Tuesday: 11-11:50am – GS 222
Tuesday: 6-6:50pm – GS 110
Thursday: 11-11:50 am – GS 222
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Physics 2 Exam 3 Review

1. Magnetic fields
    a. Magnetic field (B), just like electric field (E), has an amount and direction at a point in space
    b. Unlike electric field, magnetic field must end where it started (i.e. make a loop)
    c. B travels out of the north pole of a magnet and loops into the south pole.
        i. But B travels from south pole to north pole **inside** the magnet (Figure 1)

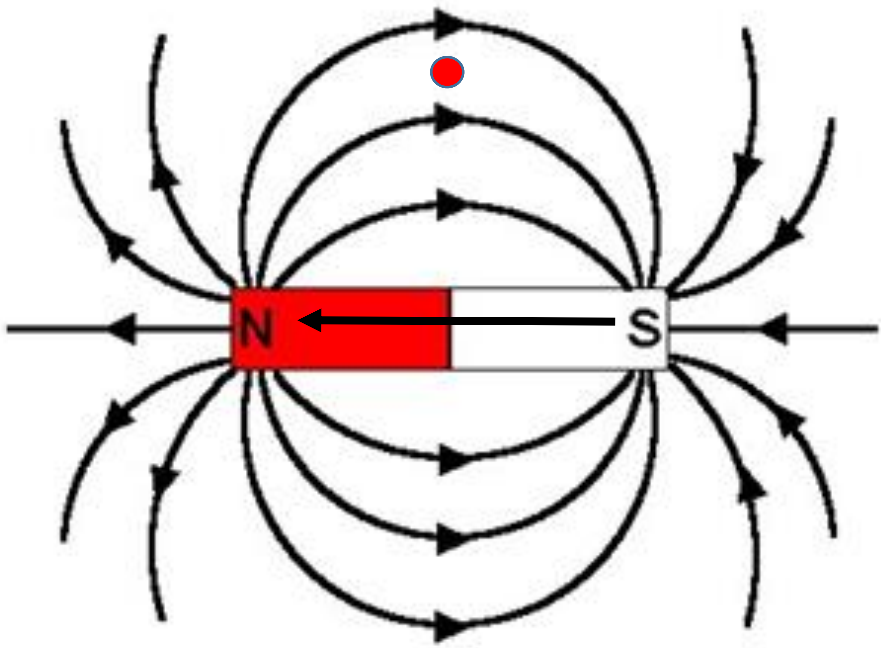


Figure 1 Magnetic field created by a bar magnet. Note: magnetic field inside the magnet travels from south to north pole.

Question 1

What direction is the magnetic field traveling at the point specified by the red circle in Figure 1 above?

    d. Magnetic fields attract if the magnetic field inside each one points in the same direction and repel if B inside face opposite direction
    e. Breaking a magnet between the north and south pole creates two full magnets

2. Magnetic fields create force on a charge moving inside them
    a. Magnetic force, F_B, on a charge from a magnetic field, depends on four factors:

i. The charge's velocity
   1. Moving faster, more force
   2. Not moving, not affected by magnetic field

ii. The magnitude and charge of the particle
   1. Neutral particles not affected

iii. The magnitude of the magnetic field, B

iv. The angle between the charge's direction of movement and the direction of the magnetic field
   1. Most force when charge is moving perpendicular
   2. No force when moving parallel to field

b. Use $F_b = |qvB\sin\theta|$ to find the magnitude of the force on the charge

Question 2

A charge is sent through a uniform magnetic field with an initial velocity. The magnetic force on the charge is 10N.

- If the initial velocity of the charge was increased by a factor of 3 and the amount of charge of the particle was decreased by a factor of 2, how much magnetic force is now on the charge?

c. F_b is always perpendicular to both B and v

   i. Means almost every problem we will do is 3-dimensional (Figure 2)

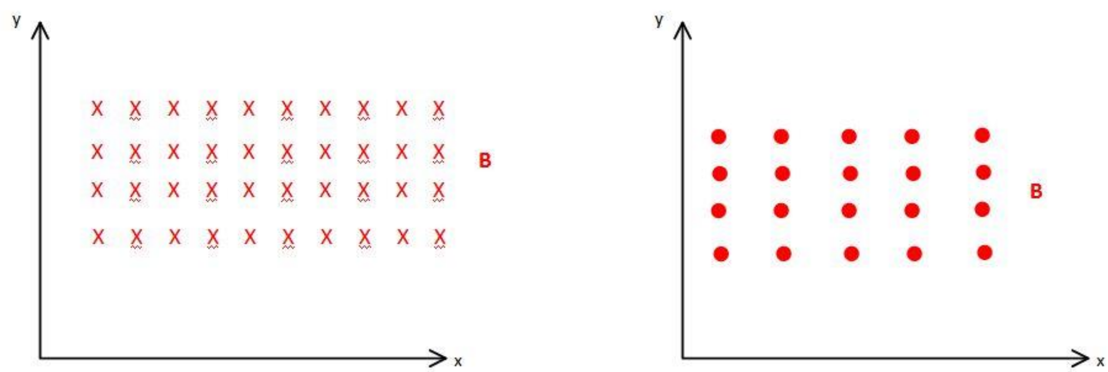


Figure 2 For 3-D problems, the x and y axes remain the same as always, but another plane, z, travels into and out of the x-y plane. Vectors in the –z direction (into the plane) are represented by x's, while those traveling out of the plane towards you (+z) are represented with dots.

d. To find the direction of F_b, B, or v, use right hand rule (RHR)

   i. Fingers on **right hand** point in direction of charge's movement

   ii. Palm faces direction of magnetic field

iii. Thumb indicates direction of magnetic force
iv. If charge is negative, everything is the same, except the final direction you find is the opposite of what you got with the RHR

Question 3

A 4C charge moves in the +x direction at 32m/s. A 2T magnetic field is directed in the +y direction. What is the magnitude and direction of the force on the charge from the magnetic field?

- What if the charge was negative? What's the direction of the force?

Question 4

A -5C charge moves in the +z direction at 24m/s. The magnetic force on the charge is 8N in the +x direction. What is the magnitude and direction of the magnetic field?

e. Work done by magnetic field is always zero
   i. Magnetic field can never change the velocity of a charge, only change its direction
   ii. Charges subject to uniform magnetic fields will always move in a circle (Figure 3)

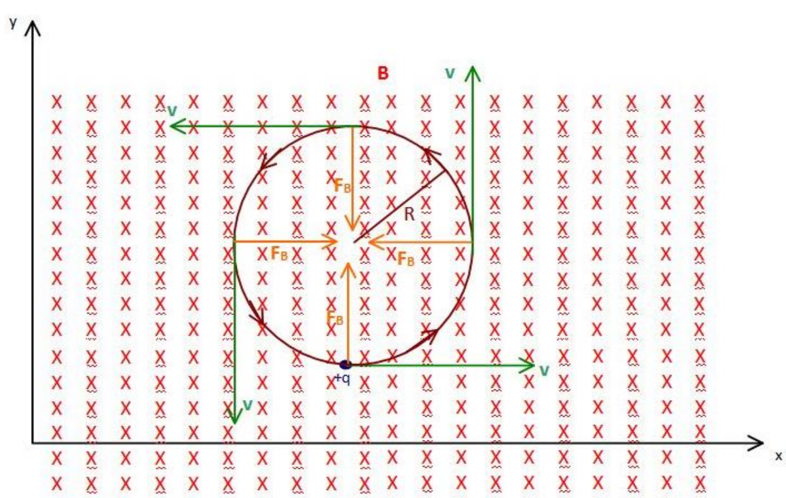


Figure 3 Motion of a positive charge in a magnetic field directed in the –z direction.

   iii. Although the charge's direction is constantly changing (as it is moving in a circle), the velocity will remain the same
   iv. Can find the radius, R, of the circle
      1. R = |(m v)/(q B)|

Question 5

A charge is moving in a circle with radius R because it's in a uniform magnetic field. If it's moved into a stronger magnetic field, will it travel in a tighter circle or larger circle (what will happen to R)?

f. Can find the frequency of the charge's movement (cyclotron frequency)
   i. How many times the charge moves around a single point in the circle in 1 second
   ii. Measured in hertz, Hz
   iii. $f = \frac{1}{2\pi} | \frac{qB}{m} |$
g. Period is the time in seconds it takes the charge to travel around the circle once
   i. $T = 1/f$

Question 6

If a 7C charge is moving around in a circle due to a magnetic field of 6T, and the charge's mass is 3kg, what is the period in seconds?

h. If a charge's direction of movement is not perpendicular to B, some velocity will continue in the direction it was going, and some will travel in a circle due to the magnetic field.

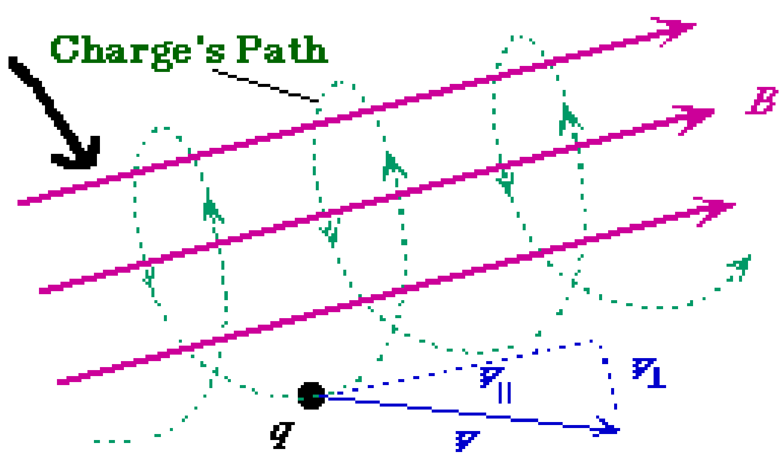


Figure 4

i. Magnetic fields and electric fields can be used together to filter out particles with certain velocities (velocity selector; Figure 5)
    i. Only particles with velocity v=E/B will travel unaffected through the device

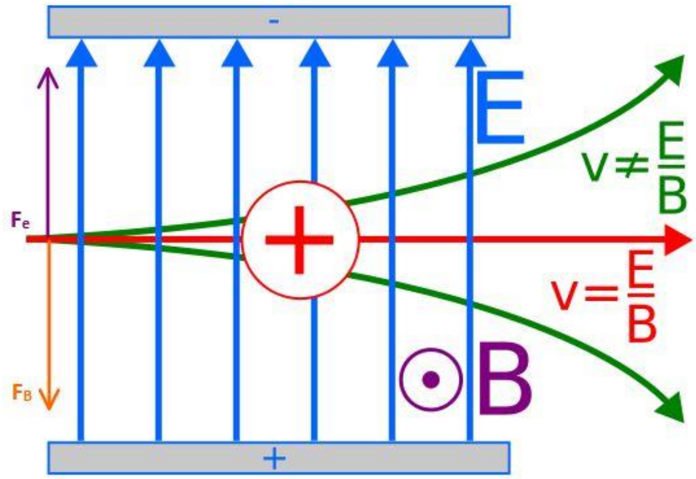


Figure 5 Velocity selector

Question 7

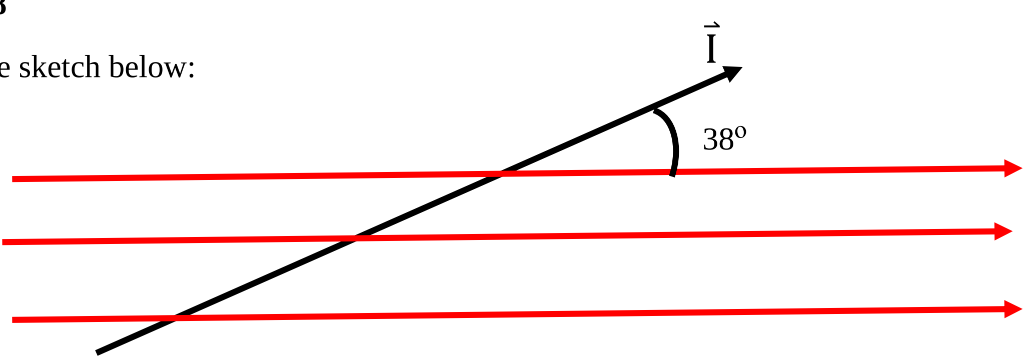
If a positive charge travelling in the +x direction is sent through a velocity selector with plates having a surface charge density of 10 $\mu C/m^2$ and a magnetic field of .5T directed in the –z direction, at what velocity will the charge pass through undeflected (the electric field is directed in the negative x direction)?

- If the velocity is greater than the one found, what direction will the charge be deflected?
- What if the velocity is less than that found?

3. Current-carrying wires in magnetic fields
    a. Magnetic fields can have a force on the wire
        i. $F_b = ILB\sin\theta$
            1. where I is the amount of current
            2. L is the length of the wire
            3. B is the magnitude of the magnetic field
            4. θ is the angle between the direction of the current and direction of the magnetic field
        ii. To find direction of F_b, use RHR
            1. Since current is movement of individual charges, fingers go in direction of current
            2. Everything else stays the same as RHR for point charges

Question 8

Refer to the sketch below:



If I = 16A and B=22T, and the length of the wire is 3m, what is the magnitude of magnetic force on the wire in Newtons?

4. Square wires and coils
    a. Magnetic moment
        i. μ = N I A
    b. for direction, use RHR
        i. this time, fingers curl in the same direction as current around the coil, and thumb is the magnetic moment (figure 6)
    c. coil will rotate such that magnetic moment will be in same direction as magnetic field

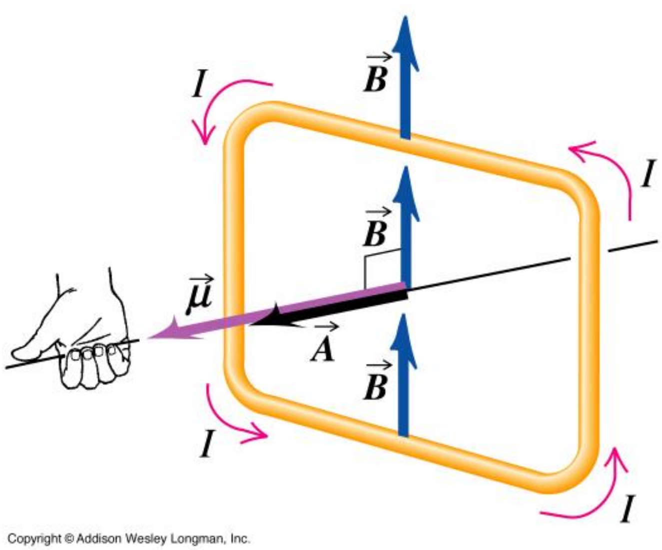


Figure 6 RHR for magnetic moment of a coil of wire

Question 9

If a square coil of wire wrapped 3 times with current of 5A traveling clockwise has sides of .7m, what is the magnitude and direction of the magnetic moment?

5. Magnetic fields created by infinite straight wires
   a. Current-carrying wires can create magnetic fields around them (Figure 7)
   b. To find magnitude of this field
      i. $B = \frac{\mu_0 I}{2\pi r}$
         1. I is current in Amps
         2. μ_0 is $4\pi \times 10^{-7}$ Tm/A
   c. Field will go clockwise or counterclockwise around the wire (Figure 7)
      i. Use RHR to figure out direction
         1. Thumb is direction of current
         2. Whatever way fingers curl is the direction of magnetic field

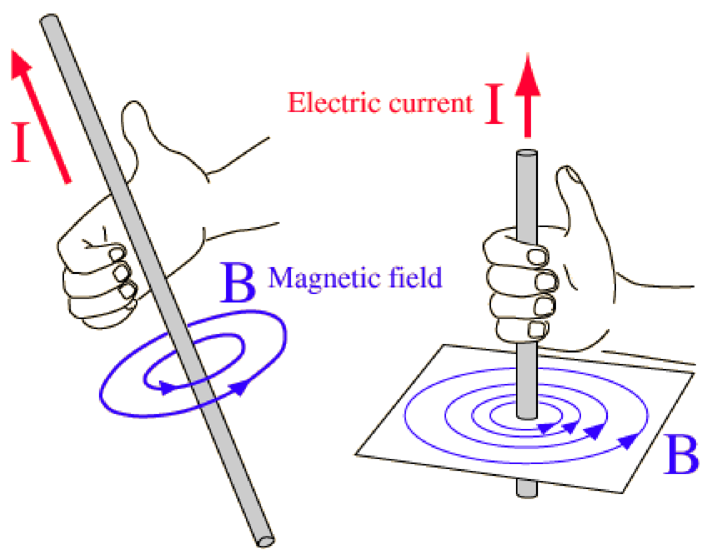


Figure 7 RHR to determine direction of magnetic field created by an infinite straight wire

Question 10

An infinite straight wire with current of 12A directed in the +y direction creates a magnetic field. At a point .5m to the left of the wire, what is the direction and magnitude of the magnetic field?

6. Two infinite wires
    a. Two infinite wires cause forces on each other via each's magnetic field
    b. Can also find the total amount of magnetic field created by both wires at a point
        i. First, using RHR, find direction of B around each wire
        ii. Second, calculate magnitude of B for each wire using $B = \frac{\mu_0 I}{2\pi r}$
        iii. Use vector addition using components of B like we did with electric force
            1. $\vec{B}_{Total} = \vec{B}_1 + \vec{B}_2$

Question 11

Suppose we have two straight wires with current in them, both parallel to the y axis and traveling in the –y direction. Wire 1 is at 1m on the x axis, while wire 2 is at 8m on the x axis. What is the direction and magnitude of the total magnetic field in micro-Teslas at a point at 5m on the x axis if wire 1 has 3A and wire 2 has 5A?

    c. Two wires can also have a force on one another
        i. Force per unit length
            1. Units of N/m
        ii. F/L = $\frac{\mu_0 I_1 I_2}{2\pi d}$
        iii. Determine direction of force using RHR
            1. Fingers point in direction of current
            2. Palm is direction of magnetic field from other wire
            3. Thumb is direction of force
        iv. If both wires have current in the same direction, the force on each wire from the other wire will be toward the other wire and they will attract (Figure 8)
        v. If current is going opposite direction, the wires will repel

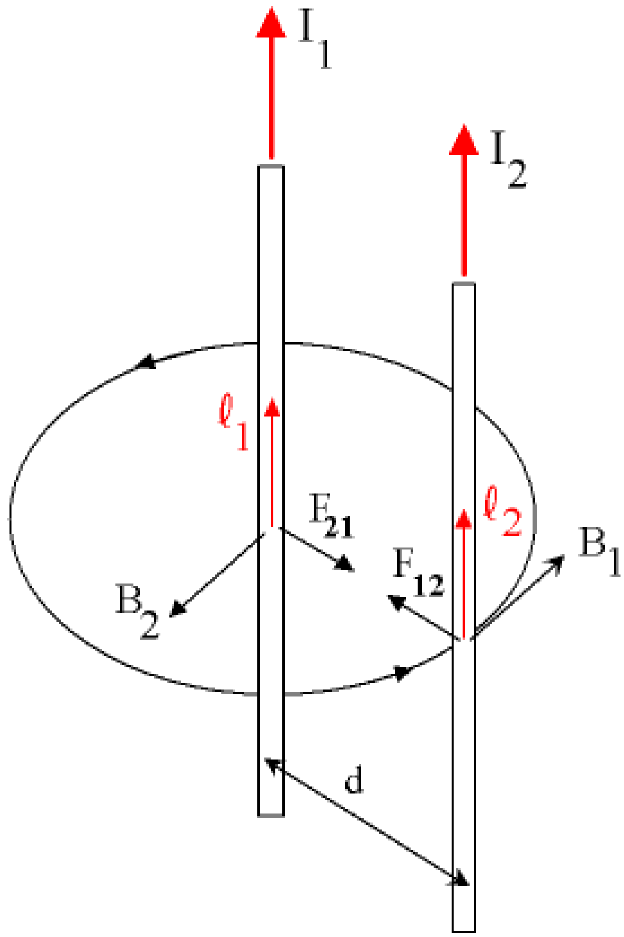


Figure 8 Force on one infinite wire from the magnetic field of another wire.

Question 12

Suppose we have two straight wires with current in them, both parallel to the y axis and traveling in the –y direction. Wire 1 is at 1m on the x axis, while wire 2 is at 8m on the x axis. What is the force per unit length on wire 2 due to wire 1? What is the force per unit length on wire 1 due to wire 2? Will they attract or repel, based on RHR?

7. Magnetic field created by circular wires
   a. Only need to know about magnetic field *at the center* of a circular wire
   b. $B = \frac{N\mu_0 I}{2R}$
   c. To find direction of B, use RHR same as to find magnetic moment (Figure 9)

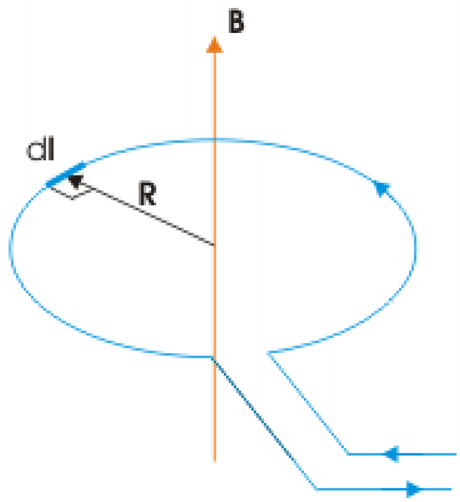


Figure 9 Direction of magnetic field at the center of a circular wire

Question 13

If the magnetic field at the center of a circular, current-carrying wire was found to be 10T, but then the wire was wrapped double the amount that it was before, what is the magnitude now?

8. Magnetic fields and infinite solenoids
   a. Solenoids are like circular wires wrapped many times in a cylindrical manner (Figure 10)
   b. Different than circular wires in that they create ***uniform*** magnetic fields through their center
   c. B = 0 outside of the solenoid
   d. To find magnitude of field for a solenoid
      i. $B = \mu_0 n I$
      ii. Where n is the number of times the wire is wrapped for a specific length
   e. To find direction, use RHR the same as for circular wires and magnetic moments

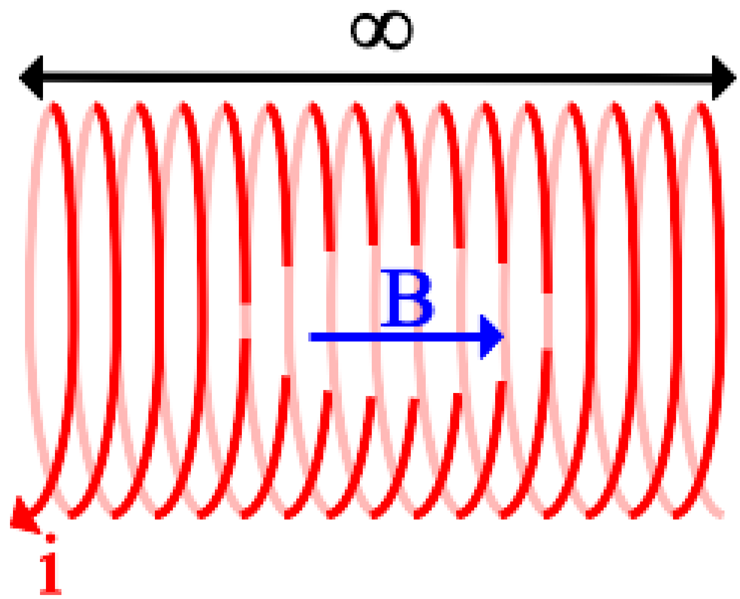


Figure 10 Magnetic field created by an infinite solenoid

9. Magnetic flux through a surface/object
   a. Magnetic fields, such as those created by a solenoid, can pass through a surface
   b. Magnetic flux, measured in Wb (Webers) indicates amount of magnetic field passing through an object/surface
   c. Very similar to electric flux
   d. $\Phi B = B\ A\ \cos(\theta)$
   e. Where θ is the angle between the magnetic field direction and the normal (figure 11)
   f. Magnetic flux through any closed object is always 0

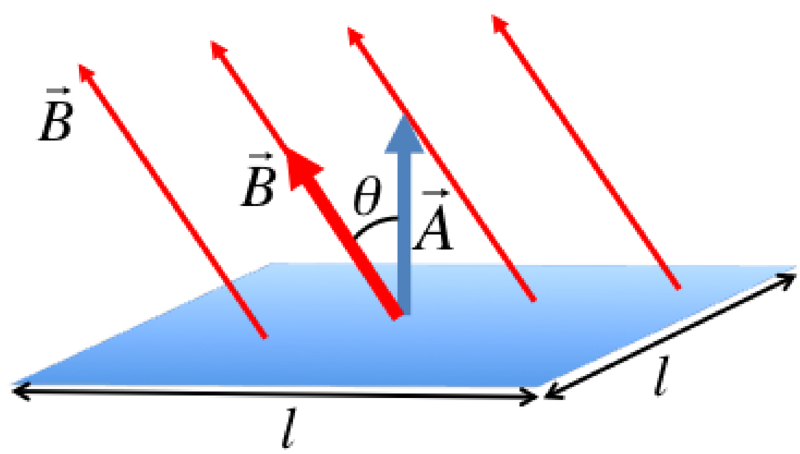


Figure 11 Magnetic flux through a sheet with sides of length l

Question 14

There is a rectangular sheet with sides of .5m and 2m with a magnetic field of 3T passing through it. If the angle between the normal and the magnetic field is 30 degrees, what is the magnetic flux? What is the magnetic flux of the object if the angle was 90 degrees?

A. R-C Circuits
   a. Circuits with one or more resistor and one or more capacitor
   b. Resistor slows down charging of capacitor
   c. Eventually charges to Q=CV, where V is the voltage of the battery
   d. $V = V_R + V_C$ (figure 12; figure 13)
      i. At moment of connection to battery, all voltage is across the resistor and none across C
      ii. As charge moves through resistor and makes it to capacitor, more voltage is across C
      iii. Eventually, all charge moves into capacitor and none in resistor, rest of circuit
         1. Capacitor is fully charge (Q max)

Figure 12 Ticket line equivalent to resistor in a circuit. When tickets first open, nobody is inside stadium. When battery is first connected, no charge is in the capacitor. Eventually, the stadium/capacitor fill up and all people/charge are in the stadium/capacitor.

e. $q(t) = C\,V(1 - e^{-t/(RC)})$ to determine charge in the capacitor at a specific time

f. RC=T

  i. Indicates how fast C will charge up

g. When **charging,** after 1 time constant, q=.63(Qmax)

h. Realize what the question is really saying (Table 1)

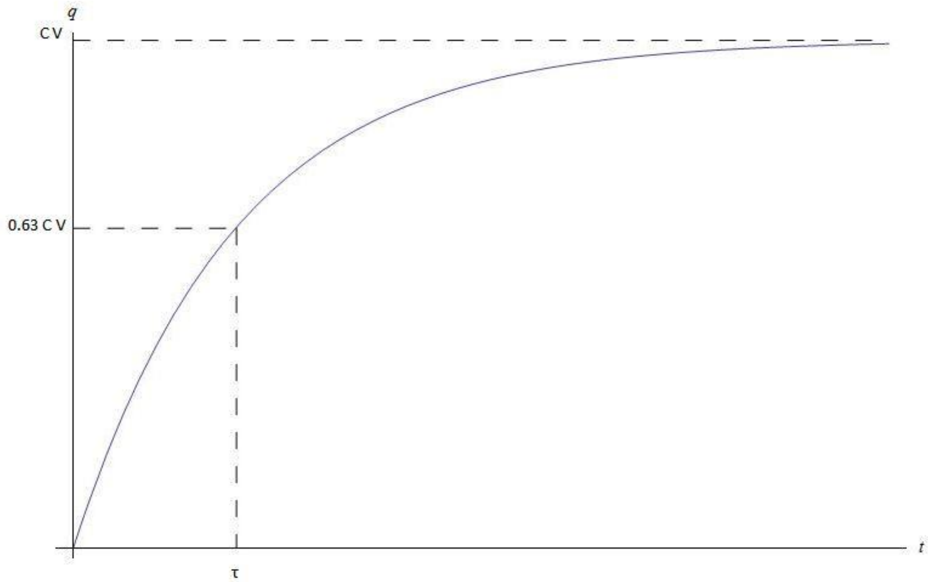


Figure 13 Capacitor charge over time when connected to a battery.

Table 1 Question phrasing for RC circuits

What the question says	What it really is saying
"An RC circuit has been connected to a battery for a very long time, and the charge in the capacitor is 20C."	The maximum charge the capacitor can hold (Qmax) is 20C.
"A capacitor charges for a very long time to 100C. At 2s of charging, the charge in the capacitor was 63C."	The time constant is 2s.
"After discharging for 20s, the capacitor has 37% of the charge it started with when it started discharging."	The time constant is 20s

Question 15

There is an RC circuit with one Resistor of 70Ω and a Capacitor of 300μF. It is connected to a 35V battery.

a. What is the Time Constant?
b. What is the charge after 2 time constants?
c. What is the charge in the capacitor at 25ms?

i. After the capacitor charges up and contains an amount of charge, we can see how it discharges when we disconnect the battery
j. When discharging, current flows out of the capacitor into the circuit in the opposite direction it was going with the battery
k. Voltage of resistor and capacitor are equal when discharging
l. To determine charge in capacitor at a given time of discharging, $q(t) = Q_0\ e^{-t/(RC)} = Q_0\ e^{-t/\tau}$
    i. After 1 time constant, $q=.37(Q_o)$

Question 16

A capacitor is discharging for 2 time constants, and the charge inside is 3C. What was the initial charge when it began discharging?

1. Induced EMF
    a. Recall that flux is how much of something going through an object/surface
        i. Since we are looking at magnetic field, we will look at magnetic flux
            1. How much magnetic field is going through a certain surface
    b. By changing the magnetic flux through a wire, we can actually create a current in the wire
        i. **Can only induce an EMF by changing flux**
        ii. Induce an electromotive force (EMF)
            1. Actually a potential difference, which leads to a force
        iii. Can find the average voltage created
            1. $\xi_{av} = N\ |\Delta\varphi_B/\Delta t|$
                a. Note that if $\Delta\varphi_B$ is 0, there will be no EMF
        iv. EMF can be created in 3 ways:
            1. By changing the magnitude of the magnetic field, B
            2. By changing the area of the coil/wire in the magnetic field
            3. By changing the angle between the coil and the magnetic field
        v. Once ξ_{av} is calculated, we can find the average induced current in the wire if the resistance of the wire is known

Question 17
Suppose we have a square coil of wire with area $25m^2$ wrapped 6 times in the x-y plane. A magnetic field of .04T is in the +z direction initially and after 5s changes to .02T. What is the average induced current in the wire if the resistance of the wire is 7Ω?

c. If the initial flux is less than the final flux (flux increases), the induced current will be in the direction so that it induced a magnetic field in the opposite direction of the magnetic field that created it
d. If the initial flux is greater than the final flux (flux decreases), the induced current will be in the direction so as to strengthen the original magnetic field.

Question 18
There is a circular wire in the x-y plane with a magnetic field traveling through it in the –z direction. If the initial flux was .5Wb, and was somehow increased to 1Wb, what is the direction of the induced current around the wire (clockwise or counter-clockwise)?