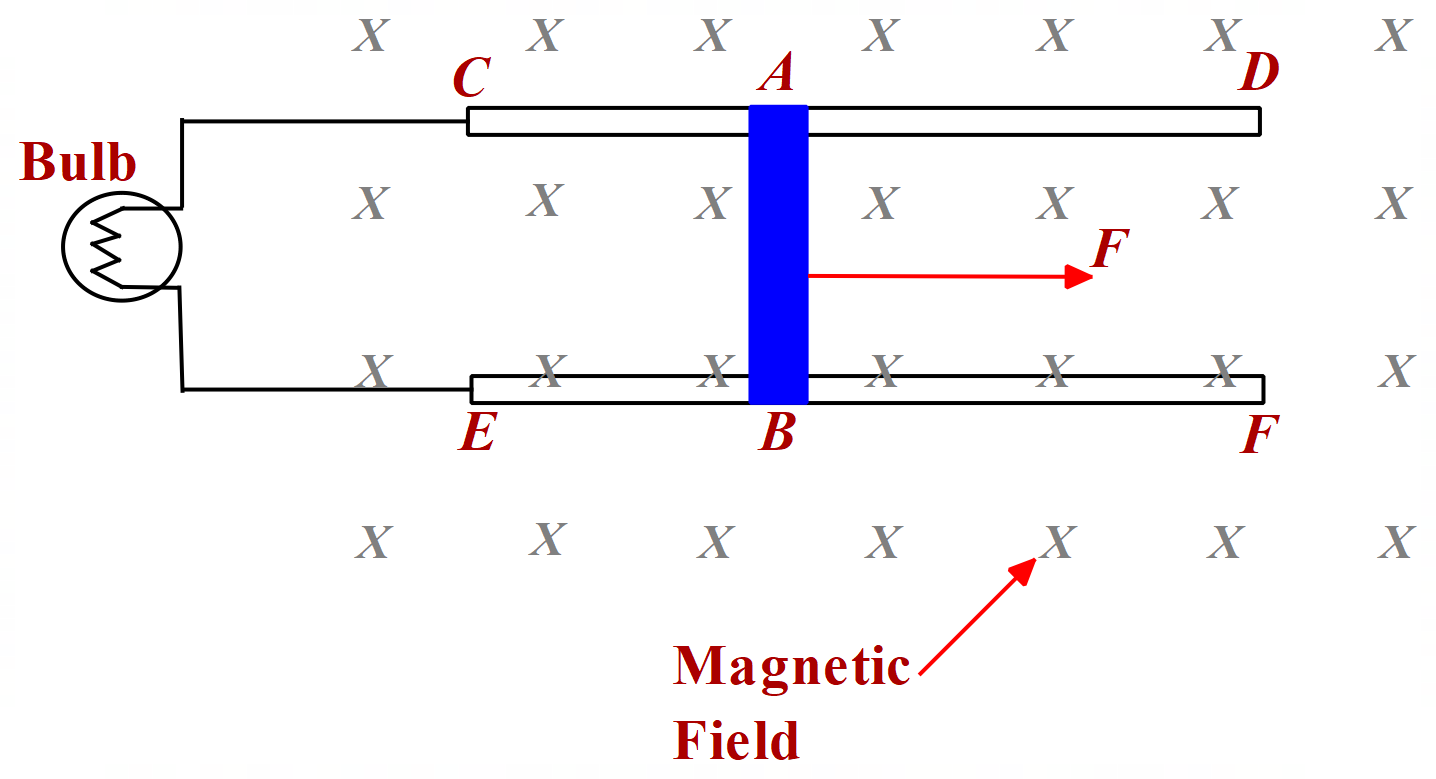
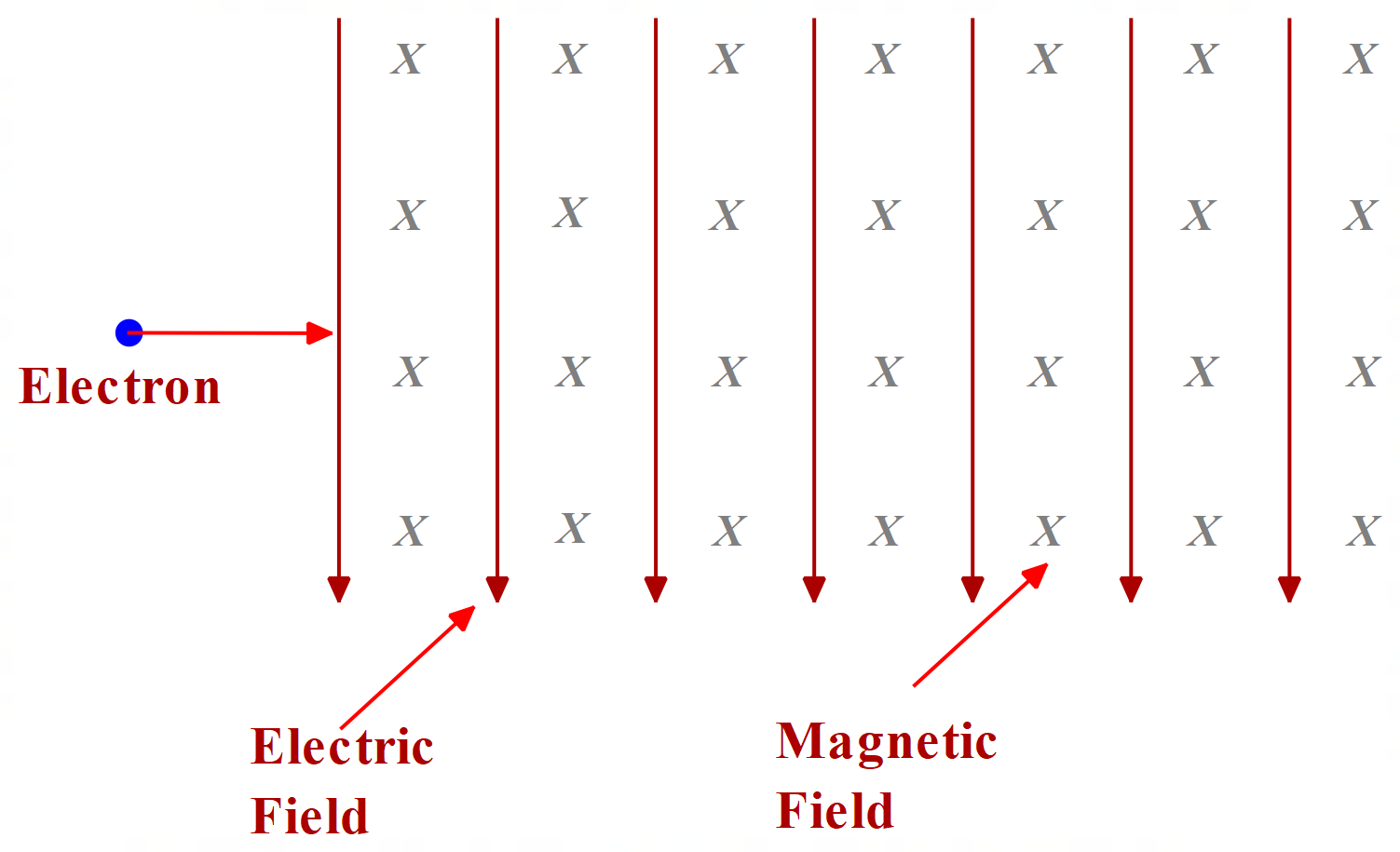
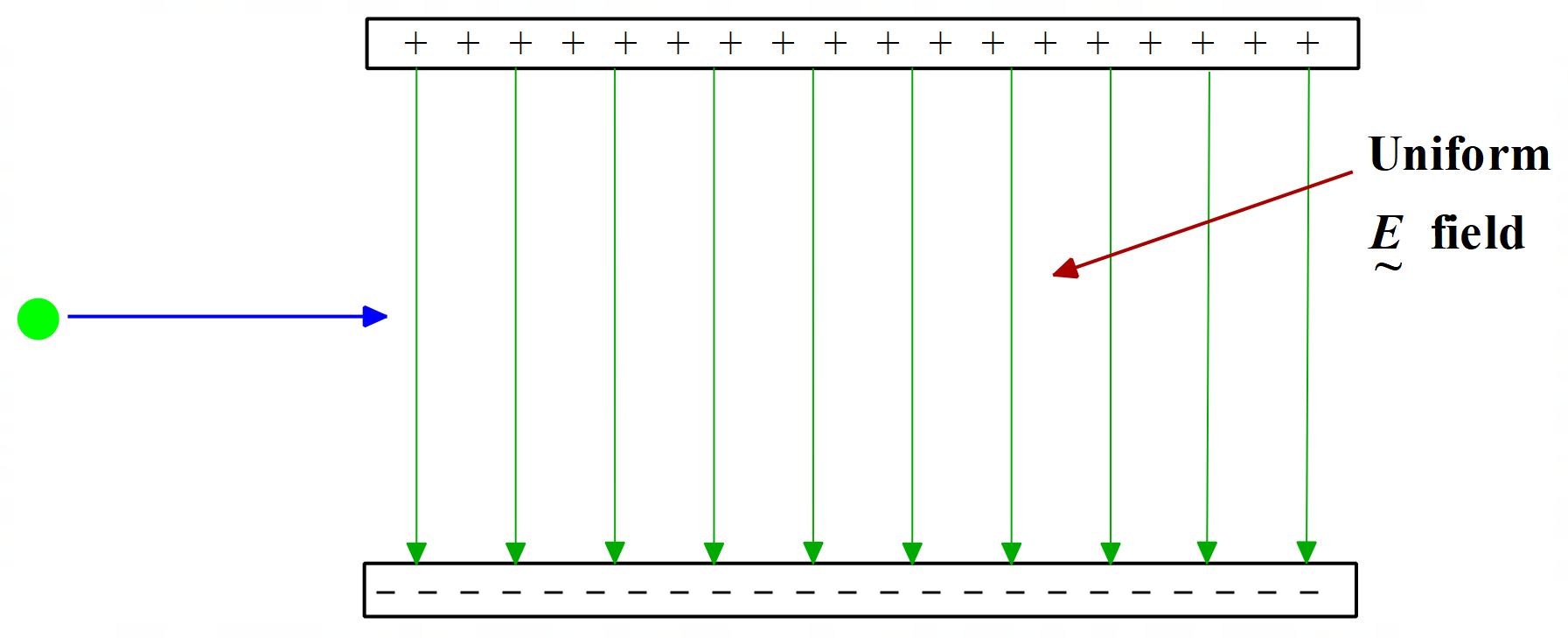
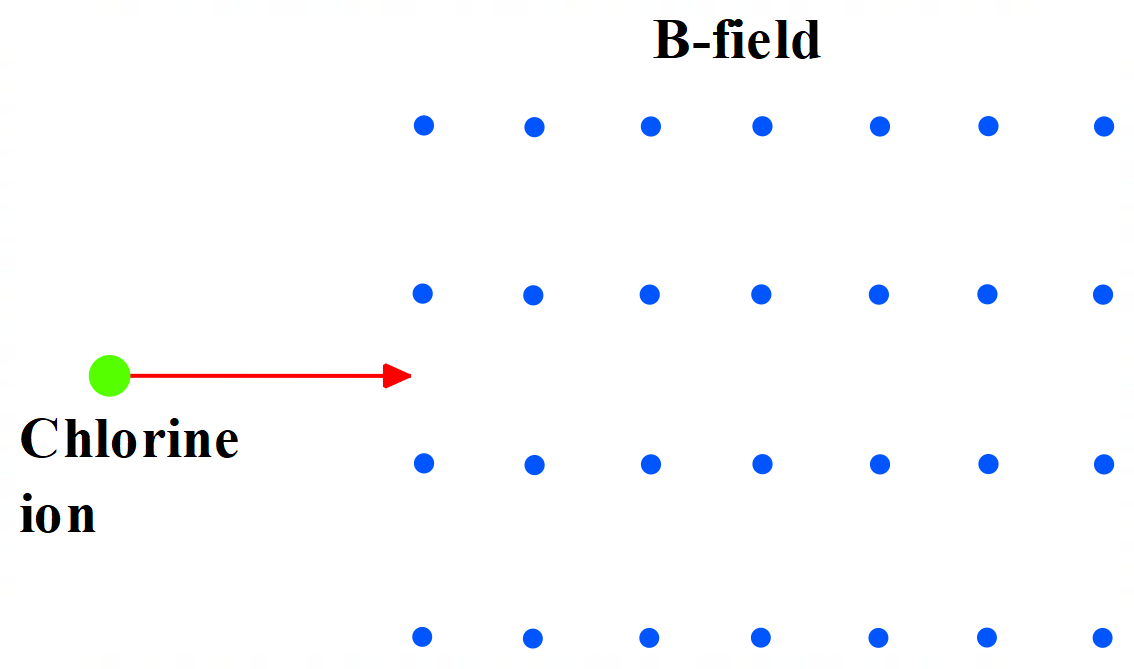
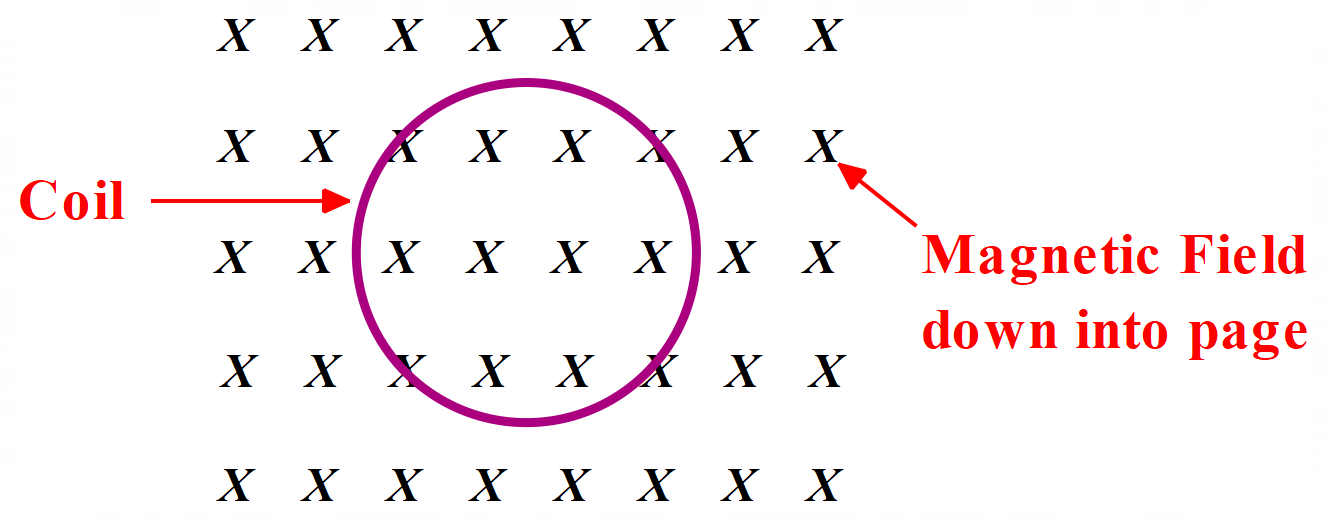
**Questions & Problems on Module 6  
  
Solutions are supplied at the end of the questions.**

1. Examine the diagram below.  
     
    Icon

   Description automatically generated  
    Diagram From: [Wikimedia Commons](https://www.google.com/search?q=wikimedia+commons+diagram+split+ring+commutator&rlz=1C1GCEU_enAU874AU874&tbm=isch&source=iu&ictx=1&fir=QoeZ9Ja-erE2fM%252CnUEuedopYG0IfM%252C_&vet=1&usg=AI4_-kS5ozXbjaI7qqXj57V78v2nQJ-NHg&sa=X&ved=2ahUKEwj2_t_qitjwAhWDYisKHfncAZoQ9QF6BAgGEAE#imgrc=nyQx21Dq1sAp1M)  
     
   Identify this electric circuit component and outline its purpose.
2. A copper bar AB, 1.3 m long, is pulled along two smooth metallic rods CD and EF at a constant speed of 3.0 ms-1 by a constant force, F. A light bulb is connected between C and E as shown in the diagram below, and the magnetic field of 0.35 T is directed into the page.  
     
      
   1. Calculate the emf induced between A and B.
   2. Assuming that the resistance of the bulb is 2.0 W, determine the magnitude and direction of the current passing through the bulb. Assume that the copper bar, rods CD and EF and the connecting wires have negligible resistance.
   3. Calculate the magnitude of the force F.
3. An electron moving horizontally at 104 ms-1 enters a vertical electric field which is crossed at right angles by a magnetic field of induction 0.1 T. The electron travels initially at right angles to the magnetic field, as shown in the following diagram.  
     
     
     
     
     
   1. Write an expression for the acceleration of the electron due to the magnetic field.
   2. If the electron passes through the crossed fields undeflected calculate the strength of the electric field.
   3. What electric field strength would be required to balance the effect of gravity on the electron?
   4. Express the tesla in terms of fundamental SI units.
4. A transformer with 200 turns of wire in its primary coil is connected to an AC supply of 240 V and 5 A. It produces an output voltage across its secondary coil of 1200 V. Assuming the transformer is ideal (ie 100% efficient – no power loss), calculate:  
   1. The number of turns in the secondary.
   2. The current flowing in the secondary.
5. Consider the diagram below of a rectangular coil of 1 turn of wire sitting in and parallel to a uniform magnetic field directed from left to right as shown. When this coil is attached to a DC power supply (not shown) the current in the coil is as shown.  
     
      
   1. Identify the direction of the force on the arm AB of the coil.
   2. Identify the direction of the force on arm BC of the coil.
   3. The current in the coil is 2 A. BC = 0.4 m. AB = 0.5 m. The magnetic flux density is 0.25 T. Calculate the magnitude of the torque on the coil.
   4. Describe the motion of the coil if it was not attached to a split ring commutator.
6. The armature windings of a DC motor have a resistance of 5.0 W. The motor is connected to a 120 V line, and when the motor reaches full speed against its normal load, the back emf is 108 V. Calculate:  
     
   (a) the current into the motor when it is just starting up; and  
     
   (b) the current when the motor reaches full speed.
7. The force per unit length between two parallel wires 1 cm apart is 10-4 Nm-1 attractive. If one of the wires carries a current of 5 A, find the current in the other wire. Are the currents in the wires flowing in the same direction or in opposite directions? Justify your answer.
8. A proton enters the area between charged plates horizontally and at right angles to the uniform electric field as shown in the diagram below.  
     
     
     
     
     
     
     
     
     
     
   The electric field intensity is 2.0 NC-1. The charge on the proton is 1.6 x 10-19 C.  
   1. Draw a diagram showing the trajectory of the proton once it enters the electric field. Draw and label a vector to represent the force **F** acting on the proton in the E-field. Assume the proton is travelling slowly enough so that it does not pass completely through the electric field and out the other side.
   2. Calculate the magnitude of the force acting on the proton due to the electric field.
   3. Describe the trajectory of the proton in the electric field and use mathematics to justify your description.
   4. Briefly compare the trajectory determined in (c) above to that of an uncharged particle falling in a uniform gravitational field.
   5. Describe the trajectory of the proton if it had entered the electric field parallel to the field lines.
   6. If the proton travels a vertical distance of 0.01 m from the time it enters the field to the time it strikes a charged plate, calculate the work done by the field on the proton.
   7. Given the mass of a proton is 1.67 x 10-27 kg, calculate the vertical velocity with which the proton strikes the charged plate.
9. A chlorine ion (Cl-) of mass 5.8 x 10-26 kg, enters a uniform magnetic field of 1.74 x 10-2 T, at a speed of 9.6 x 102 ms-1, as shown below. The field direction is vertically up out of the plane of the page. (For those who do not do Chemistry, and cannot remember from Junior School Science, a chlorine ion is negatively charged. The charge on the ion is equal to one electronic charge.)



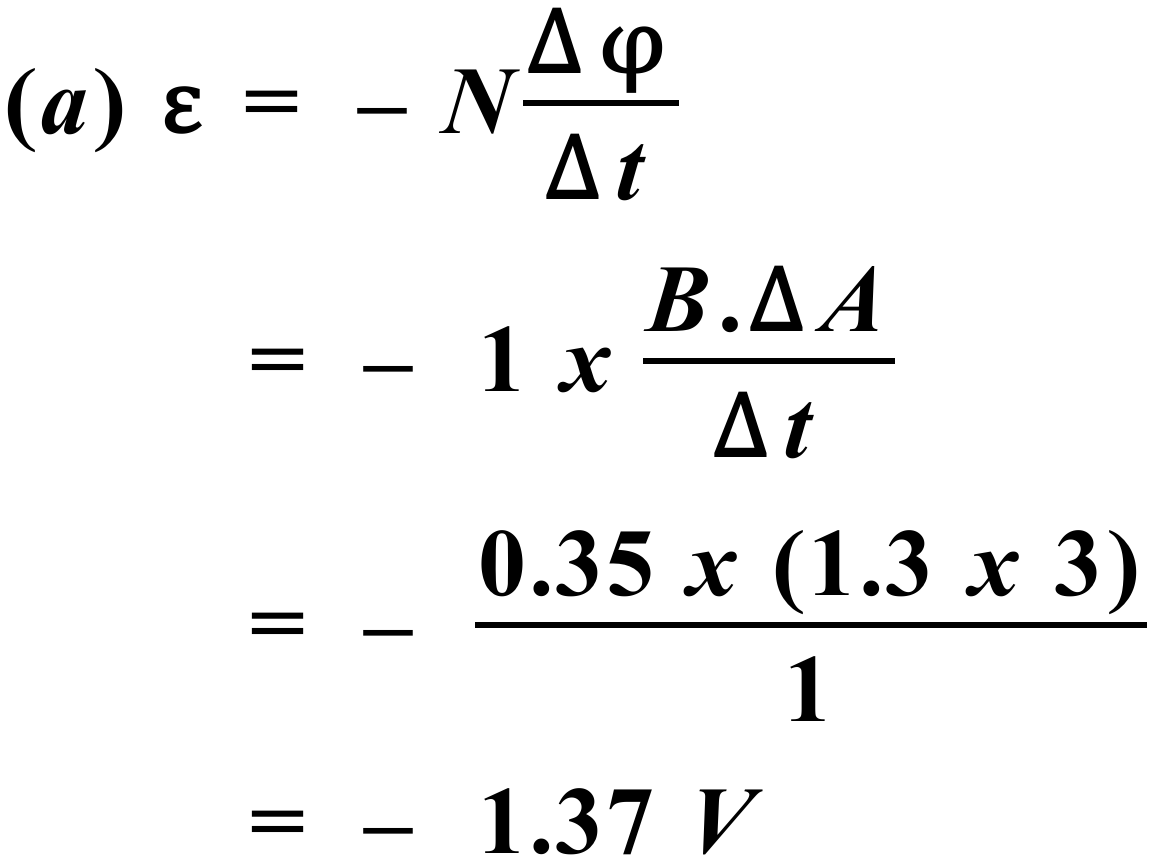
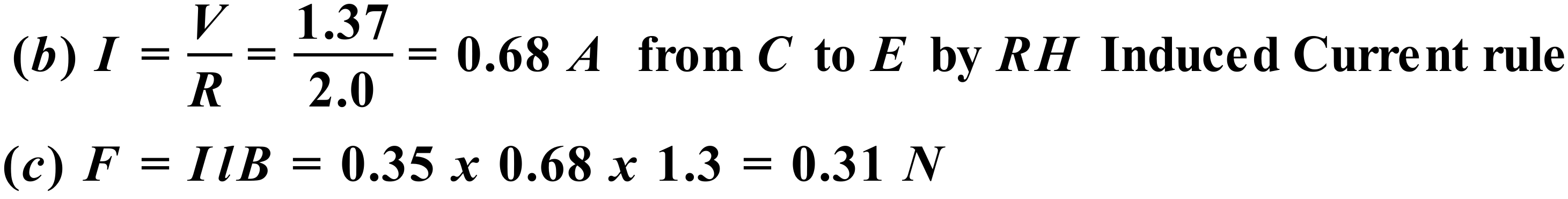
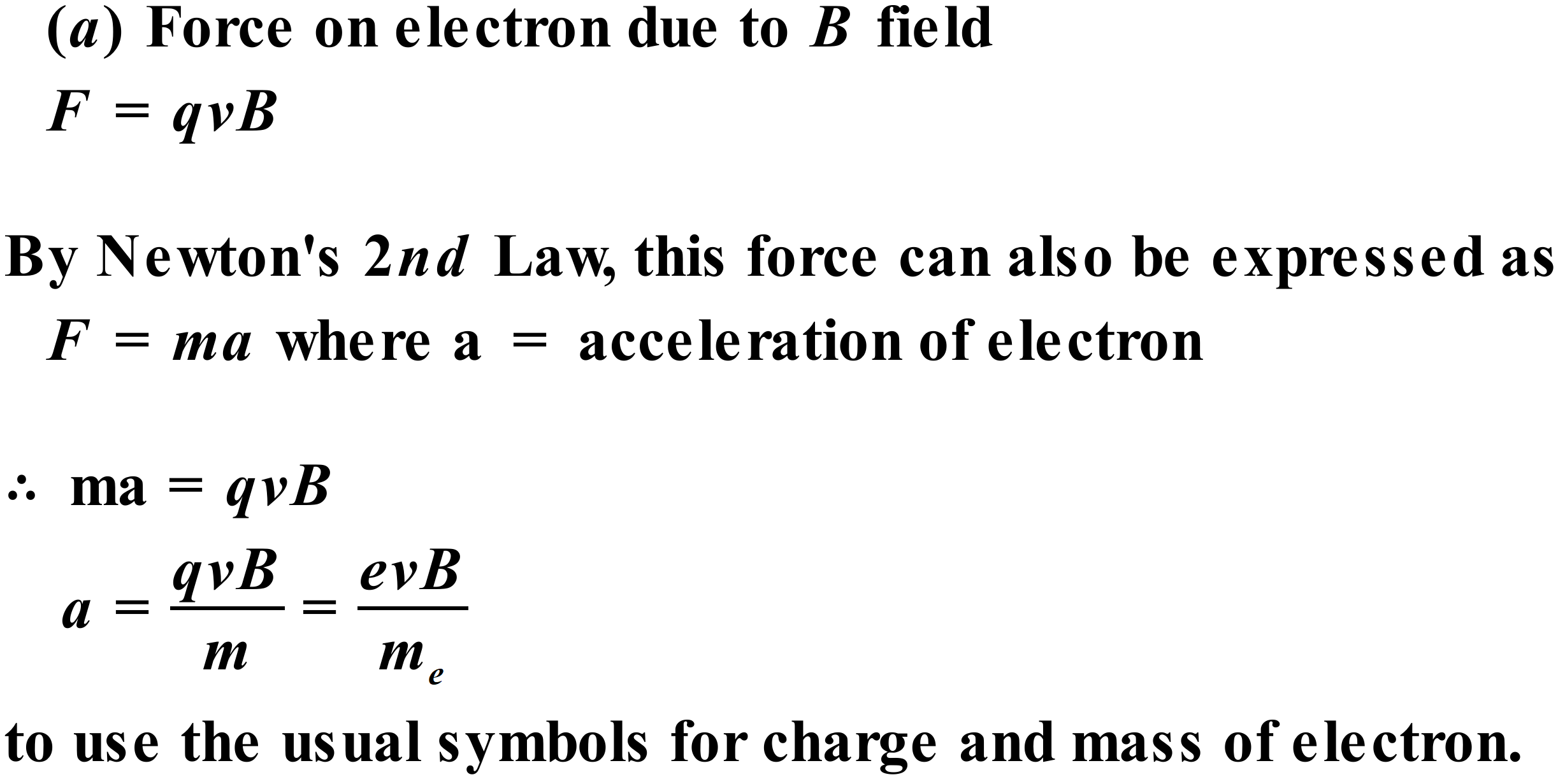
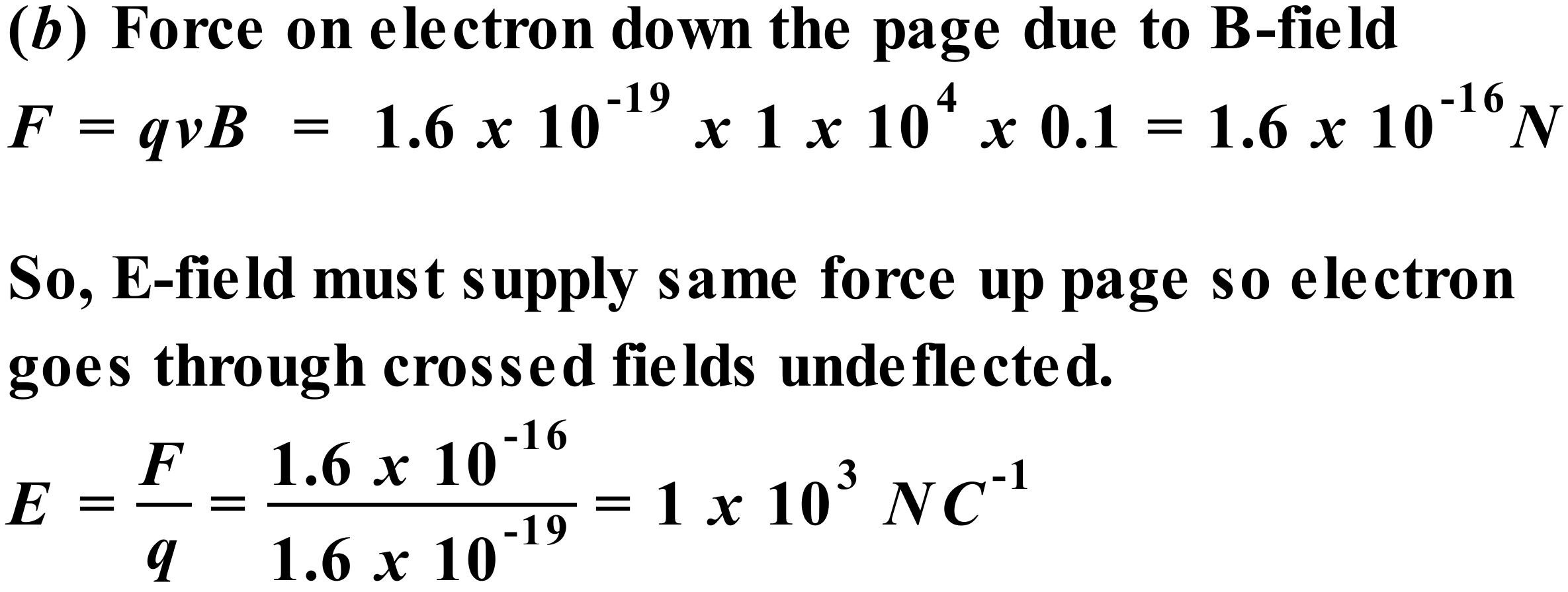
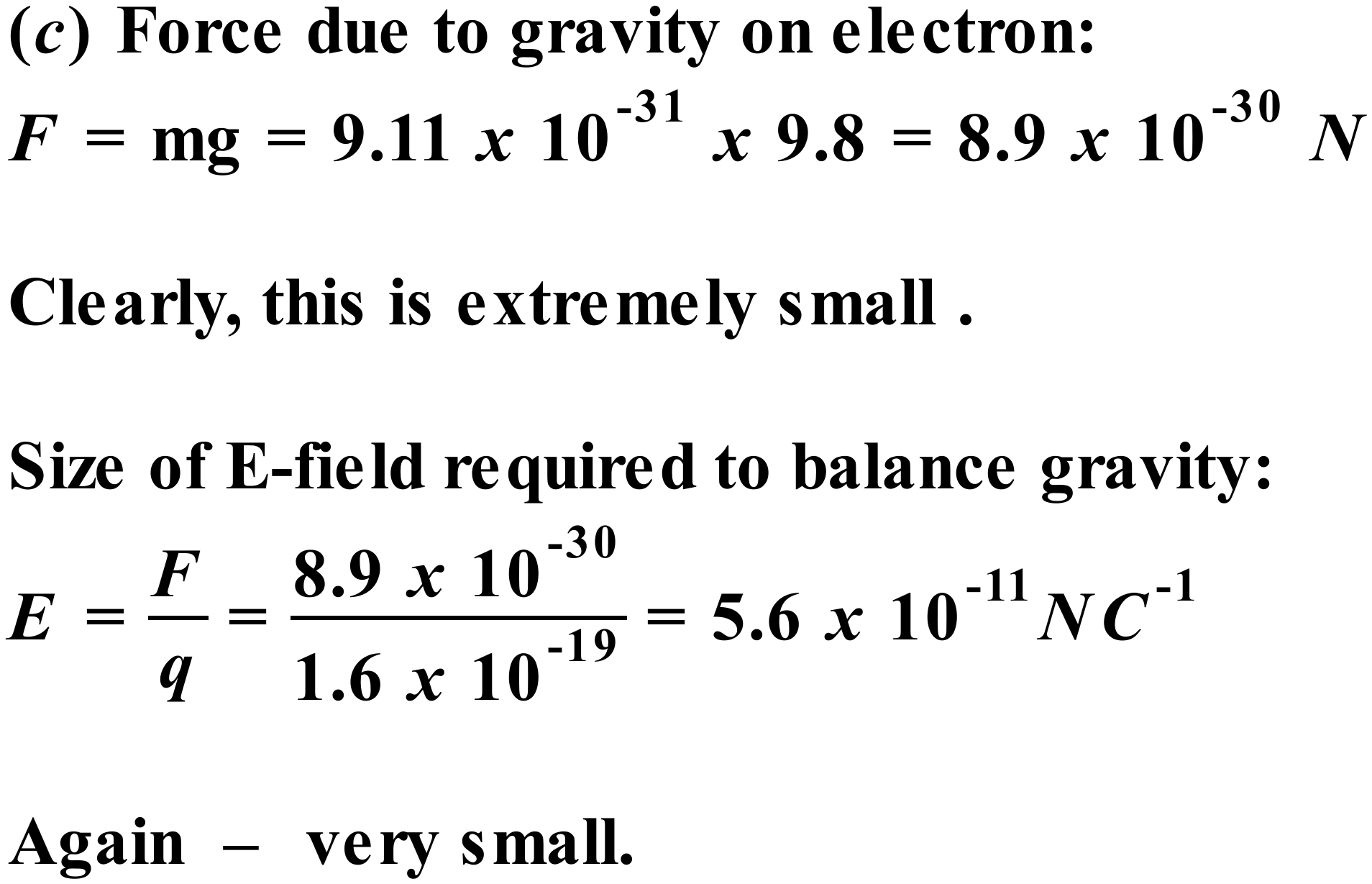
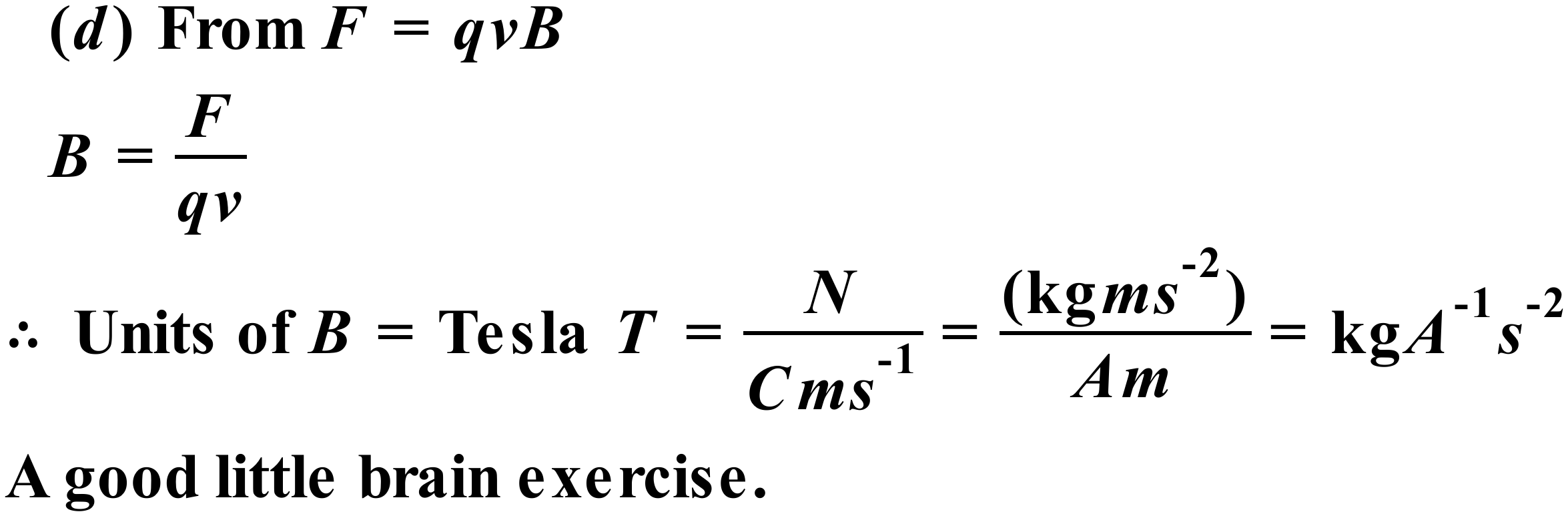
* 1. Draw a diagram showing a possible path of the chlorine ion once it enters the magnetic field. Assume the force due to the magnetic field is the only relevant force acting on the ion.
  2. Calculate the radius of the circular path of the ion in the field.

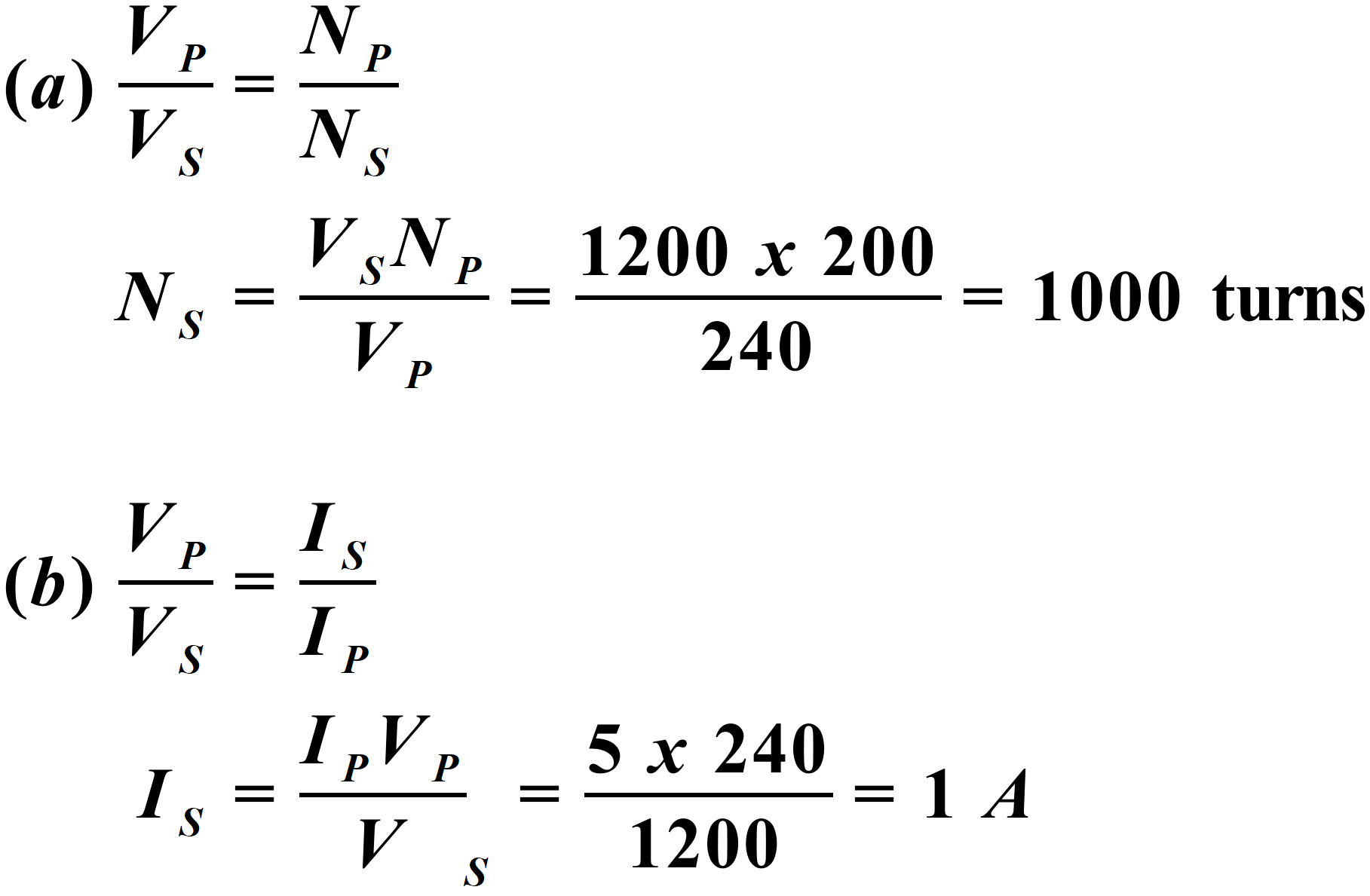
1. The diagram below shows a coil consisting of 20 identical turns of conducting wire held at right angles to a magnetic field of induction 6.0 x 10-4 T. The cross-sectional area of the coil is 3.0 x 10-2 m2.

1. The magnetic field is steadily reduced to zero over a period of 1.0 x 10-2 s. Calculate the emf generated in the coil.
2. The magnetic field is changed from 6.0 x 10-4 T to 1.0 x 10-3 T in 2.0 seconds. Determine the resulting change of flux linking each turn of the coil.
3. As the magnetic field is reduced to zero, in which direction will the induced conventional current flow in the coil? Give your answer as either clockwise or anticlockwise, looking down on the coil as it is drawn on the page above. Justify your answer.

**Solutions follow on the next page.**

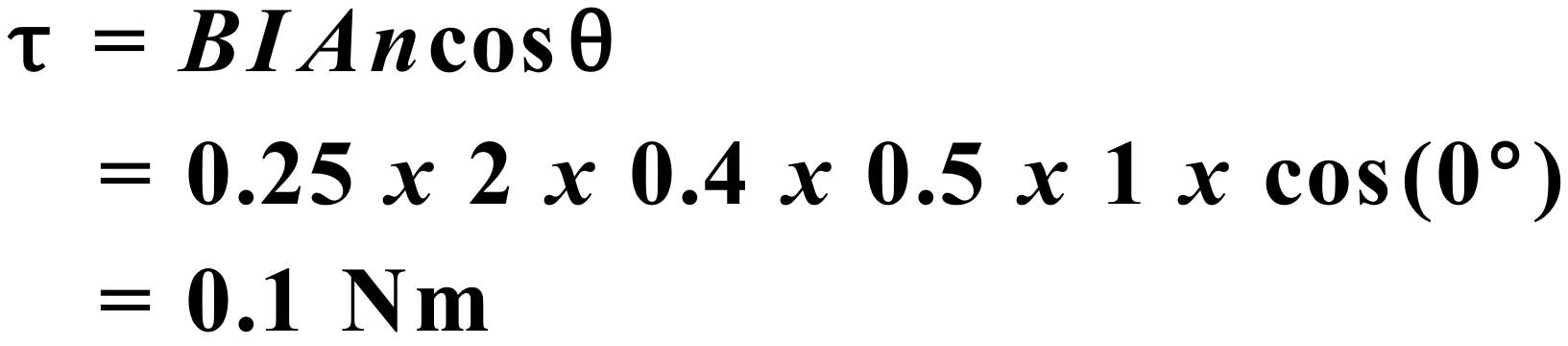
**Solutions**

1. This is a split ring commutator. The split-ring commutator and the brushes form a mechanism which enables the current to change direction through the coil of a DC electric motor every half turn, keeping the torque on the coil in the same direction, so that the coil continues rotating in the same direction. The split-ring commutator can also be attached to the armature of an AC generator to reverse the connections of the coil to the external circuit each time the current in the coil reverses. Thus, a DC output is achieved from the AC generator.
2.    
     
   The minus sign simply reminds us that the emf opposes the change that caused it. So, the emf between A and B is 1.37 V. (If you are unsure about the area calculation above, the copper bar, AB, moves 3 m to the right every second. The area covered by the bar each second is therefore 1.3 x 3 = 3.9 m2.)  
     
    
3.    
     
     
       
       
     
     
    



1. (a) Force on AB is down into plane of page.

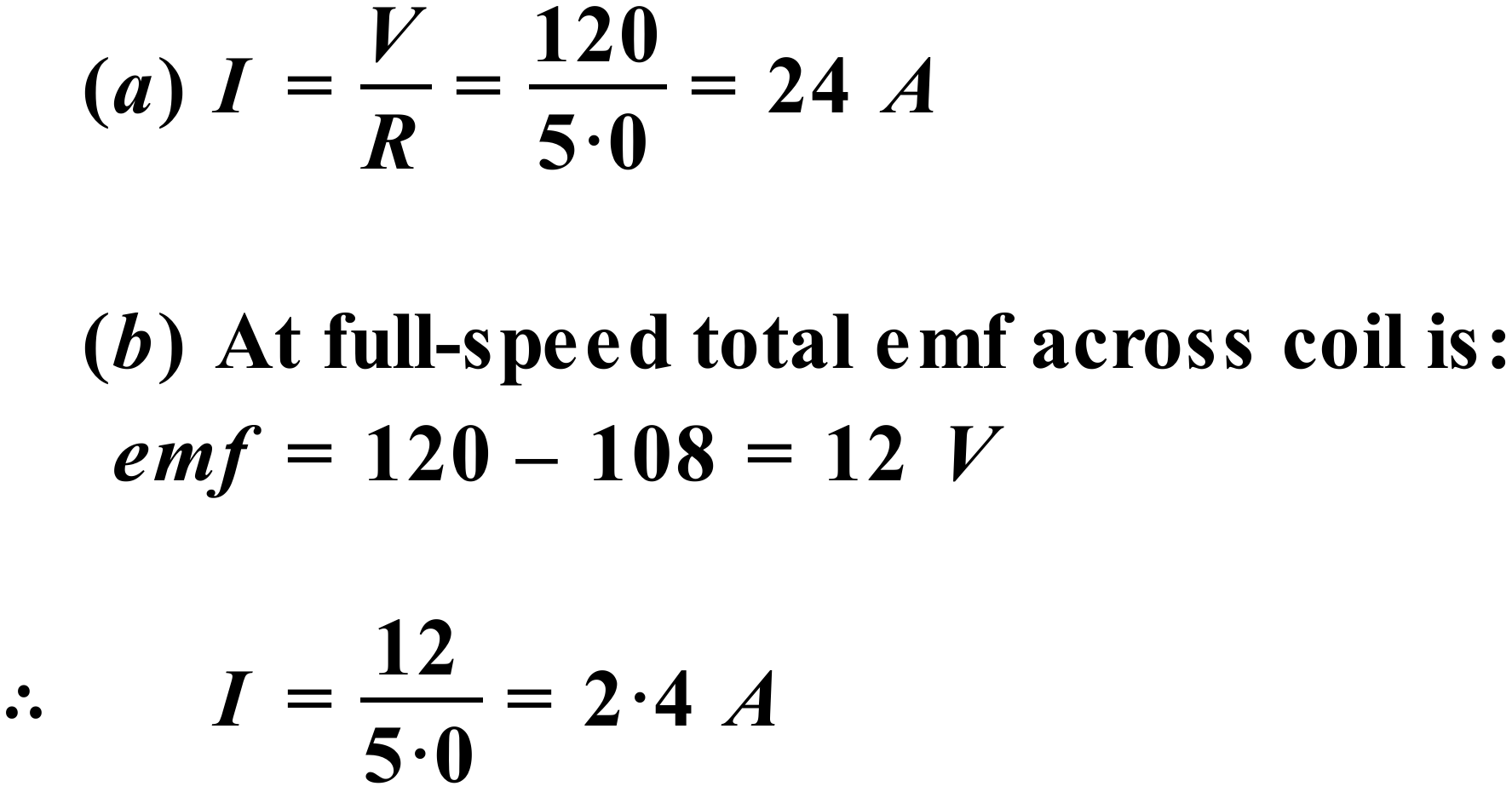
(b) Force on BC is zero, since BC is parallel to the B-field direction.  
 F = IlBsinq and q = the angle made by conductor with magnetic field = 0º. Sin 0º = 0.

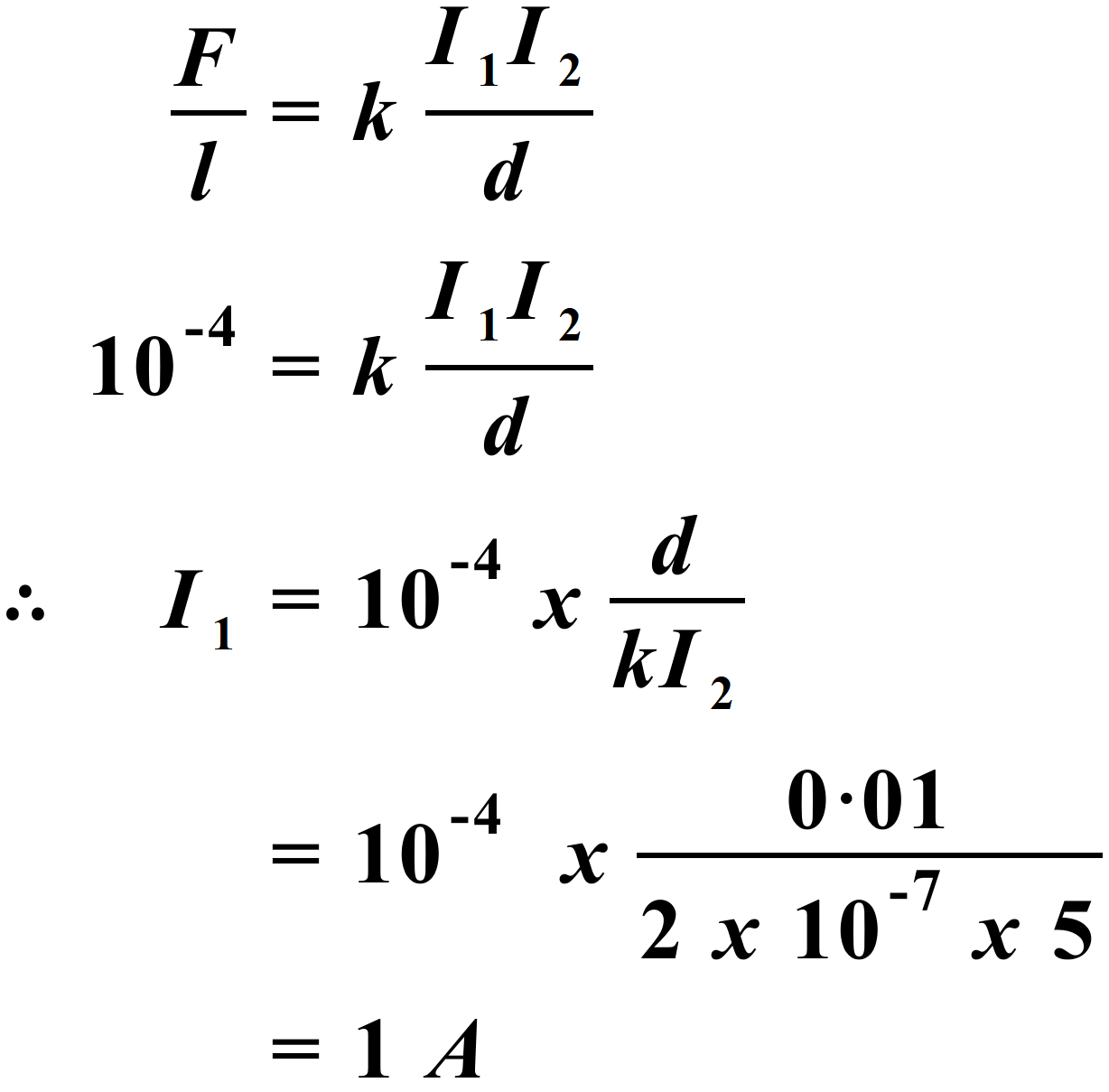
(c)    
  
(d) Coil would rotate initially with AB moving into plane of page and DC out of page.  
 As coil passes through position where its plane is perpendicular to B-field, the forces  
 on AB and DC reverse direction and begin to decelerate the coil. Momentum carries

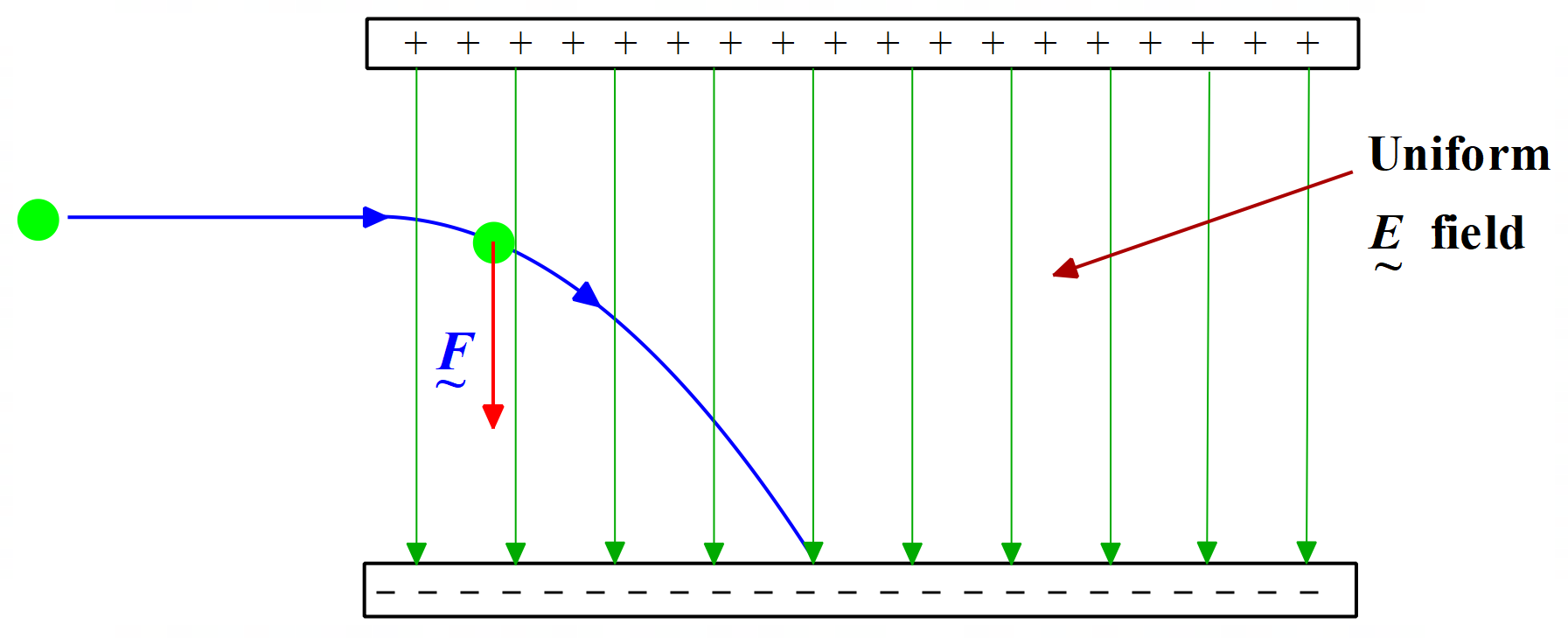
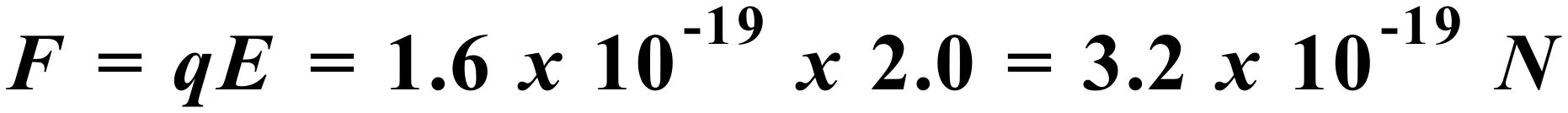
coil a little further in same spin direction until coil stops and begins to spin in opposite  
 direction under influence of the new forces acting on AB and DC. This process will

repeat when coil again passes through perpendicular position. If DC current

continues to flow, the single-turn coil will continue to oscillate between clockwise  
 and anticlockwise spin directions.

1. As the motor is just starting up, it is turning very slowly, so there is no induced back emf. The only voltage is the 120 V line. We can use Ohm’s Law to calculate this current. At full speed, we must include as emfs both the 120 V applied emf and the opposing back emf.  
     
       
     
   Note: This result shows that the current can be very high when a motor first starts up. Adjustable starting resistors are sometimes placed in series with the motor to ensure the motor does not burn out when starting up. These resistors are switched out once the motor reaches normal operating speed.

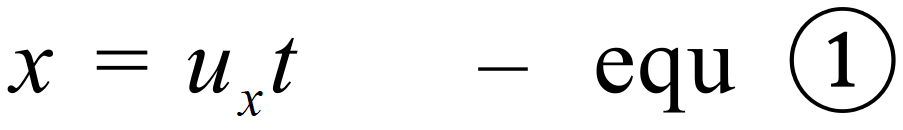
   
  
As the force between the wires is attractive, the currents in the two wires are flowing in the same direction. See diagram below.  
  
   
  
By RH Grip rule, B-field from conductor 1 passes vertically down into the plane of the page through conductor 2. By Fleming’s LH rule, force on conductor 2 due to carrying current through the B-Field of conductor 1 is up the page toward conductor 1. Likewise, conductor 1 is sitting in a B-field from conductor 2 that passes through it vertically upward through the plane of the page. Again, the LH rule indicates that the force on conductor 1 due to carrying current through the B-Field of conductor 2 is down the page toward conductor 2. Clearly, the currents in the two wires must be in the same direction for the force between the wires to be attractive.

1. (a)   
     
     
     
     
     
     
     
     
     
     
     
     
   (b) 

(c) The trajectory of the proton is parabolic.

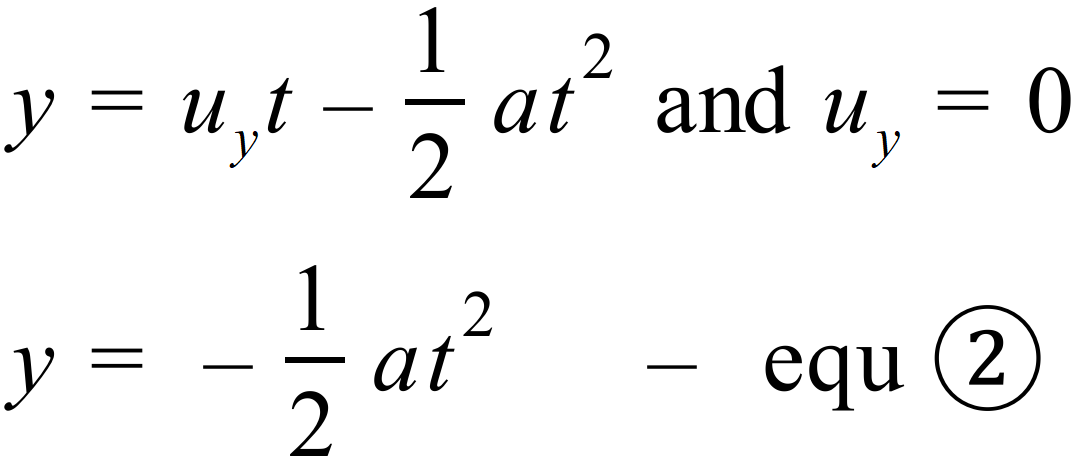
Once inside the field, the proton experiences constant acceleration vertically (y-direction). It has no acceleration horizontally (x-direction). The displacement of the particle at any time **t** can be determined using the equations of uniformly accelerated motion.

In the x-direction, the position x at time t is:

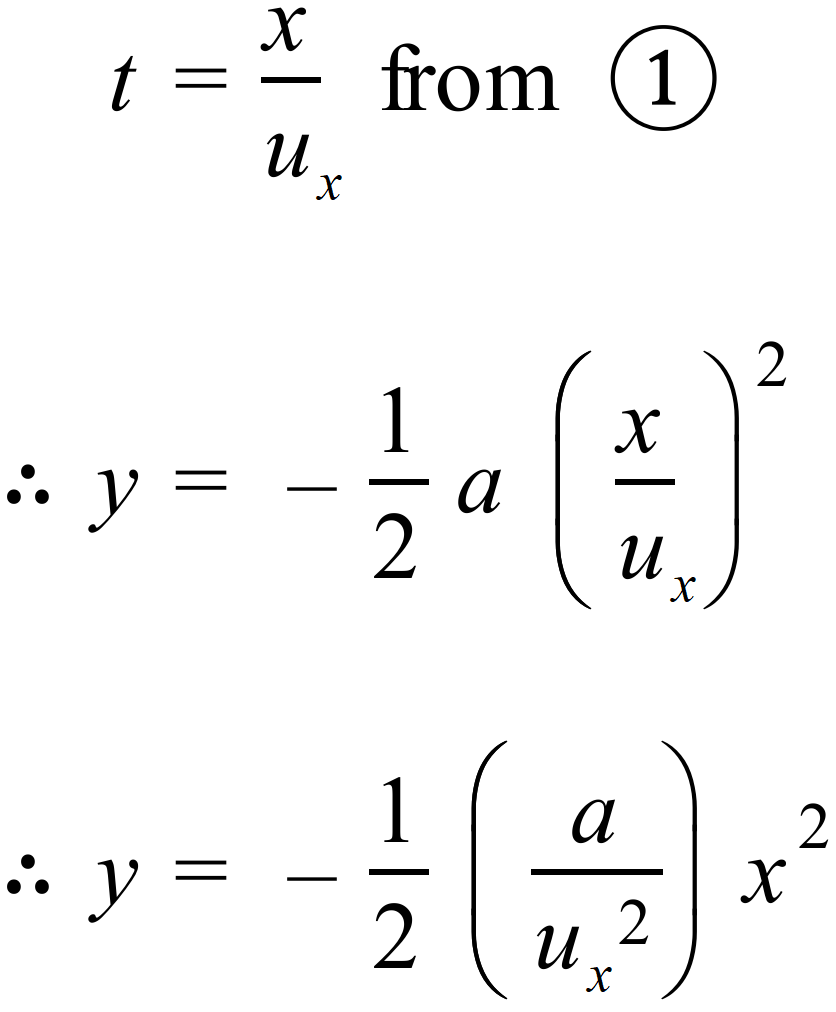


where **ux** is the constant horizontal velocity of the particle.

In the y-direction, the position y at time t is:



The minus sign appears because acceleration is acting downward. If we now eliminate t from these parametric equations, we obtain:



As **a** and **ux** are constant, clearly the trajectory of the particle in the electric field is a parabola.

(d) This is the same trajectory exhibited by an uncharged particle falling in a uniform

gravitational field.

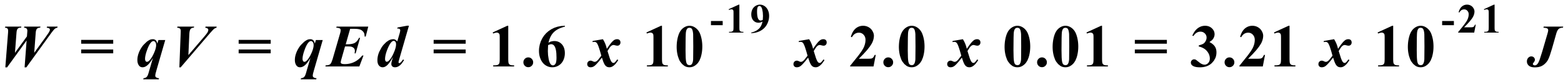
(e) If the proton entered the E-field parallel to the field lines, it’s path would have been a

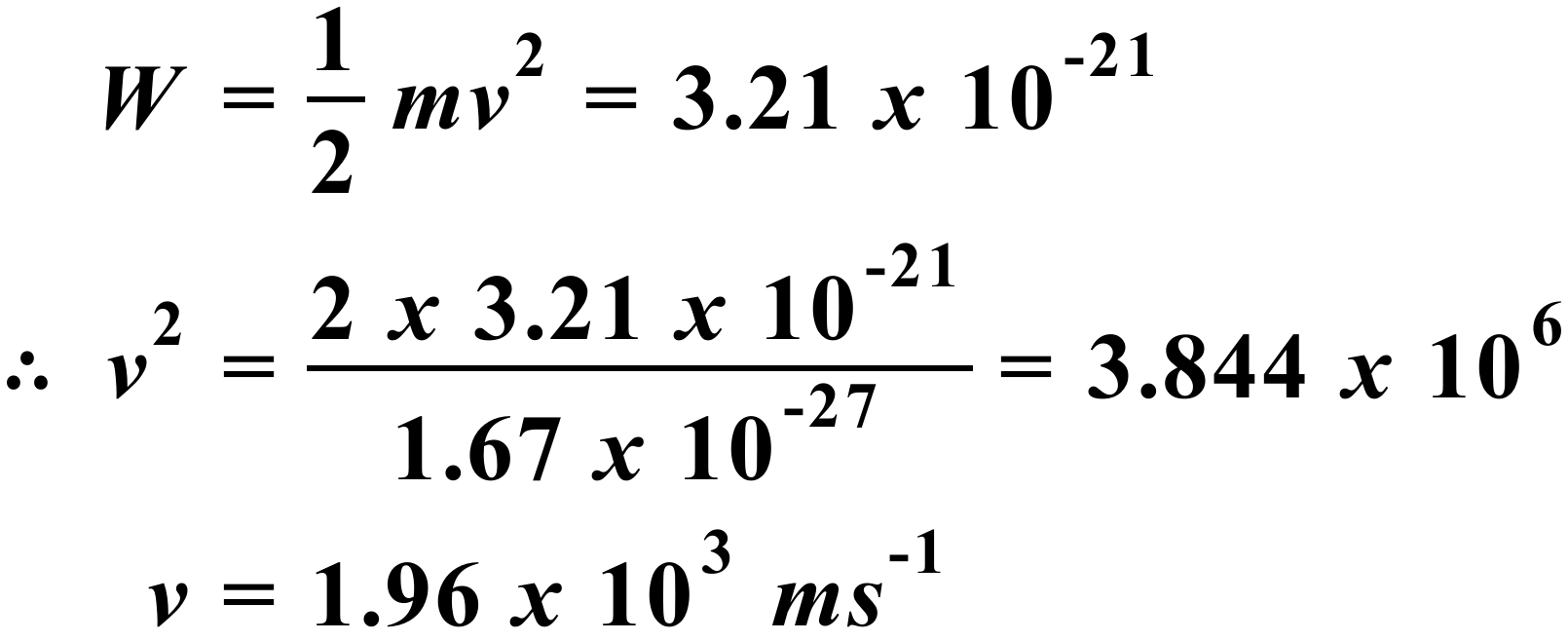
straight line. If it was travelling in the direction of the field, it would accelerate

downward. If it was initially travelling opposite to the field direction, it would be

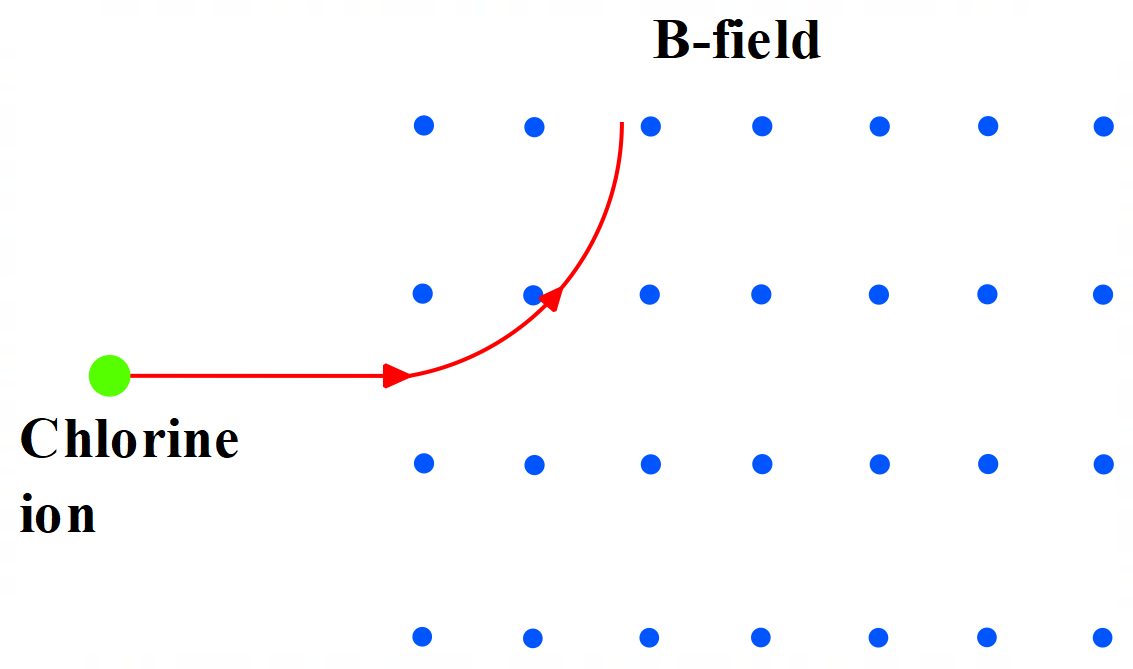
retarded by the field until its velocity was zero and then accelerated in the direction of

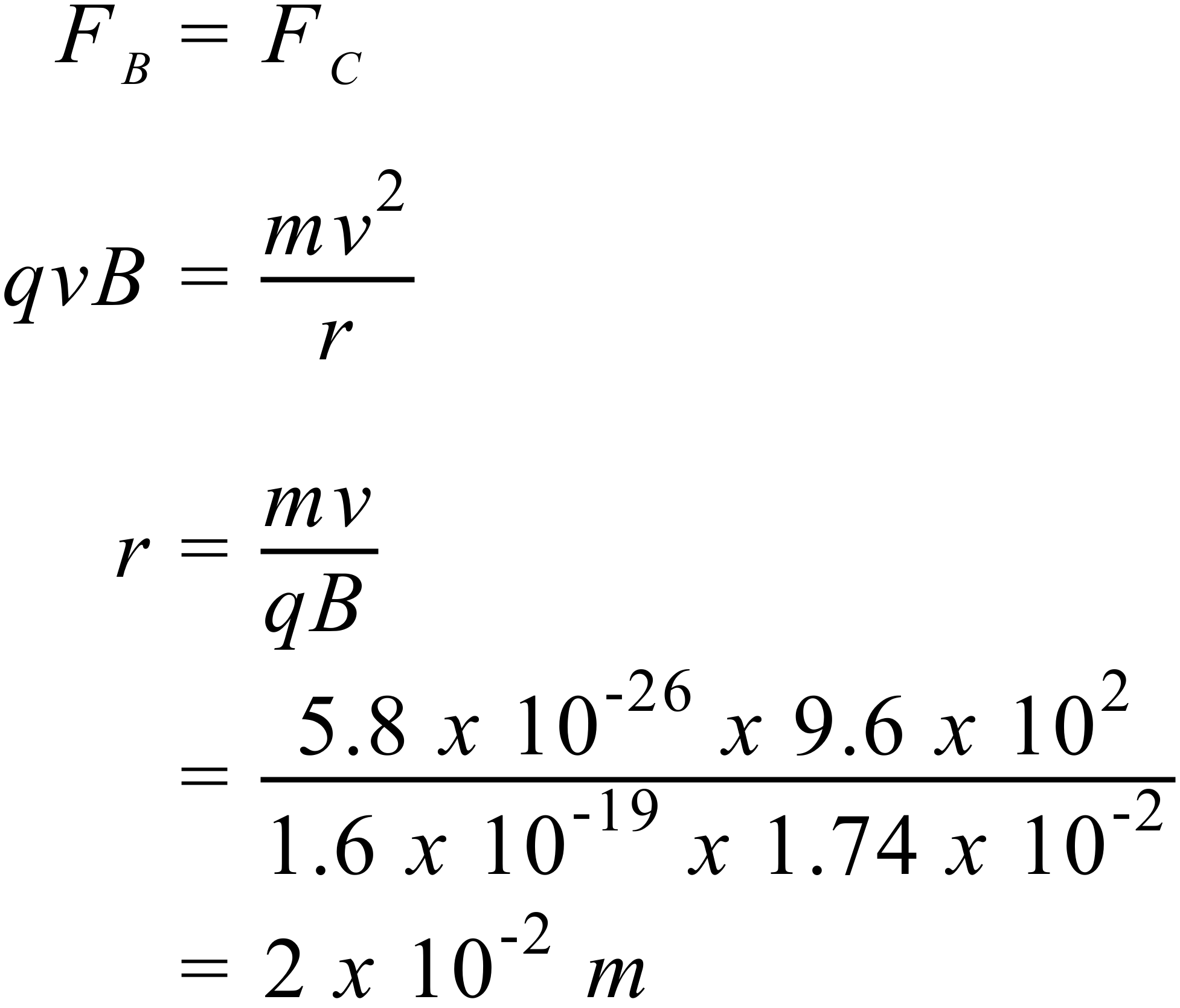
the field.

(f) 

(g) 

1. (a)

  
  
Fleming’s LHR indicates direction of force is up toward top of page. The path in the field is circular.  
  
There are many possible correct answers to this question. It would even be acceptable to draw the ion being capture by the field and executing circular motion completely within the field. The initial force direction upon entering the field must be up toward top of page. If captured by the field, the circular orbit would be anticlockwise.  
  
(b) We can express the force on the ion as both a magnetic force and a centripetal force,

since the path in the B-field is circular.  
  
 

1. 