to conventional current) it is found that the electron must initially move *towards* the wire and *perpendicular* to it, as in (C) and not (D).

8. **D** $F = qvB \sin\theta = m\frac{v^2}{r}$

$$r = \frac{mv^2}{qvB \sin\theta} = \frac{mv}{qB \sin\theta} = \frac{9.109\times10^{-31}\times8.0\times10^{6}}{1.602\times10^{-19}\times2.1\times10^{-2}\times\sin 90} = 2.166\times10^{-3} \text{ m s}^{-1}$$

$\therefore$ radius is 2.2×10^{-3} m s^{-1}, as in (D).

[Note: B is indicated as being into the page (×) and v is in the plane of the page, so θ is 90°. The angle 40° shown on the diagram indicates a direction and not the angle between the velocity and the magnetic field.]

9. **A** The electric field between two parallel, charged plates will be uniform and the field shows the direction of the force on a positive charge at any point. So the electric field will point away from the positive plate towards the negative plate, as in (A). Hence (C) is incorrect. Both (B) and (D) incorrectly show the field being parallel to the charged plates.

10. **B** $F = qvB \sin\theta$ and $F = \frac{mv^2}{r}$

$\therefore qvB = \frac{mv^2}{r}$ ($\theta = 90°$, so $\sin\theta = 1$), so $r = \frac{mv}{qB}$

So, if B is doubled then r will be halved. So (B) is the answer.

11. **C** The direction of the conventional current is to the right (as the positive particle is moving to the right). The direction of the uniform force, as given by the Right Hand Palm Rule is to the right of the velocity and perpendicular to the velocity, so the motion will follow an even curve. So (C) is the answer and (B) is incorrect as it shows a force to the left of the velocity, not to the right. (A) shows no force acting and (D) shows as a non-uniform force to the left, so (A) and (D) are incorrect.

12. A The motion of the electron is circular with the force at all times perpendicular to the velocity. Therefore there is zero change in the electron's energy. So the answer is (A) and not (B), (C) or (D).

13. C $F = qvB \sin\theta = 1.602 \times 10^{-19} \times 4.0 \times 10^{6} \times 0.5 \times 1$

$= 3.204 \times 10^{-13}$ N ... as in (C).

14. D Cathode rays consist of negative electrons (e^-). Using the right-hand palm rule: × shows magnetic field goes into page, thumb points to opposite direction of e^- movement, so direction of force due to magnetic field is down the page (↓). This will deflect the cathode ray down the page. The applied electric field must balance this by an upward force on the e^-. So electric field must be directed down the page (↓), for the negative e^- to experience an upward force. So (D) is the answer.

15. C $F = ma = \frac{mv^2}{r} = qvB$. So $r = \frac{mv^2}{vqB} = \frac{mv}{qB}$. However, r for both particles remains the same for the two particles to follow the same path. If velocity is halved to $\frac{v}{2}$ and B is doubled to $2B$, r would become $(\frac{m}{q})(\frac{v}{4B})$. So if r is to remain constant, $\frac{m}{q}$ needs to be 4 times what it was before, i.e. $4m$ and q ... as in (C).

16. A (A) is correct because the magnetic field is down the page, velocity to the right and charge on the particle is negative. (C) is incorrect because no force acts on a stationery particle. (B) and (D) are incorrect because there is no net magnetic force at F.

[Note: To answer this question, it is best to firstly draw the lines of the magnetic field onto the diagram.]

17. C Force on a charged particle moving in a magnetic field is given by: $F = qvB \sin\theta$. Charge (q) on a proton does not vary. Magnetic field strength (B) is the same in each case. Force is zero in (A) and (B), since v is zero in (A) and $\sin\theta = 0$ in (B) as v and B are parallel. In (C), $F = q40B \sin 90° = 40qB$ newtons. In (D), $F = q50B \sin 45° = 35.4qB$ newtons. So the greatest force is in (C).

18. A $F = Bqv = 0.48 \times 1.602 \times 10^{-19} \times 2.5 = 1.92 \times 10^{-19}$. This value is given in (A) and (B). The right-hand rule is used to give the direction remembering that the electron is negative. This shows that the force will be to the left. So (A) is the answer.

19. C The electric field force is given as: $F_E = Eq$. So F_E is independent of any relative motion between the electron and electric field. The magnetic field force is given as: $F_m = qvB \sin\theta$. If there is no relative motion between the electron and the constant magnetic field, $v = 0$ and so $F_m = 0$. Hence only the electric field will exert a force, as in (C).

20. **A** Force 1: $F_1 = qE = q\frac{V}{d}$

Force 2: $F_2 = qvB$

So, for the beam to remain undeflected:

$$qvB = q\frac{V}{d}$$

$$vB = \frac{V}{d}$$

$$2 \times 10^6 \times B = \frac{V}{1 \times 10^{-3}}$$

$$B = \frac{1000}{1 \times 10^{-3} \times 2 \times 10^6} = 0.5$$

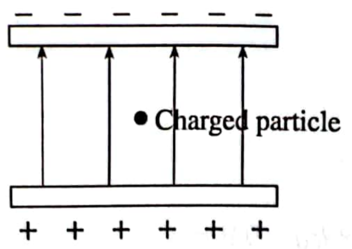
$= 5 \times 10^{-1}$ T into the page … as in (A)

21. **B** Force on the electron is: $F = qvB$. So, if v increases, then F increases, as in (A) and (B).

The force on the electron provides the centripetal acceleration: $F_c = \frac{mv^2}{r}$.

So, if v increases, r also increases … as in (B), but not (A). So (B) is the answer.

22. (a)



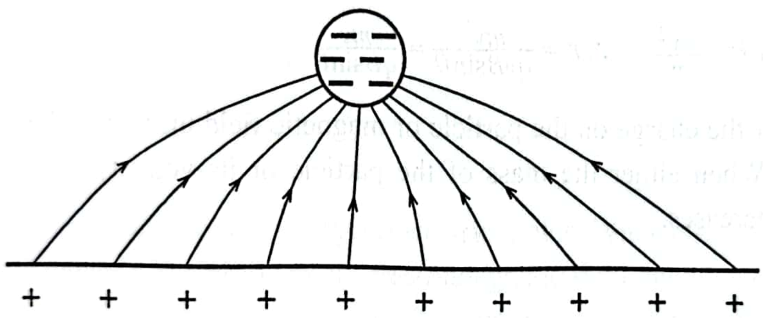
(b) $E = \frac{V}{d} = \frac{49}{0.02} = 2450 \text{ V m}^{-1}$

(c) To remain motionless, weight force downwards = electrostatic force upwards,

i.e. $mg = qE$

$\therefore q = \frac{mg}{E} = \frac{9.6 \times 10^{-6} \times 9.8}{2450} = 3.84 \times 10^{-8} \text{ C}$

23. (a)



(b) $F = ma$ so $F = 1\times10^{-30}\text{kg}\times7.0\times10^{21}\text{m s}^{-2}$ $\therefore$ $F = 7.0\times10^{-9}$ N

$\therefore E = \frac{F}{q} = \frac{7.0\times10^{-9}\text{ N}}{+6\times10^{-12}\text{ C}} = 1.1666\times10^{3} = 1.2\times10^{3}\text{N C}^{-1}$ directed towards the cylinder

24. (a) Yes – X is at a higher potential than Y. This is because work is done when moving from Y to X as it is against the field.

(b) No – Z and Y have the same potential. This is because no work is done in moving from Y to Z as this movement is perpendicular to the electric field.

(c) The force on an electron is opposite to the field, as an electron is negatively charged. Therefore its potential is increased as it moves from X to Y.

25. $F = qvB\sin\theta = \frac{mv^2}{r}$ So $r = \frac{mv^2}{qvB\sin\theta} = \frac{mv}{qB\sin\theta}$

$\therefore$ radius, $r = \frac{9.109\times10^{-31}\times1\times10^{7}}{1.602\times10^{-19}\times9\times10^{-4}}$

$= 0.063$ m

$= 6.3$ cm

26. (a) $E = \dfrac{V}{d}$

$V = Ed$

$= 100 \text{ V m}^{-1} \times 2 \text{ m}$

$= 200 \text{ V}$

(b) $F_E : F_g = qE : mg$

$= 1.0 \times 10^{-9}\, C \times 100\, V\, m^{-1} : 1.0 \times 10^{-8}\, kg \times 9.8\, m\, s^{-2}$

$= 1.0 \times 10^{-7} : 9.8 \times 10^{-8}$

$= 1.0 : 0.98$

$\approx 1:1$

27. (a) They have opposite electrical charges.

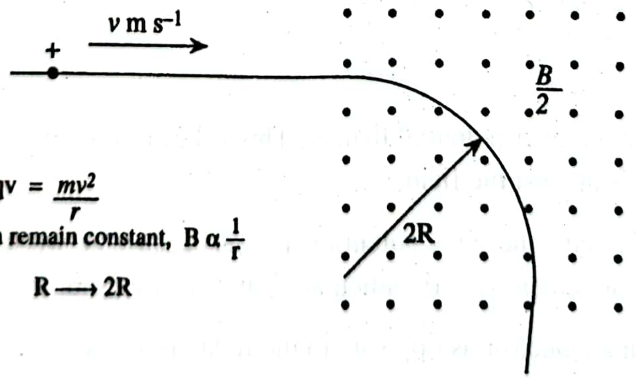
(b) The force is at 90° to both the magnetic field and the direction of motion. This gives centripetal acceleration to the particle, so that it follows a circular path.

(c) $F = qvB\sin\theta = \dfrac{mv^2}{r} \quad \therefore r = \dfrac{mv^2}{qvB\sin\theta} = \dfrac{mv}{qB\sin\theta}$

When either the charge on the particle or magnetic field increases, the radius of curvature decreases. When either the mass of the particle or its velocity increases, the radius of curvature increases.

28. (a) When a charged particle such as a proton (+ charge) enters a magnetic field, it is acted on by a force. This force is at right angles to the direction of the magnetic field and to its instantaneous direction of motion. So its path is the arc of a circle while in the field.

(b)



NOTE: $F = Bqv = \dfrac{mv^2}{r}$

Since q, v and m remain constant, $B \propto \dfrac{1}{r}$

$\therefore$ **If** $B \longrightarrow \dfrac{B}{2} \quad R \longrightarrow 2R$

29. Magnetic force, $F = qvB\sin\theta$

So $F = 1.602 \times 10^{-19} \times 1 \times 10^4 \times 0.5 \times \sin 90 = 8.01 \times 10^{-16}$ N from M to N.

If undeflected, the electrostatic force will be equal and opposite to the magnetic force.

$\therefore F = Eq = 8.01 \times 10^{-16}$ N

$\therefore$ Magnitude of electric field, $E = \dfrac{F}{q} = \dfrac{8.01 \times 10^{-16}}{1.602 \times 10^{-19}} = 5000 \text{ V m}^{-1}$ from M to N.