Physics 122 – Class #26 – (4/16/15)

- Announcements
- RC Circuits
- Magnetism

Announcements

- Read Ch. 32 for Tuesday, excepting sections 32.9, 32.10
- Written Homework 31.45, 31.60, 31.70 (due next Thurs)
- Test #3 is 1 week from today
  - Ch. 28, 29, 30, 31

Unidentified Clickers

- Baugh, Ben
- Burgess, Patrick
- Hammond, Joseph
- Holguin, Brandon
- Ludi, Jordan
- Misla, Aaron
- Philips, Nicholas
- Reyes, Andres
- Woolridge, Ryan

Physics 122 – Class #26 – (4/16/15)

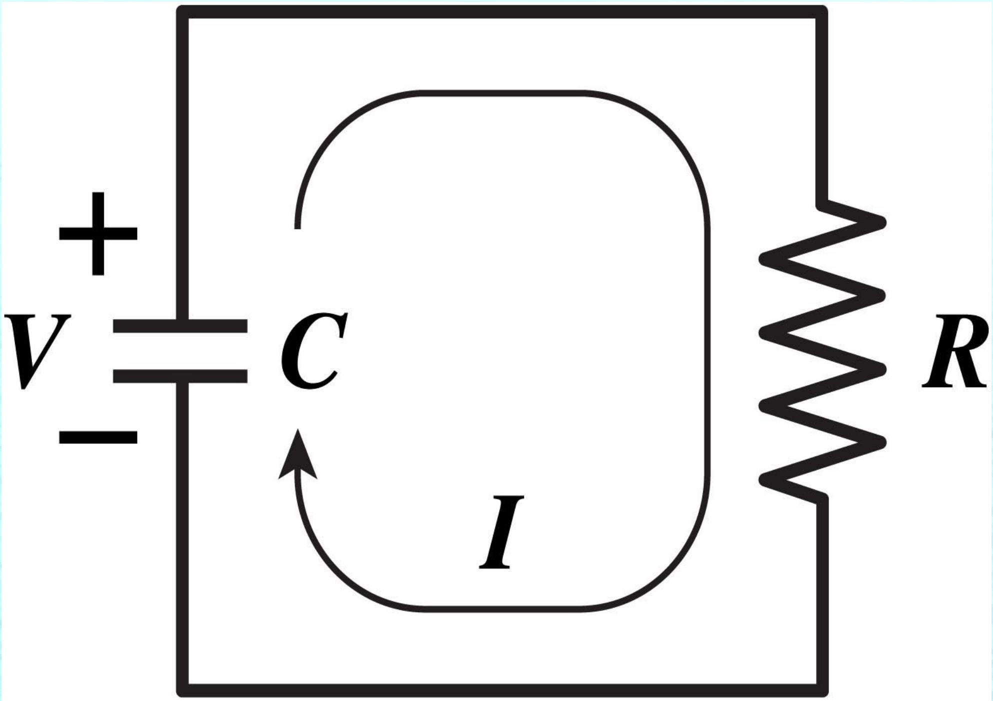
- RC Circuits
- Magnetism

RC Circuits

A circuit with both a resistor and a capacitor in it is called an “RC-circuit”.

A circuit of pure resistors comes to equilibrium in less than a picosecond.

RC circuits have a characteristic time $\left(\tau = RC\right)$
Before they reach equilibrium.



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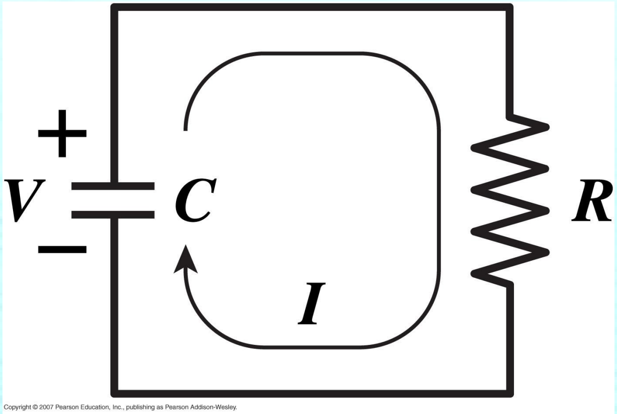
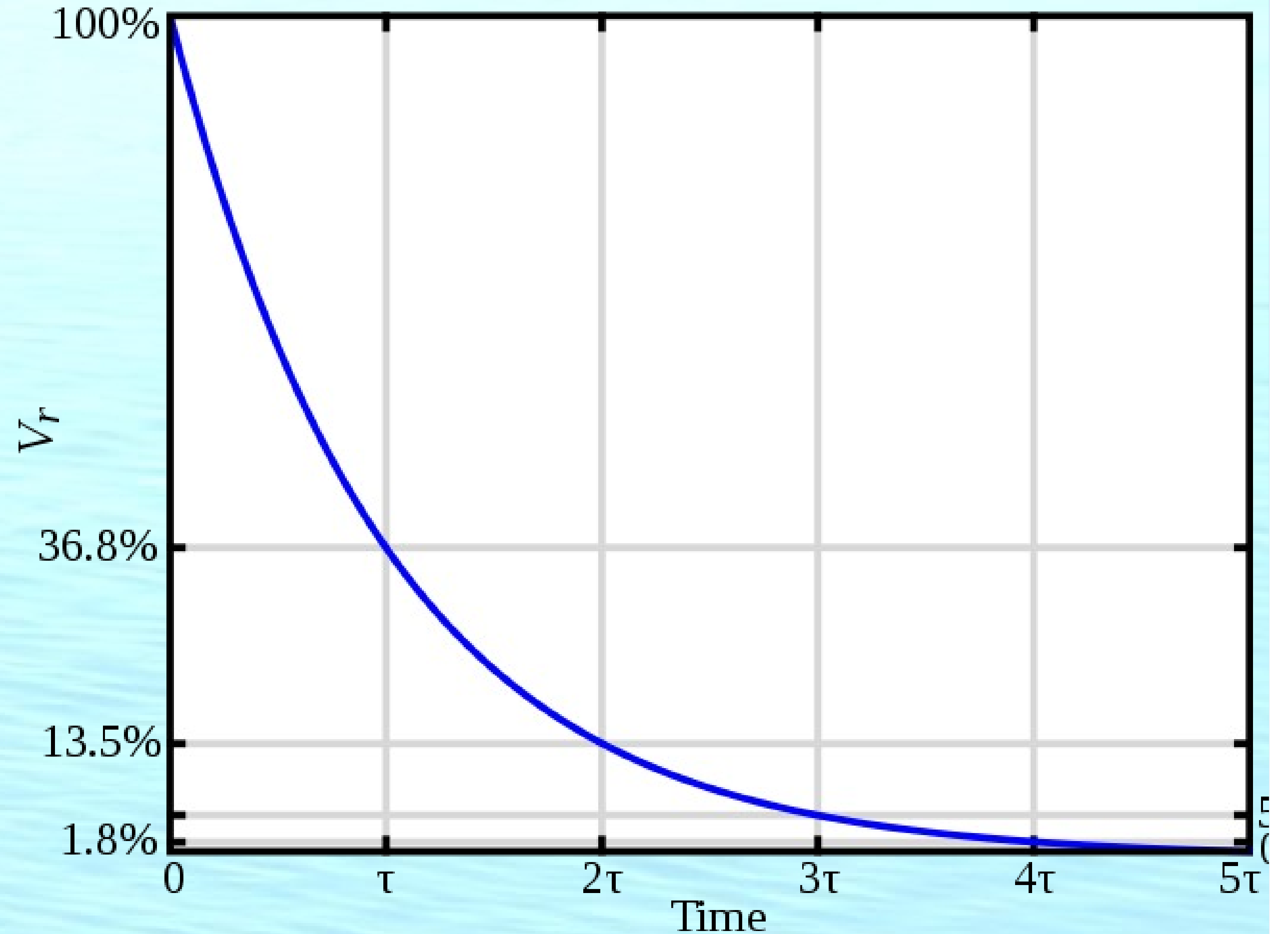
If capacitor begins charged --->

$$Q_C = Q_0 e^{-t/RC}$$

$$V_C = V_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$





If capacitor begins charged ---> $Q_C = Q_0 e^{-t/\tau}$

$\tau = RC$

$$V_C = V_0 e^{-t/\tau}$$

$$I = I_0 e^{-t/\tau}$$

Is an Ohm Farad really a second?

$$Q = CV \rightarrow C = \frac{Q}{V} \rightarrow [\text{Farad}] = \frac{[\text{Coul}]}{[\text{Volt}]}$$

$$V = IR \rightarrow R = \frac{V}{I} \rightarrow [\text{Ohm}] = \frac{[\text{Volt}]}{[\text{Amp}]}$$

$$RC = [\text{Ohm}][\text{Farad}] = \frac{[\text{Volt}]}{[\text{Amp}]} \times \frac{[\text{Coul}]}{[\text{Volt}]}$$

$$RC = \frac{[\text{Coulomb}]}{[\text{Amp}]} = \frac{[\text{Coul}]}{[\text{Coul/second}]} = \text{seconds!}\text{¿}$$

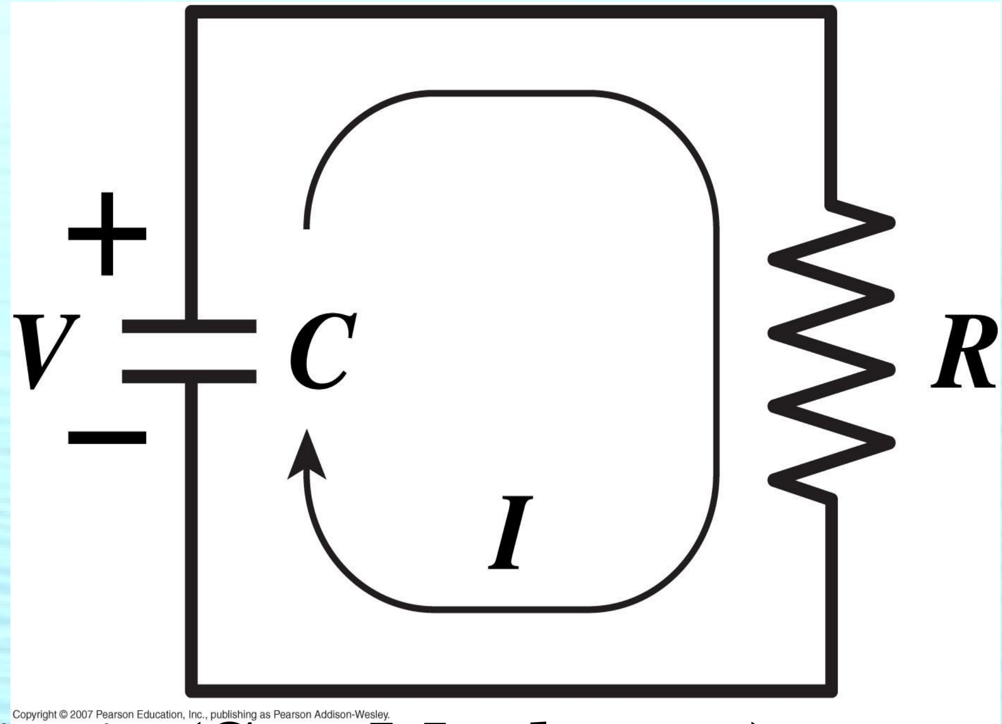
RC Circuits Demo (RC_time_constant1.avi)

$C = 0.5\ [\text{Farad}], \tau = 0.3\,\text{sec}, R = ?$

Method of "Guesses"

$$V + IR = 0 \rightarrow \frac{Q}{C} + \frac{dQ}{dt} R = 0$$

$$\frac{dQ}{dt} = -\frac{Q}{RC}$$



A differential equation is an equation with a derivative (one or more) in it (See Math 335)

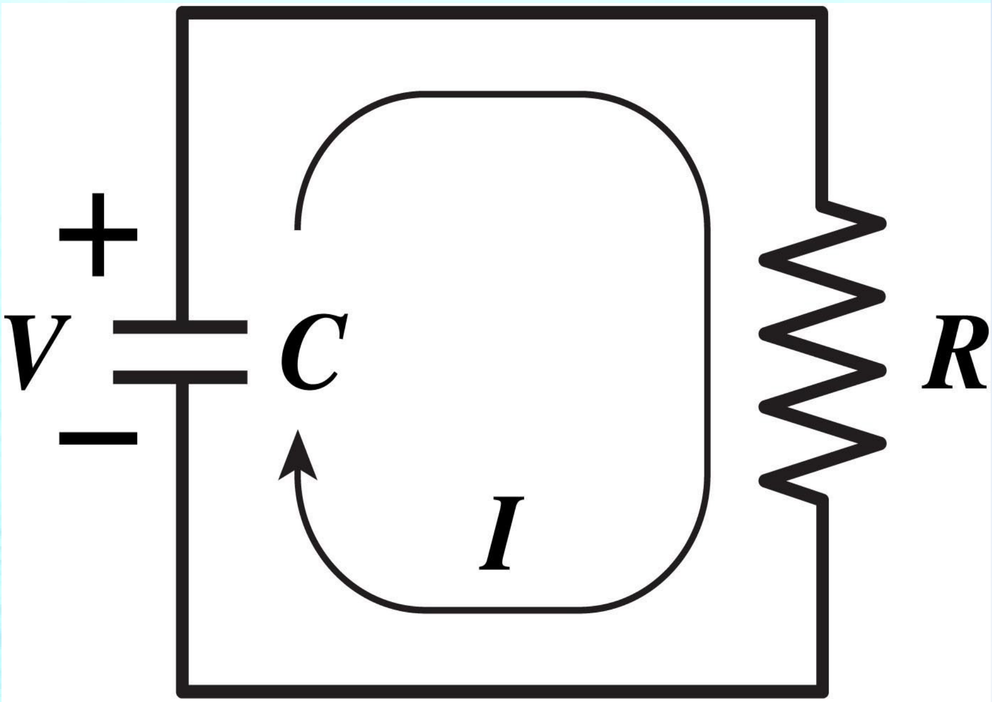
$$\frac{d}{dt} e^t = e^t$$

$$\frac{d}{dt}\left(Ze^{at} + \text{Constant}\right) = aZe^{at}$$

Method of "Guesses"

$$\frac{dQ}{dt} = -\frac{Q}{RC}$$

$$\frac{d}{dt}\left(Ze^{at} + Const.\right) = aZe^{at}$$



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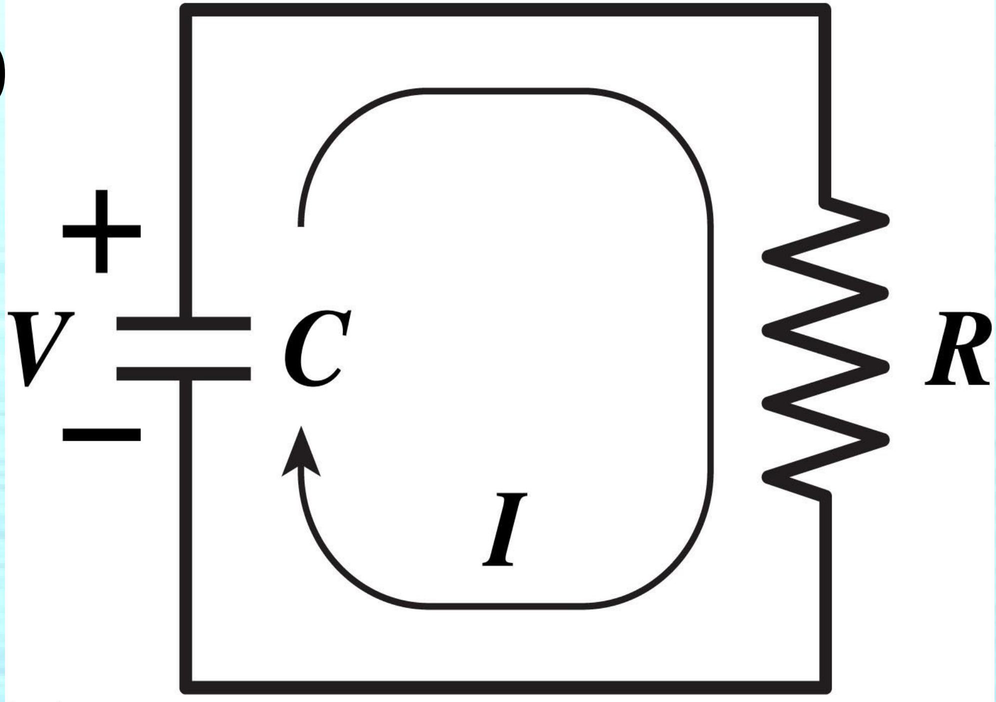
Direct integration method

$$V + IR = 0 \rightarrow \frac{Q}{C} + \frac{dQ}{dt}R = 0$$



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$$\frac{dQ}{dt} = -\frac{Q}{RC}$$

$$\frac{dQ}{Q} = -\frac{dt}{RC}$$

$$\int \frac{dQ}{Q} = -\frac{1}{RC}\int dt$$

$$\ln Q = -\frac{t}{RC} + \kappa$$

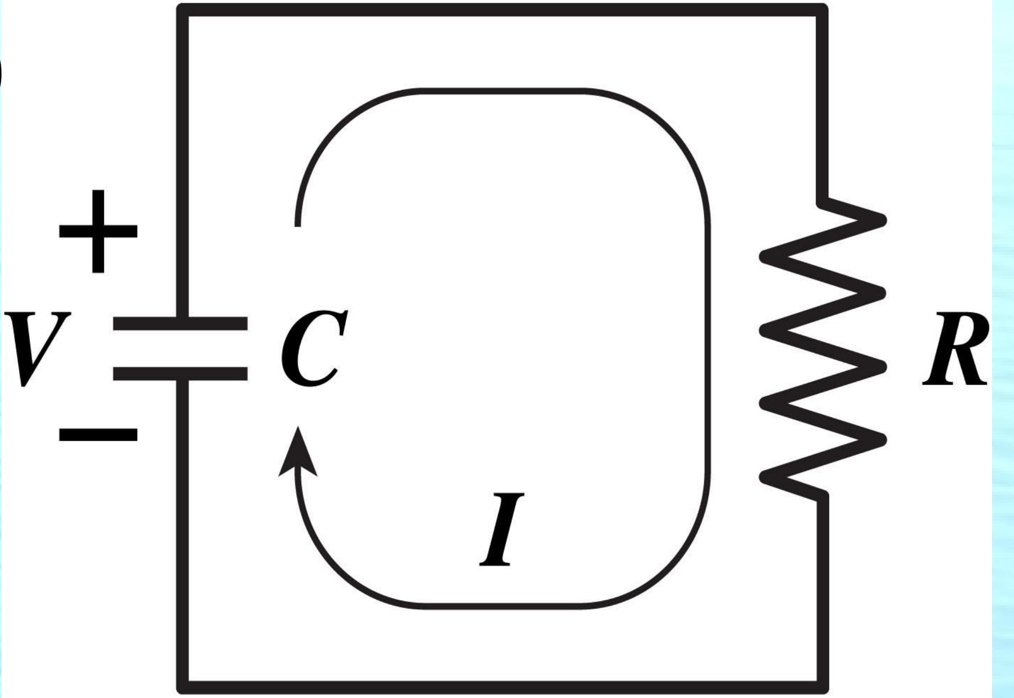
$$Q = e^{-t/RC}e^{\kappa}$$

$$Q = Q_0 e^{-t/RC}$$

$$V_C = \frac{Q_0}{C}e^{-t/RC}$$

If capacitor begins charged ...

$$V + IR = 0 \rightarrow \frac{Q}{C} + \frac{dQ}{dt}R = 0$$



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$$\frac{dQ}{dt} = -\frac{Q}{RC}$$

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$$\ln Q = -\frac{t}{RC} + \kappa$$

$$Q = e^{-t/RC} e^{\kappa}$$

$$Q = Q_0 e^{-t/RC}$$

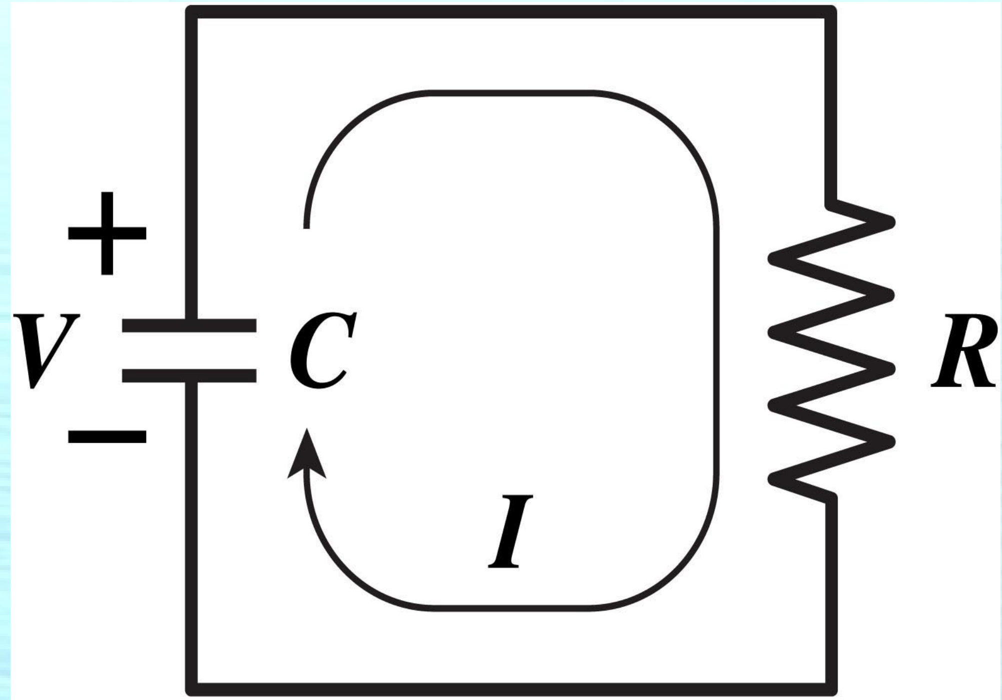
$$V_C = \frac{Q_0}{C} e^{-t/RC}$$

If capacitor begins charged ...

$$\frac{dQ}{dt} = -\frac{Q}{RC}$$

$$Q = Q_0 e^{-t/RC}$$

What is I(t)?



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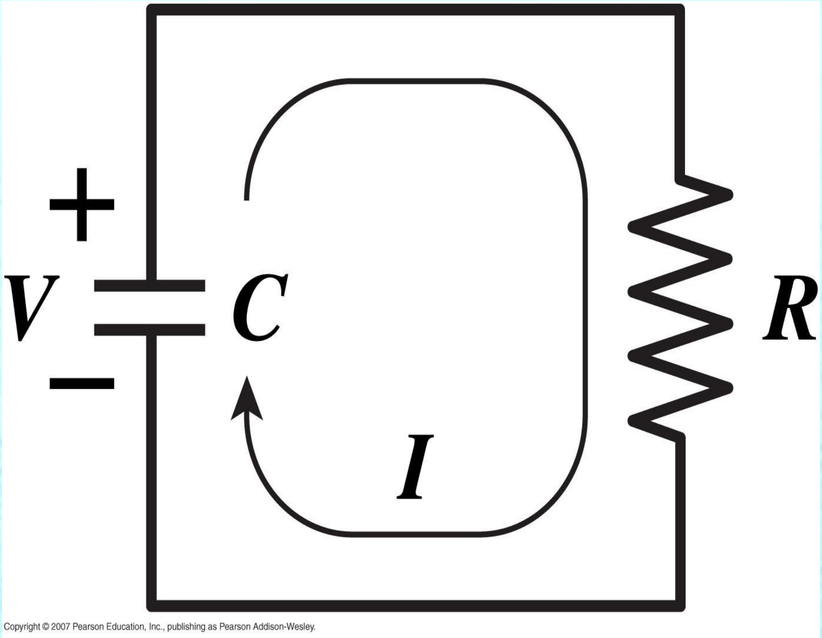
Given $Q(t) = Q_0 e^{-t/RC}$

And $I(t) = \frac{-dQ}{dt}$

What is $I(t)$?



$[A]\ Q_0 e^{-t/RC}$

$[B]\ Q_0 RC e^{-t/RC}$

$[C]\ -Q_0 RC e^{-t/RC}$

$[D]\ \frac{1}{RC} e^{-t/RC}$

$[E]\ \frac{Q_0}{RC} e^{-t/RC}$

RC Circuits

RC circuits have a characteristic time $(\tau = RC)$
Before they reach equilibrium. Note that R and C never appear alone

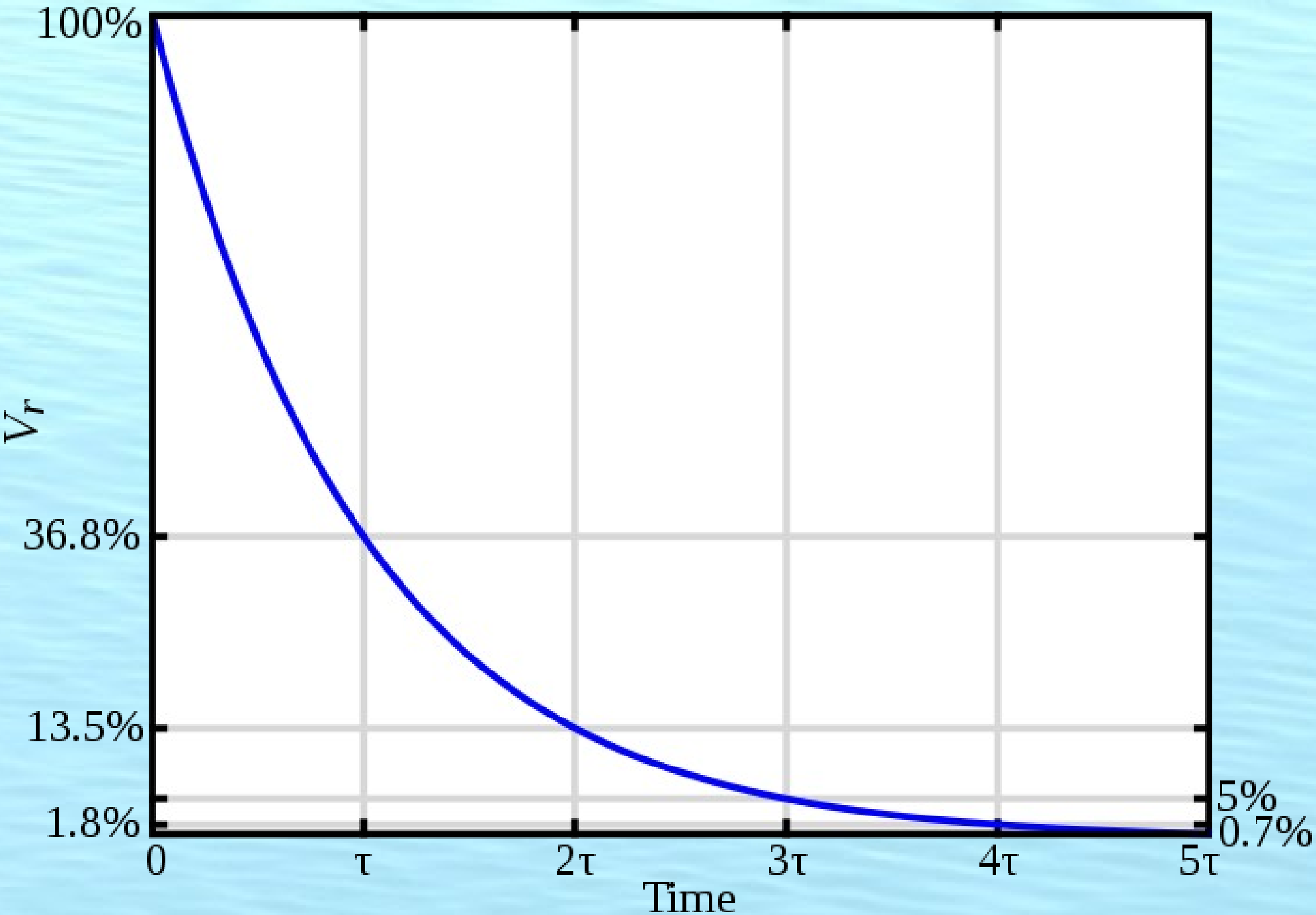
$$Q = Q_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

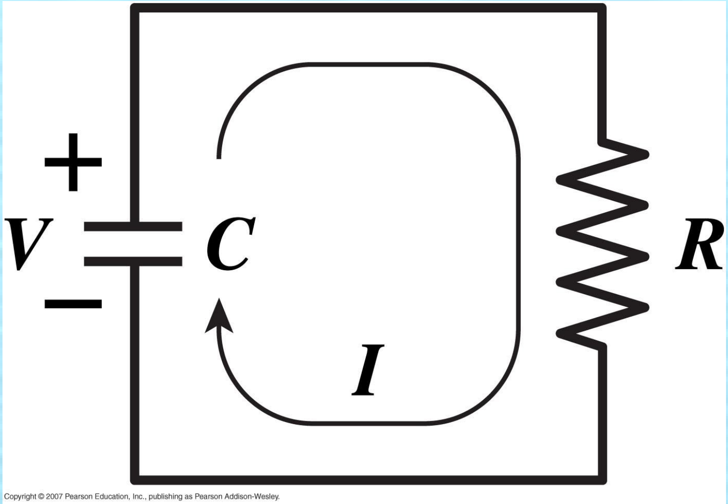
$$I = -\frac{Q_0}{RC} e^{-t/RC}$$

$$V_C = V_0 e^{-t/RC}$$

$$V_C = \frac{Q_0}{C} e^{-t/RC}$$



A 200 kΩ resistor is in series with C=10 μF. A t=0, the voltage on the capacitor is 8 V. What is the voltage on the capacitor and the current through the resistor after 1 sec, 2 sec and 4 seconds?



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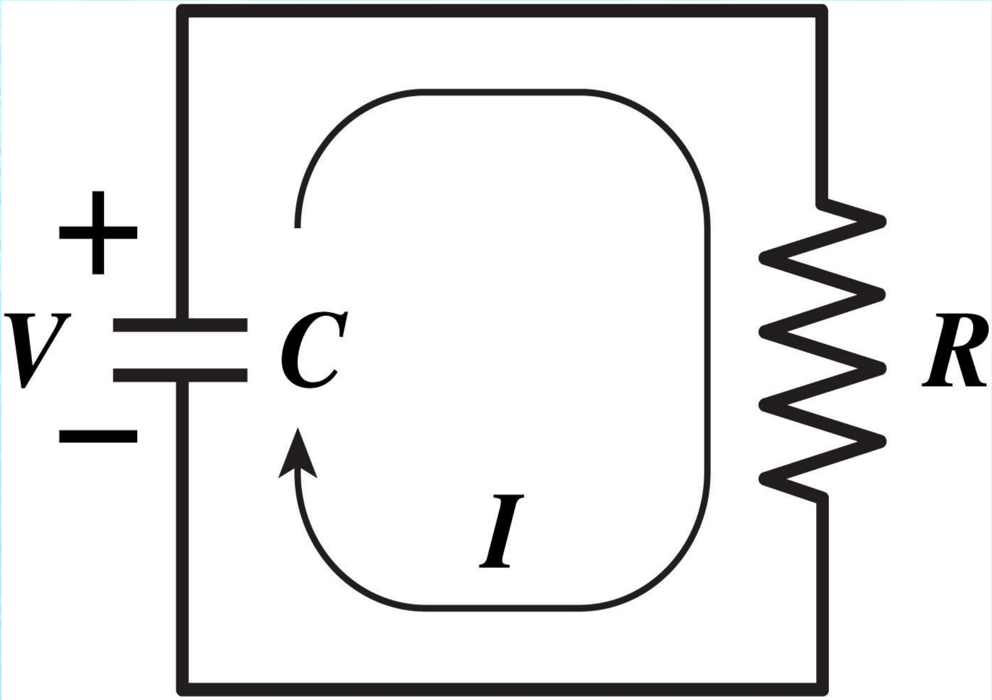
A 200 $k\Omega$ resistor is in series with $C=10\,\mu F$. A t=0, the voltage on the capacitor is 8 V. What is the voltage on the capacitor and the current through the resistor after 1 sec, 2 sec and 4 seconds?

$$I=I_0 e^{-t/RC} \qquad I=\frac{V_0}{R}e^{-t/RC}$$

$$V=V_0 e^{-t/RC}$$

$$RC=(2.0\times10^{5}\,\Omega)(1.0\times10^{-5}\,F)$$



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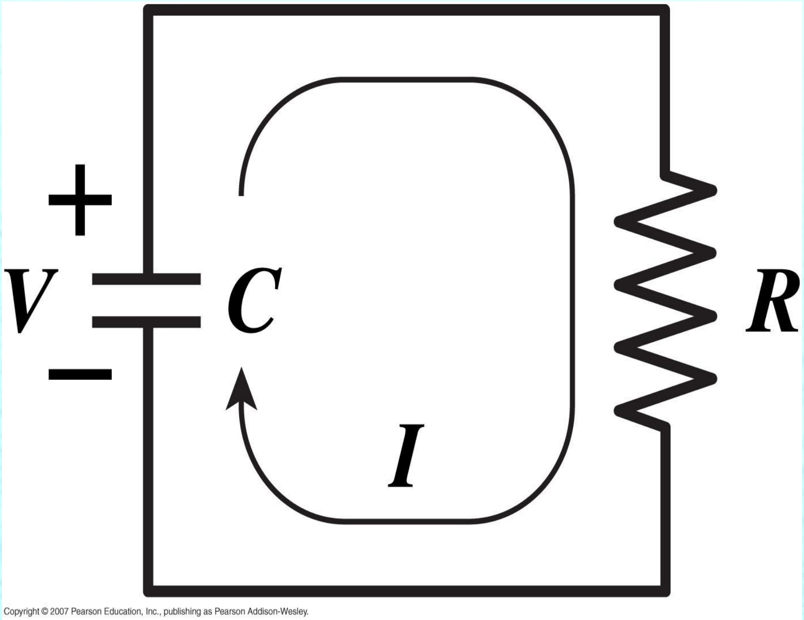
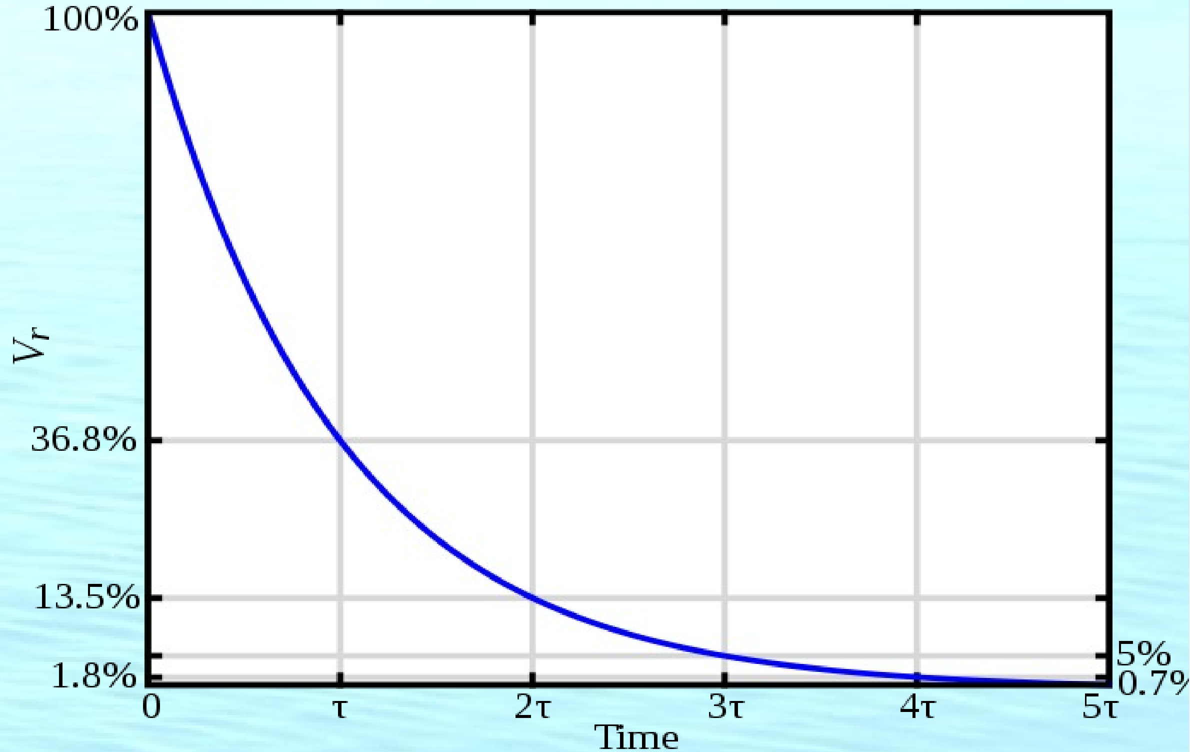
$$V(4)=8e^{-4.00s/2.00s}\text{ Volts}$$

$$V(4)=8\times0.135=1.08\text{ Volts}$$

Time for pHeT (AC Circuits Lab)





In this circuit, where capacitor begins charged --->

$$V_C = V_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

Find the resistance needed in an RC circuit to discharge a 20 μF capacitor to 55% of full charge in 140 ms.

Find the resistance needed in an RC circuit to discharge a $20\ \mu F$ capacitor to 55% of full charge in 140 ms.

$$Q_C = Q_0 e^{-t/RC}$$

$$0.55\,Q_0 = Q_0 e^{-t/RC}$$

$$0.55 = e^{-t/RC}$$

$$\ln(0.55) = \ln\left(e^{-t/RC}\right)$$

$$-0.597 = \frac{-t}{RC}$$

$$R = \frac{t}{0.597\,C}$$

$$R = \frac{1.40 \times 10^{-1}\ \text{s}}{0.597 \cdot 2.0 \times 10^{-5}\ \text{F}}$$

$$R = 11.74\ \text{k}\Omega$$

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- Magnetism

Electricity and Magnetism

Electricity from the Greek *elektrum* (amber). The ancient Greeks were rubbing rods.

Magnetism from the Greek region of *Magnesia* where natural magnets were found.

Originally considered separate, now known to be tightly unified into "electromagnetism"

Electricity and Magnetism

Static Electricity – Ch. 25, 26 Forces & fields of non-moving (static) charges. Voltage is potential energy per unit charge (Ch. 28), or E-field acting through a distance (Ch. 29).

Currents and Circuits (Electrodynamics) – Ch 30, 31. Practical electric circuits and how currents happen and what resistance means.

Static Magnetism – Ch. 32. Constant currents create constant B-fields which put force on moving charges (

Ch. 33 – Induction and electromagnetism – When currents change, they cause changing magnetic fields AND electric fields… and light!

Electricity

Charges create electric fields (E-fields)

Positive charges emit Field lines, negative charges Absorb field lines.

Charges feel electric Fields whether the charges Are moving or not.

$$\vec{F} = q\vec{E}$$

Magnetism

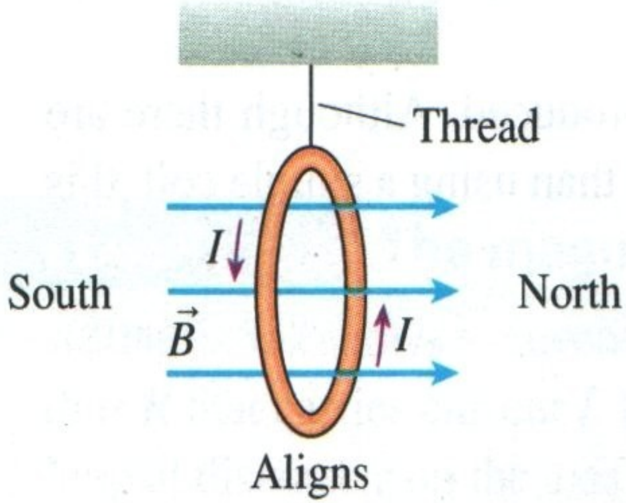
Moving charges (or currents) Create B-fields

North poles emit field lines, south Poles absorb them.

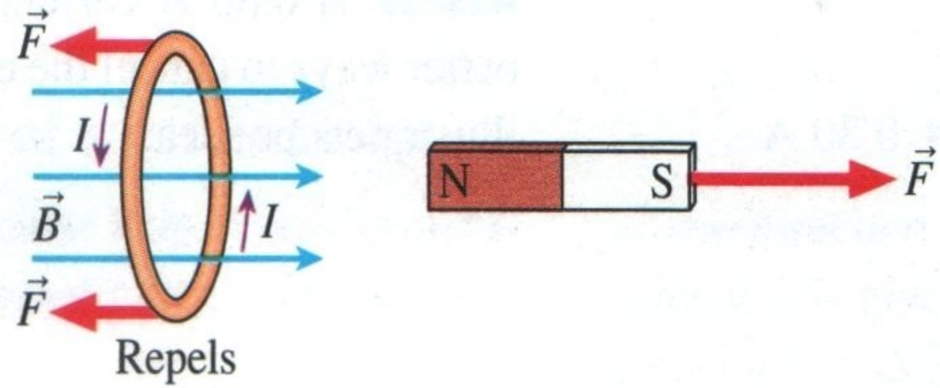
Only moving charges or currents Feel magnetic fields

$$\vec{F} = q\vec{v} \times \vec{B}$$

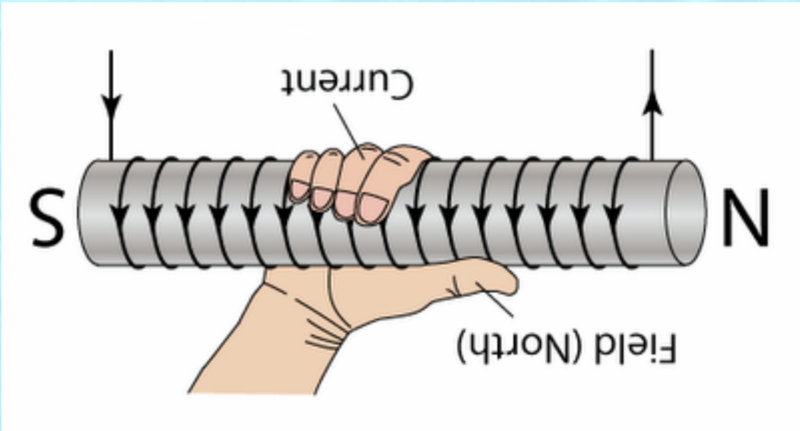
Investigating current loops

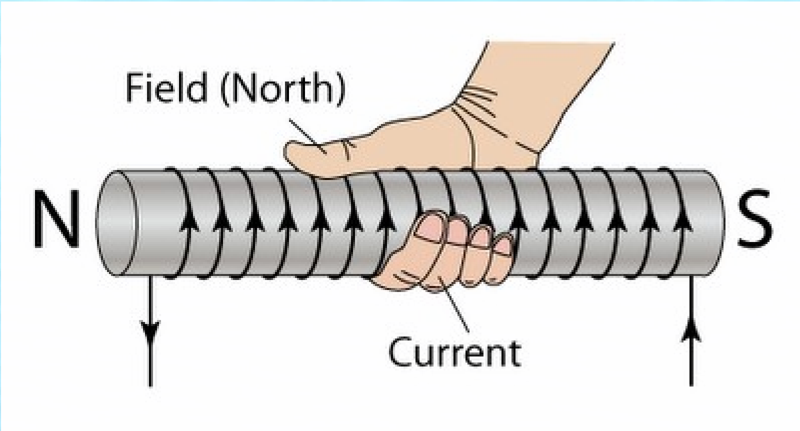


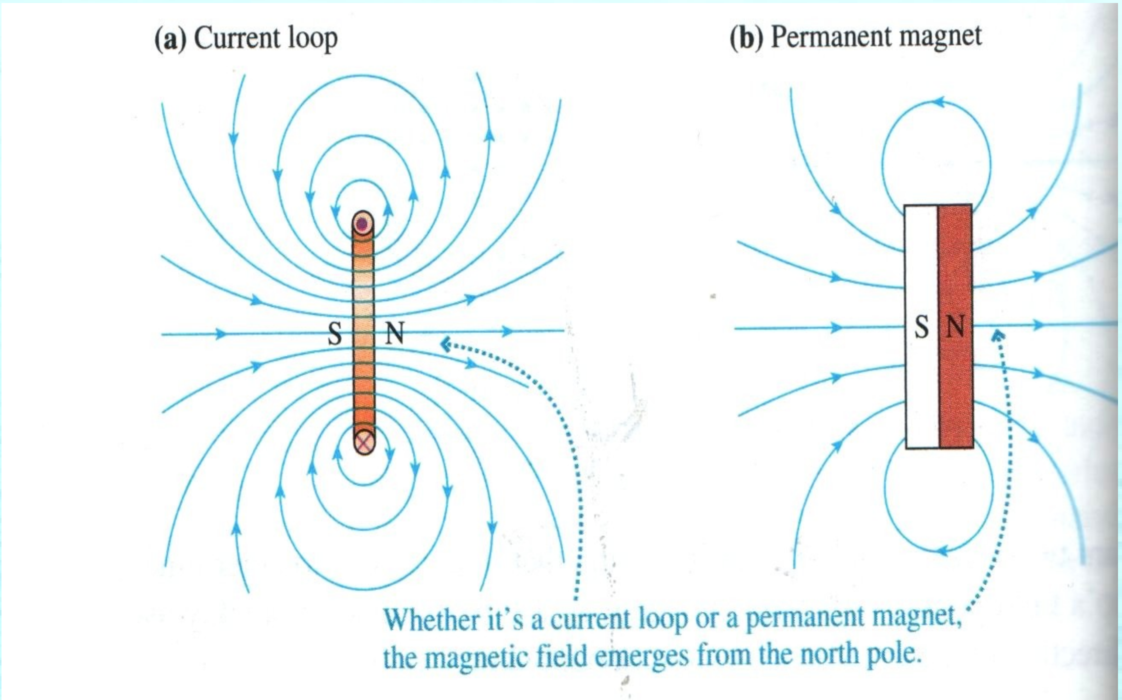
A current loop hung by a thread aligns itself with the magnetic field pointing north.

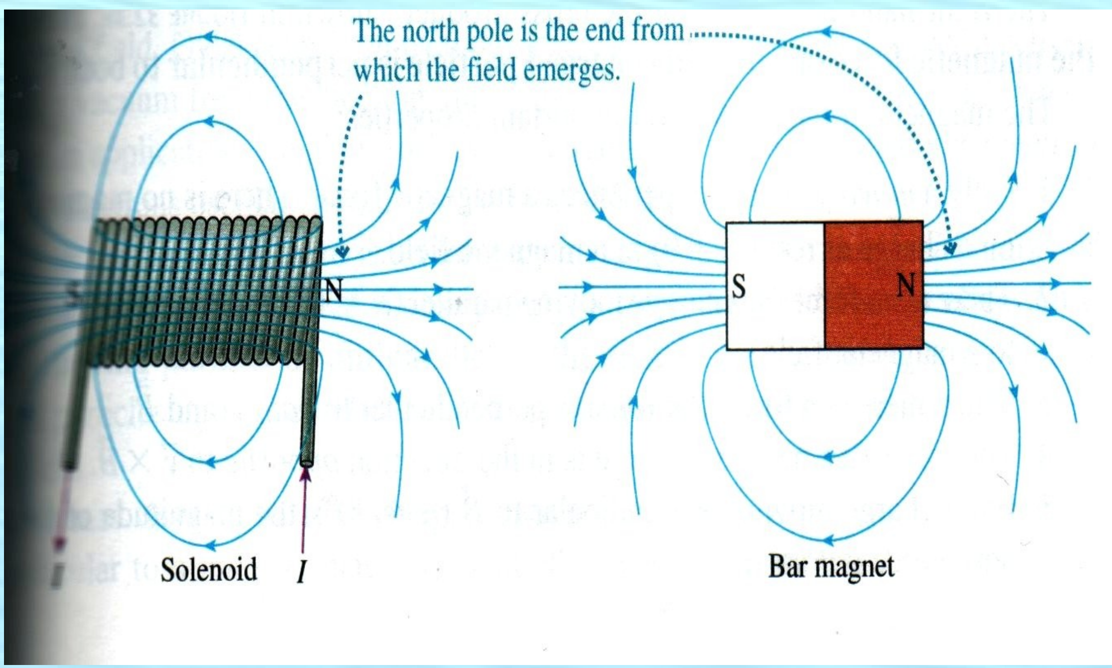


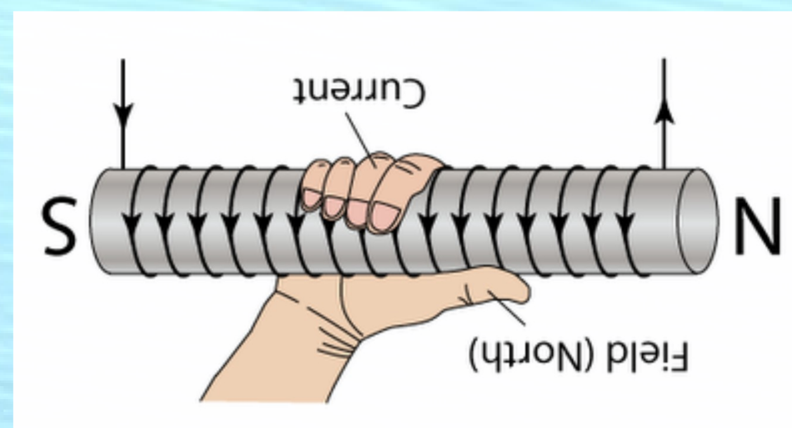
The north pole of a permanent magnet repels the side of a current loop from which the magnetic field is emerging.

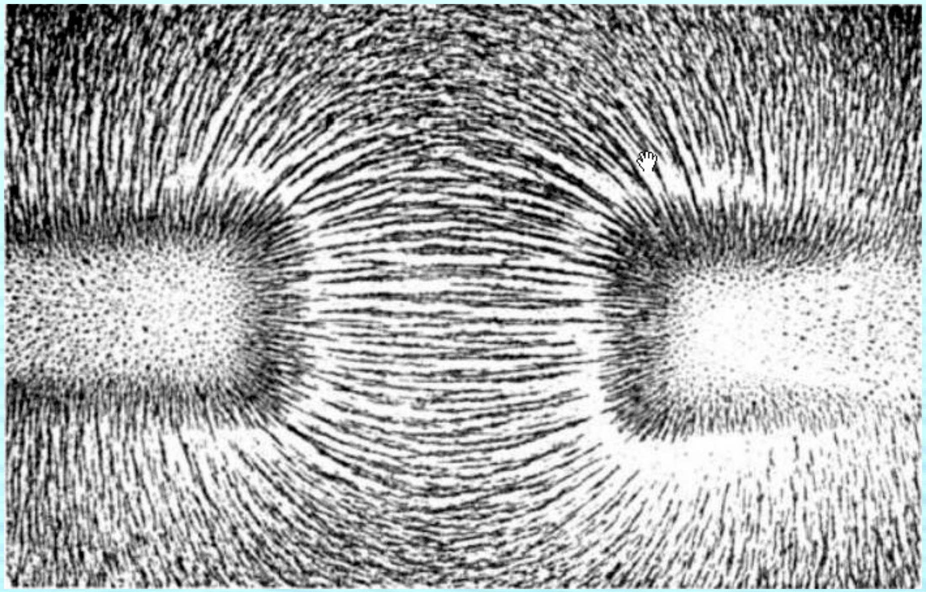


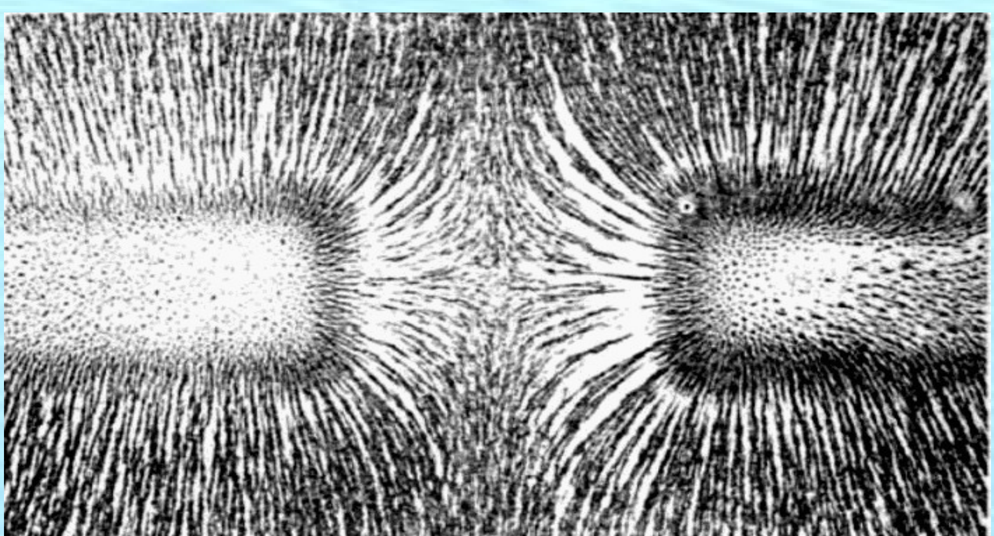



(a) Current loop
(b) Permanent magnet
S
N
S
N
Whether it's a current loop or a permanent magnet, the magnetic field emerges from the north pole.


The north pole is the end from which the field emerges.
N
S
N
Solenoid
I
Bar magnet


Current
S
N
Field (North)





The top and bottom Pictures are:

[A] Two North poles and Two South Poles
[B] Two South Poles and Two North Poles
[C] A north-south pair And Two North Poles
[D] A north-south pair And either two North or Two south poles

Where do magnetic fields come from?

Magnetic fields come from moving charges. If you have lots of moving charges, you have a current. Magnetic fields come from currents.
But … magnetic fields also come from magnets!!
What can you conclude about magnets?
[A] Magnets are just different
[B] Magnets are made of magnetic materials, they don't need currents.
[C] Magnets contain currents
[D] Nothing makes sense, where is the battery in a magnet … how can there be a current w/ no voltage source?
[E] C and D.

What do I need to know?

Magnetic field around a straight wire is circular

A loop of wire acts like a magnet with north pole given by right hand rule.

A “solenoid” acts like a bar magnet with north pole given by RH rule.

Given a magnetic field, what is the force on a current or on a moving charge?

http://www.youtube.com/watch?v=4BdKQIOzgf0
Magnetic field around a wire.

Tinyurl.com/WireBField

http://www.youtube.com/watch?v=XUz1ZI-w6LQ
Beautiful ferrofluid sculpture to music. Start 1:50 in.

Tinyurl/ferrofluidsculpture

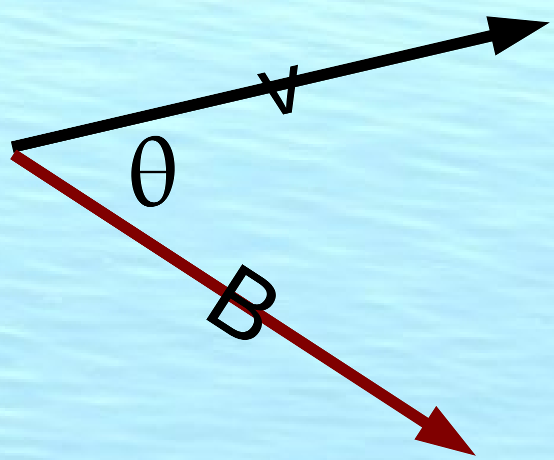
Iron filings in mineral oil.
http://www.youtube.com/watch?v=CgDYx3B8c_I

Tinyurl.com/3DBField <-- Useful because it remind people the fields are 3D..

Magnetic field is measured in “Tesla” (T)
Forces are at right angles to fields.
Forces are velocity dependent.

$$\vec{F} = q\,\vec{v} \times \vec{B}$$

$$F = q\,v\,B \sin(\theta)$$

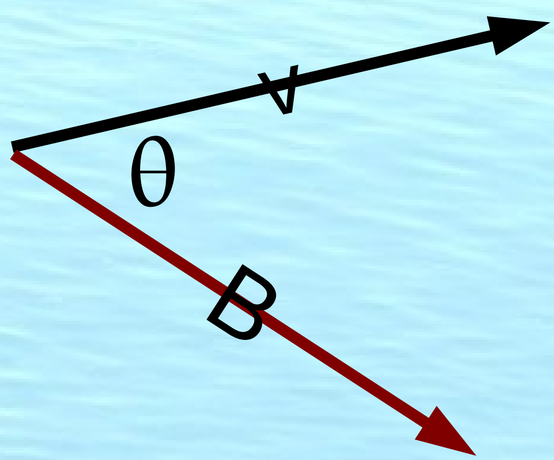


Find the magnitude of the magnetic force on a proton moving at $v = 2.5\times10^{5}\,m/s$ Perpendicular, at 30 degrees, parallel to a 0.5 T magnetic field.

Magnetic force on a charge --->

$$\vec{F} = q\,\vec{v}\times\vec{B}$$

$$F = q\,v\,B\sin(\theta)$$

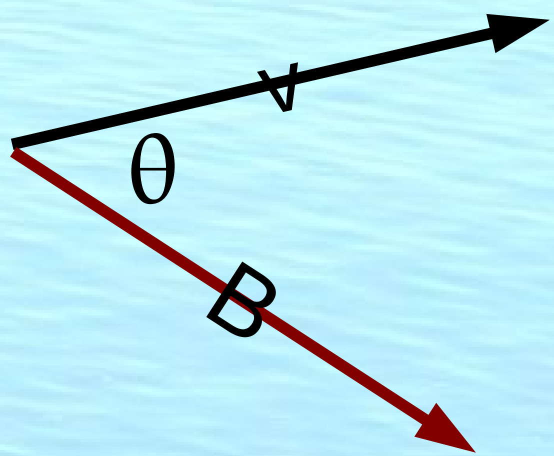


Find the magnitude of the magnetic force on a proton moving at $v = 2.5\times10^{5}\,\mathrm{m/s}$ at 30 degrees to a 0.5 T magnetic field.

Magnetic force on a charge --->

$$\vec{F} = q\,\vec{v}\times\vec{B}$$

$$F = q\,v\,B\sin(\theta)$$



$$F = (1.6\times10^{-19}\ \mathrm{C})(2.5\times10^{3}\ \mathrm{m/s})(0.5\ \mathrm{T})(\sin(30))$$