PHYS 1441 – Section 002
Lecture #17

Wednesday, Nov. 4, 2020

Dr. Jaehoon Yu

- CH26
  - Discharging through RC circuit
  - Application of RC circuit
- CH27
  - Electric Current and Magnetism
  - Magnetic Force on Electric Current
  - Magnetic Force on a Moving Charge

Announcements

- Reading assignments: CH27.6 – 8
- 2nd Non-comprehensive exam on Quest
  - At the start of the class next Wednesday, Nov. 11
  - Covers: CH25.1 – What we finish coming Monday, Nov. 9
  - BYOF: You may bring a one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants for the exam
  - No derivations, word definitions, setups or solutions of any problems, figures, pictures, diagrams or arrows, etc!
  - No additional formulae or values of constants will be provided!
  - Must send me the photos of front and back of the formula sheet, including the blank, no later than **11am the day of the test**
    - Once submitted, you cannot change, unless I ask you to delete some part of the sheet!

SP#5 – Civic Duty II: Election Participation

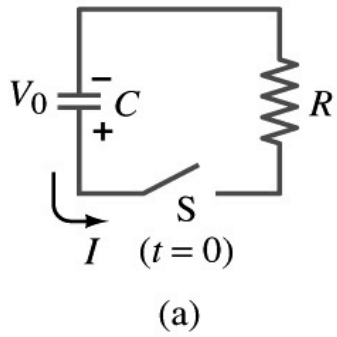
- Election is over! Deadline: **1pm, Monday, Nov. 9**
- For those with legal voting rights: You can submit three access code green sheet for 20 points total – one your own and two others who voted, 5 points each. Any additional ones will earn 2 points each
- For those without legal voting rights: You can submit for the first four access code green sheets for 20 points total, 5 points each and any additional combinations 2 points each.
- Be sure to tape one side of the access code (or "I Voted" sticker if the voting was not using an electronic machine) on a sheet of paper with the date, the precinct number, the name of the person voted
- None of the stickers can be from the same person on someone else's extra credit or on your own. All of those with any of the identical persons on your extra credit sheet will get 0 credit.
- Deadline: Beginning of the class **Monday, Nov. 9**

Access code sheet/Sticker

This must be accompanied with date of the vote, the county name, the precinct number, the full name of the person voted and the signature of the person

Discharging RC Circuits

- When a capacitor is already charged, it is allowed to discharge through a resistance R.
  - When the switch S is closed, the voltage across the resistor at any instant equals that across the capacitor. Thus IR=Q/C.
  - The rate at which the charge leaves the capacitor equals the negative of the current flows through the resistor
    - I= - dQ/dt
    - This is because the current is leaving the capacitor
  - Then the voltage equation becomes a differential equation



(a)

$$-\frac{dQ}{dt}R = \frac{Q}{C} \quad \xrightarrow{\text{Rearrange terms}} \quad \frac{dQ}{Q} = -\frac{dt}{RC}$$

Discharging RC Circuits

– Now, let's integrate from t=0 when the charge is Q_0 to t when the charge is Q $\int_{Q_0}^{Q} \frac{dQ}{Q} = -\int_0^t \frac{dt}{RC}$

– The result is $\ln Q\Big|_{Q_0}^{Q} = \ln \frac{Q}{Q_0} = -\frac{t}{RC}$

– Thus, we obtain $Q(t) = Q_0 e^{-t/RC}$

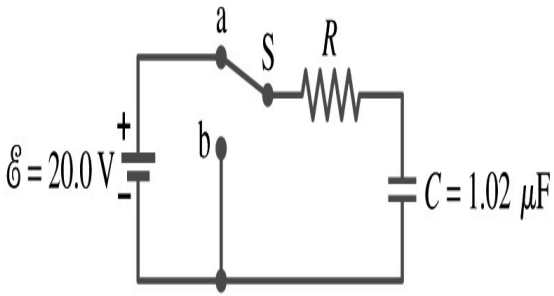
– What does this tell you about the charge on the capacitor?

- It decreases exponentially w/ time at the time constant RC
- Just like the case of charging

– The current is: $I = -\frac{dQ}{dt} = \frac{Q_0}{RC} e^{-t/RC}$ What is this? $I(t) = I_0 e^{-t/RC}$

- The current also decreases exponentially w/ time w/ the time constant RC

Example 26 – 13



Discharging RC circuit. In the RC circuit shown in the figure the battery has fully charged the capacitor, so $Q_0=C\mathcal{E}$. Then at t=0, the switch is thrown from position a to b. The battery emf is 20.0V, and the capacitance C=1.02μF. The current I is observed to decrease to 0.50 of its initial value in 40μs. (a) what is the value of R? (b) What is the value of Q, the charge on the capacitor, at t=0? (c) What is the value of Q at t=60μs?

(a) Since the current reaches to 50% of its initial value in 40μs, we can obtain

$$I(t)=I_0e^{-t/RC} \xrightarrow{\text{For } 0.5I_0} 0.5I_0=I_0e^{-t/RC} \xrightarrow{\text{Rearrange terms}} -t/RC=\ln 0.5=-\ln 2$$

Solve for R

$$R=t/(C\ln 2)=40\times10^{-6}/(1.02\times10^{-6}\cdot\ln 2)=56.6\Omega$$

(b) The value of Q at t=0 is

$$Q_0=Q_{\max}=C\varepsilon=1.02\times10^{-6}\cdot 20.0=20.4\mu C$$

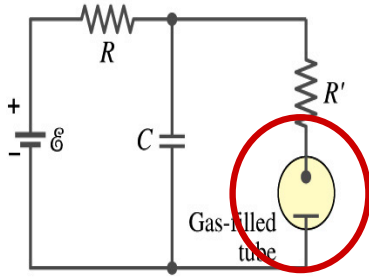
(c) What do we need to know first for the value of Q at t=60μs?

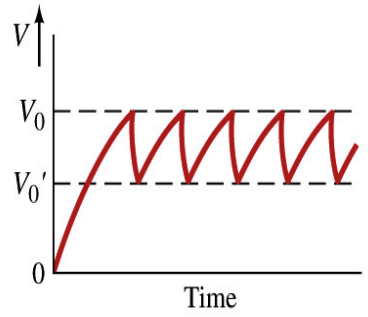
The RC time $\tau=RC=56.6\cdot1.02\times10^{-6}=57.7\mu s$

Thus $Q(t=60\mu s)=Q_0e^{-t/RC}=20.4\times10^{-6}\cdot e^{-60\mu s/57.7\mu s}=7.2\mu C$

Application of RC Circuits

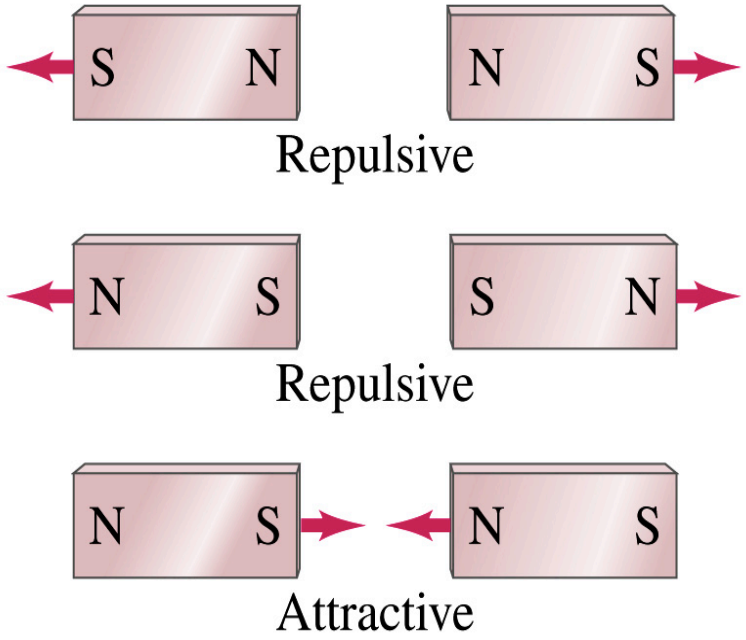
- What do you think the charging and discharging characteristics of RC circuits can be used for?
  - To produce voltage pulses at a regular frequency
  - How?
    - The capacitor charges up to a particular voltage and discharges
    - A simple way of doing this is to use breakdown of voltage in a gas filled tube
      - The discharge occurs when the voltage breaks down at V_0
      - After the completion of discharge, the tube no longer conducts
      - Then the voltage is at V_0' and it starts charging up
      - How do you think the voltage as a function of time look?
        - » A sawtooth shape
    - Pacemaker, intermittent windshield wiper, etc





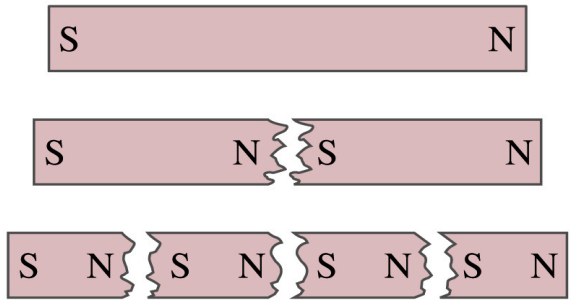
Magnetism

- What are magnets?
  - Objects with two poles, North and South poles
    - The pole that points to the geographical North is the North pole and the other is the South pole
      - Principle of compass
  - These are called the magnet due to the name of the region, Magnesia, where the rocks that attract each other were found
- What happens when two magnets are brought to each other?
  - They exert force onto each other
  - What kind?
  - Both repulsive and attractive forces depending on the configurations
    - Like poles repel each other while the unlike poles attract



Magnetism

- So the magnetic poles are the same as the electric charge? (poll 14)
  - No. Why not?
  - While the electric charges (positive and negative) can be isolated, the magnetic poles cannot be isolated.
  - So what happens when a magnet is cut?
    - If a magnet is cut, two magnets are made.
    - The more they get cut, the more magnets are made



  - Single pole magnet is called the monopole but it has not been seen yet
- Ferromagnetic materials: Materials that show strong magnetic effects
  - Iron, cobalt, nickel, gadolinium and certain alloys
- Other materials show very weak magnetic effects

Magnetic Field

- Just like the electric field that surrounds electric charge, the magnetic field surrounds a magnet
- What does this mean?
  - Magnetic force is also a field force
  - The force one magnet exerts onto another can be viewed as the interaction between the magnet and the magnetic field produced by the other magnet
  - What kind of quantity is the magnetic field? (poll 2) **Vector**
- So one can draw magnetic field lines, too.
  - The direction of the magnetic field is **tangential to the field line at any point**
  - The direction of the field is the direction the north pole of a compass would point to; **out of N and into S**
  - The number of lines per unit area is proportional to the strength of the magnetic field
  - Magnetic field lines continue inside the magnet
  - Since magnets always have both the poles, magnetic field lines **form closed loops** unlike electric field lines