Unit 2 : PARTICLES & WAVES

Forces on Charged Particles

Electric Fields

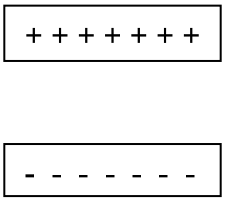
1. Draw the electric field patterns surrounding each arrangement of charges:

(a)

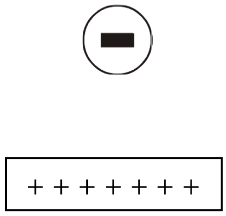
(b)

(c)

(d)



(e)

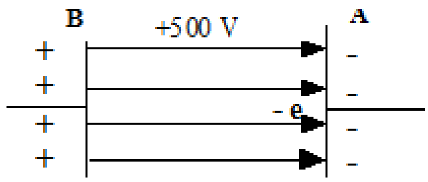


2. An electron volt (eV) is a unit of energy. It represents the change in potential energy of an electron that moves through a potential difference of 1 V (the size of the charge on an electron is $1{\cdot}6 \times 10^{-19}$ C).
   What is the equivalent energy of 1 eV in joules?

3. An electron has energy of 5 MeV. Calculate its energy in joules.

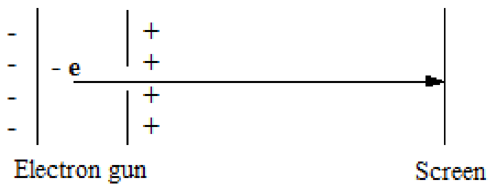
4. The diagram shows an electron accelerating between two parallel conducting plates A and B.

   The p.d. between the plates is 500 V.
   (mass of electron = $9{\cdot}1 \times 10^{-31}$ kg
   charge on electron = $1{\cdot}6 \times 10^{-19}$ C)



   (a) Calculate the electrical work done in moving the electron from plate A to plate B.
   (b) How much kinetic energy has the electron gained in moving from A to B?
   (c) What is the speed of the electron just before it reaches plate B?

5. An electron gun in a cathode ray oscilloscope uses a high voltage to accelerate electrons.



   (a) How much energy does an electron have if the accelerating voltage is 2.0 kV?

   (b) Calculate the speed of the electron just before it hits the screen.

6. The charge on a proton is $1{\cdot}6 \times 10^{-19}$ C and its mass is $1{\cdot}7 \times 10^{-27}$ kg. What is the resulting velocity when a proton is accelerated between two plates if the potential difference is 12 kV?

7. What is the accelerating voltage in an electron gun if each electron leaves the gun with a kinetic energy of $1{\cdot}2 \times 10^{-12}$ J?

8. What accelerating voltage is required in an electron gun to give electrons a velocity of $5{\cdot}0 \times 10^{6}$ ms^{-1}?

9. In an X-ray tube electrons forming a beam are accelerated from rest and strike a metal target. The metal then emits X-rays. The electrons are accelerated across a potential difference of 25 kV. The beam of electrons forms a current of 3·0 mA.

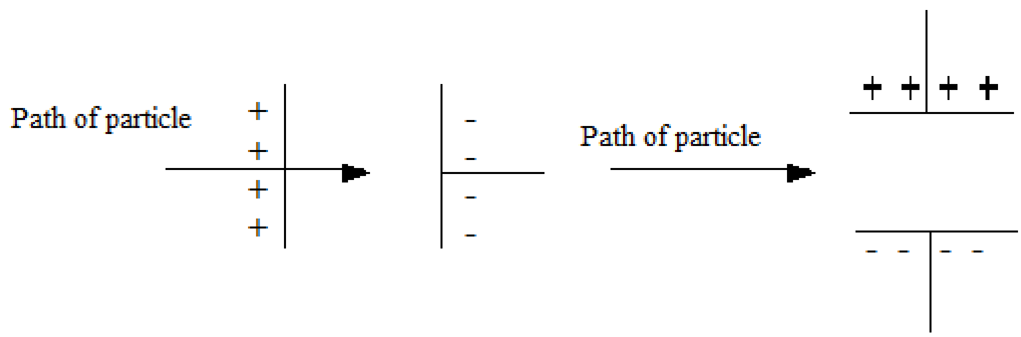
   (a) Calculate the kinetic energy of each electron just before it hits the target.

   (b) Calculate the speed of an electron just before it hits the target.

   (c) Find the number of electrons hitting the target each second.

   (d) What happens to the kinetic energy of the electrons?

10. Sketch the paths which an alpha-particle, a beta-particle and a neutron would follow if each particle, with the same velocity, enters the electric fields shown in the diagrams below.



Magnetic Fields

11. An electron travelling with a constant velocity enters a region where there is a uniform magnetic field. There is no change in the velocity of the electron. What information does this give about the magnetic field?

Higher Physics

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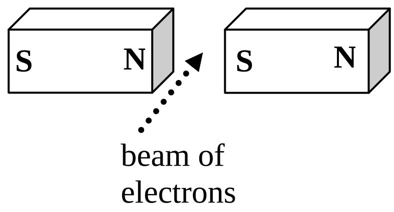
12. The diagram shows a beam of electrons as it enters the magnetic field between two magnets.

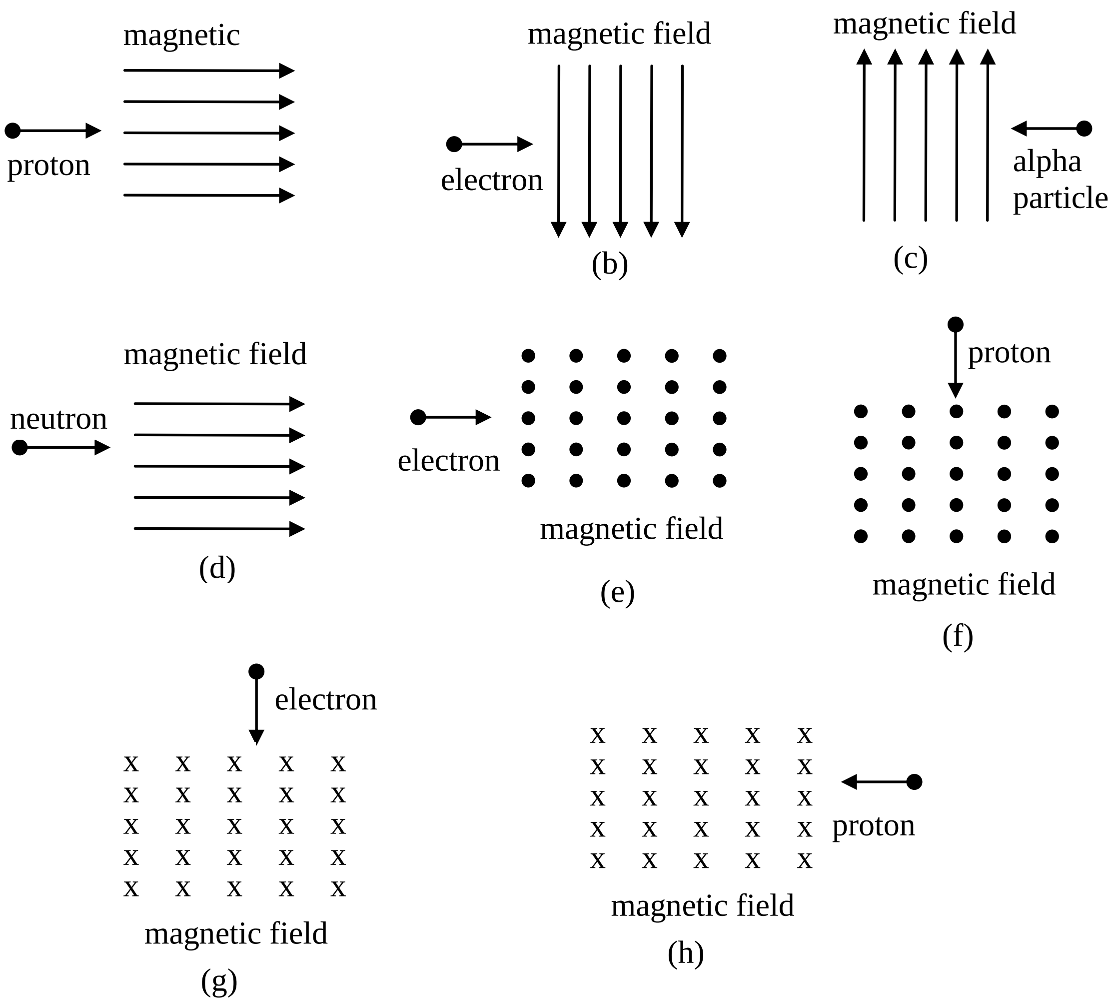


The electrons will:

A be deflected to the left (towards the N pole)
B be deflected to the right (towards the S pole)
C be deflected upwards
D be deflected downwards
E have their speed increased without any change in direction.

13. The diagrams show particles entering a region where there is a uniform magnetic field.

Use the terms: ***up, down, into the paper, out of the paper, left, right, no change in direction*** to describe the deflection of the particles in the magnetic field.



14. An electron enters a region of space where there is a uniform magnetic field. As it enters the field the velocity of the electron is at right angles to the magnetic field lines.
    The energy of the electron does not change although it accelerates in the field.
    Use your knowledge of physics to explain this effect.

Particle Accelerators

15. A linear accelerator is used to accelerate a beam of electrons, initially at rest, to high speed in an evacuated container. The high-speed electrons then collide with a stationary target. The accelerator operates at 2·5 kV and the electron beam current is 3 mA.

    (a) Calculate the gain in kinetic energy of each electron.
    (b) Calculate the speed of impact of each electron as it hits the target.
    (c) Calculate the number of electrons arriving at the target each second.
    (d) Give a reason for accelerating particles to high speed and allowing them to collide with a target.

16. The power output of an oscilloscope (cathode-ray tube) is estimated to be 30 W. The potential difference between the cathode and the anode in the evacuated tube is 15 kV.

    (a) Estimate the number of electrons striking the screen per second.
    (b) Calculate the speed of an electron just before it strikes the screen, assuming that it starts from rest and that its mass remains constant.

17. In an X-ray tube a beam of electrons, initially at rest, is accelerated through a potential difference of 25 kV. The electron beam then collides with a stationary target. The electron beam current is 5 mA.

    (a) Calculate the kinetic energy of each electron as it hits the target.
    (b) Calculate the speed of the electrons at the moment of impact with the target assuming that the electron mass remains constant.
    (c) Calculate the number of electrons hitting the target each second.
    (d) What happens to the kinetic energy of the electrons?

18. In an oscilloscope electrons are accelerated between a cathode and an anode and then travel at a constant speed towards a screen. A p.d. of 1000 V is maintained between the cathode and anode. The distance between the cathode and anode is $5{\cdot}0 \times 10^{-2}$ cm. The electrons are at rest at the cathode and attain a speed of $1{\cdot}87 \times 10^{7}$ ms^{-1} on reaching the anode. The tube is evacuated.

(a) (i) Calculate the work done in accelerating an electron from the cathode to the anode.

(ii) Show that the average force on the electron in the electric field is $3{\cdot}20 \times 10^{-15}$ N.

(iii) Calculate the average acceleration of an electron while travelling from the cathode to the anode.

(iv) Calculate the time taken for an electron to travel from cathode to anode.

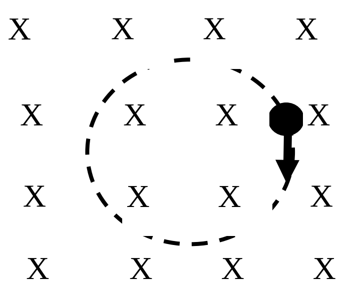
(v) Beyond the anode the electric field is zero. The anode to screen distance is 0·12 cm. Calculate the time taken for an electron to travel from the anode to the screen.

(b) Another oscilloscope has the same voltage but a greater distance between cathode and anode.

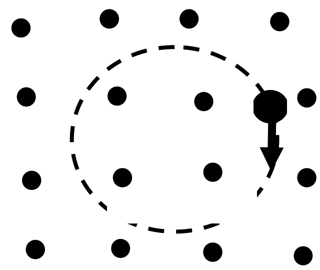
(i) Would the speed of the electrons be higher, lower or remain at $1{\cdot}87 \times 10^{7}$ ms^{-1}? Explain your answer.

(ii) Would the time taken for an electron to travel from cathode to anode be increased, decreased or stay the same as in (a) (iv)? Explain your answer.

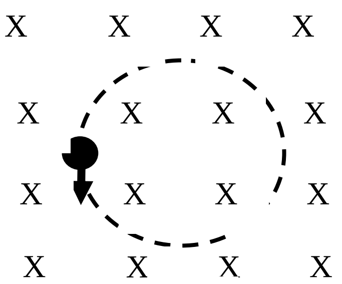
19. In the following examples identify the charge of particle (positive or negative) which is rotating in a uniform magnetic field. (X denotes magnetic field into page and • denotes magnetic field out of page.)



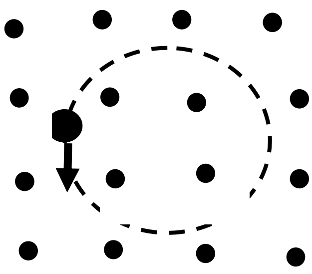
(a)



(b)



(c)



(d)

20. In the following passage about particle accelerators, some words and phrases have been replaced by the letters A to R.

In a linear accelerator bunches of charged particles are accelerated by a series of ____**A**____. The final energy of the particles is limited by the length of the accelerator. This type of accelerator is used in ____**B**____ experiments.

In a cyclotron the charged particles are accelerated by ____**C**____. The particles travel in a ____**D**____ as a result of a ____**E**____, which is ____**F**____ to the spiral. The radius of the spiral increases as the energy of the particles ____**G**____. The diameter of the cyclotron is limited by the ____**H**____ of the magnet. The resultant energy of the particles is limited by the diameter of the cyclotron and by ____**I**____.

This type of accelerator is used in ____**J**____ experiments.

In a synchrotron bunches of charged particles travel in a ____**K**____ as a result of C shaped magnets whose strength ____**L**____. The particles are accelerated by ____**M**____. As the energy of the particles increases the strength of the magnetic field is ____**N**____ to maintain the radius of the path of the particles. In synchrotron accelerators the particles can have, in theory, an unlimited series of accelerations as the particles can transit indefinitely around the ring. There will be a limit caused by ____**O**____.

In this type of accelerator particles with ____P____ mass and ____**Q**____ charge can circulate in opposite directions at the same time before colliding. This increases the energy of impact. This type of accelerator is used in ____**R**____ experiments.

From the table on the next page choose the correct words or phrases to replace the letters.

Letter	*List of replacement word or phrase*
A, C, E, M	constant magnetic field, alternating magnetic fields, alternating electric fields, constant electric fields
B, J, R	colliding-beam, fixed-target
D, K	spiral of decreasing radius, spiral of increasing radius, circular path of fixed radius
F	perpendicular, parallel
G	decreases, increases
H	physical size, strength
I, O	gravitational effects, relativistic effects
L	can be varied, is constant
N	decreased, increased
P, Q	the same, different