Unit 5: Electricity and Magnetism

Review of Electrostatics:

1. Law of Electric Charges — like charges repel
— unlike charges attract
— neutral ⟶ both

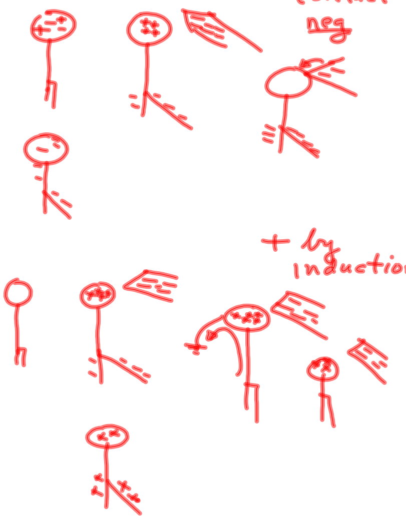
2. Conductors vs Insulators and more

conductor
insulator
resistor
semiconductor
superconductor

3. Methods of charging an object

contact
neg

+ by induction



Electric Force (Coulomb's Law)

$$F_{el} = k\frac{Q_1 Q_2}{r^2}$$

$k = 9\times10^{9}\ \frac{Nm^2}{C^2}$

arbitrary

$G = 6.67\times10^{-11}$

$e = 1.6\times10^{-19}\ C$

charge on 1 electron

$-e$

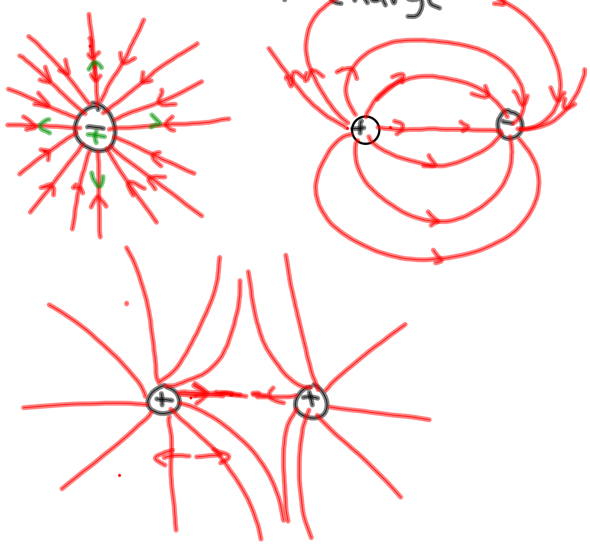
$Q = ne$

Electric Fields

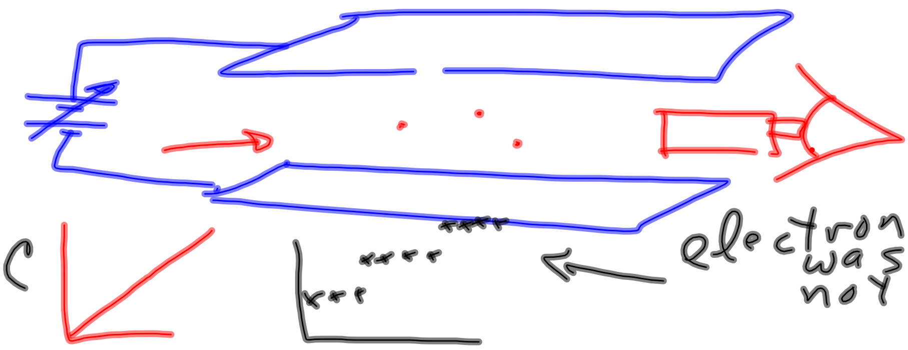
field ⇒ region of influence

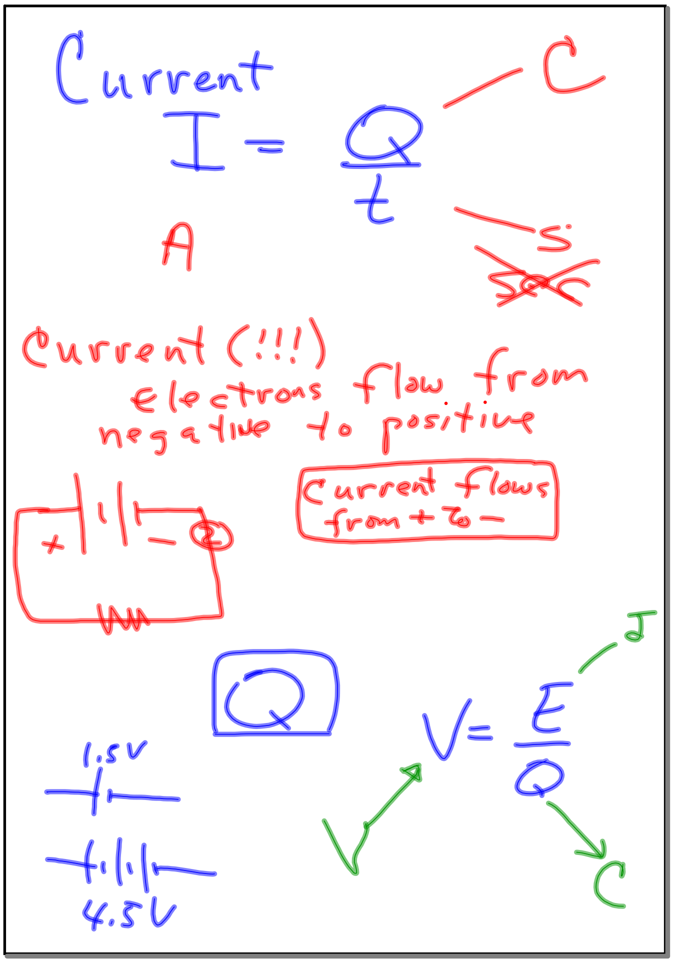
by convention...

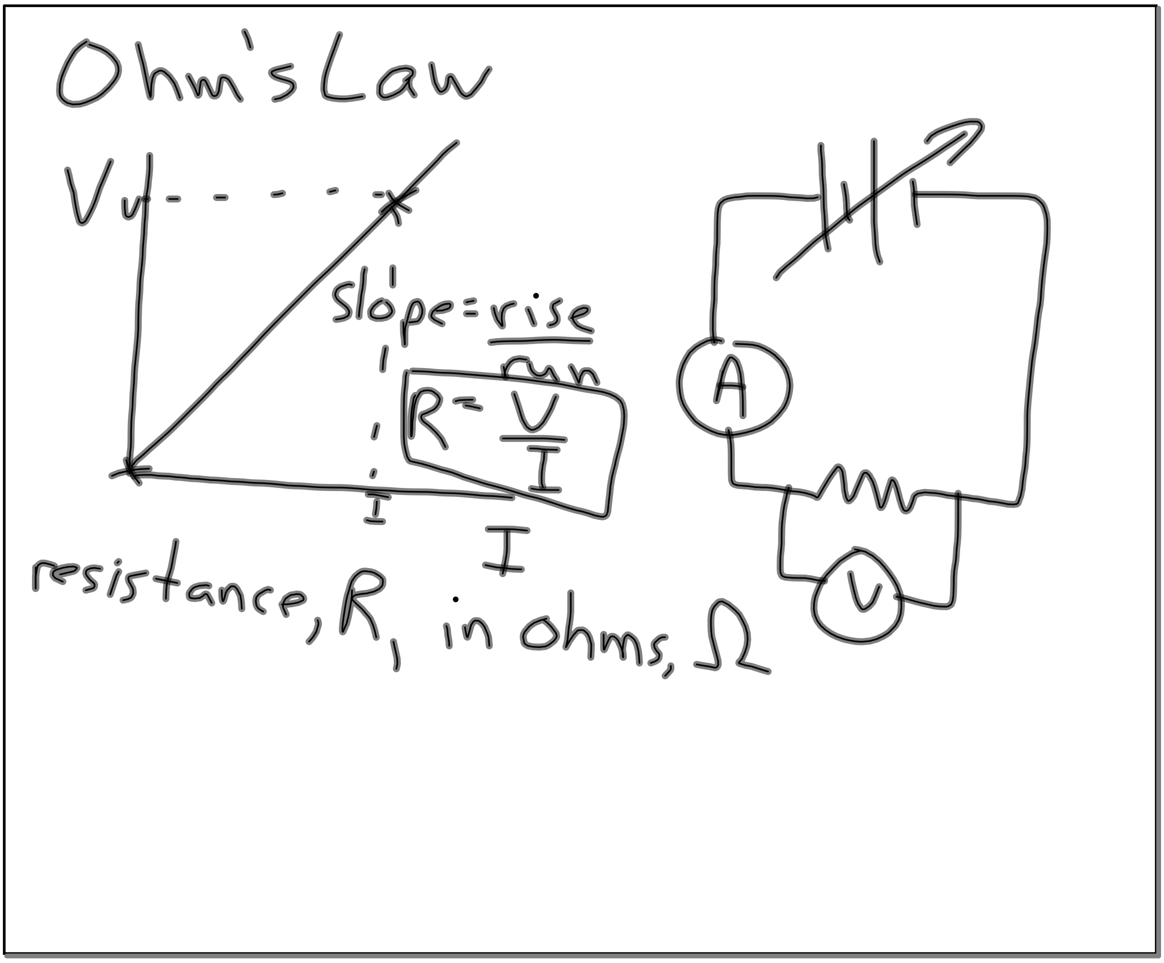
...the direction of the electric field is the direction of the force on a + charge



Millikan's Oil Drop Experiment

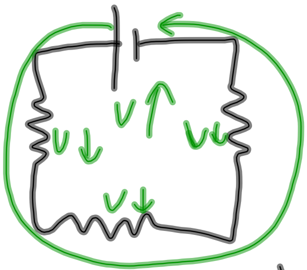


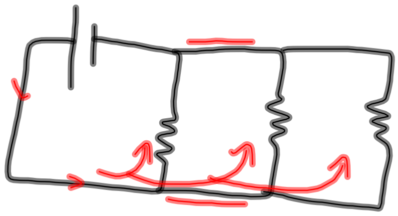

Current
I = Q / t
C
A
s
sec
Current (!!!)
electrons flow from negative to positive
Current flows from + to −
+
−
e
Q
V = E / Q
J
V
C
1.5V
4.5V


Ohm's Law
V
I
slope = rise / run
R = V / I
A
V
resistance, R, in ohms, Ω

Series vs Parallel

Series	Parallel
- one path	- several paths





Series:
- current is constant everywhere
- voltage is split (not always equally)

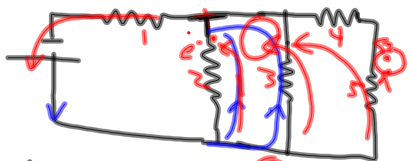
Parallel:
- current splits (not always equally)
- voltage is the same in each "branch"

What about combination circuits?

Kirchhoff's Laws

1- Kirchoff's Current Law (KCL)
- the current entering a junction is the same as the current leaving it

2- Kirchhoff's Voltage Law (KVL)
- in any "loop" of a circuit, the voltage gained must be equal to the voltage lost



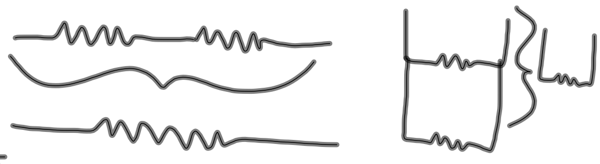
	S	1	2	3	4	5
V	12V	8V	4V	4V	3V	1V
I	1A	1A	0.2A	0.4A	0.4A	0.4A

$V_S = V_1 + V_2$
$V_S = V_1 + V_3$
$\therefore V_2 = V_3$

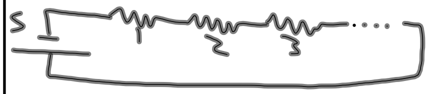
$I_S = I_1$ $I_S = I$

$I_S = I_2 + I_3 +$

Equivalent Resistance



In series...



$R_s = \frac{V_s}{I_s}$ ← but in series $V_s = V_1 + V_2 + V_3 + \ldots$

$= \frac{V_1 + V_2 + V_3 \ldots}{I_s}$

$= \frac{V_1}{I_s} + \frac{V_2}{I_s} + \frac{V_3}{I_s} \ldots$ but $I_s = I_1 = I_2 \ldots$

$= \frac{V_1}{I_1} + \frac{V_2}{I_2} + \frac{V_3}{I_3} \ldots$

$$R_s = R_1 + R_2 + R_3 \ldots$$

In parallel....

$R_p = \frac{V_p}{I_p}$

$\frac{1}{R_p} = \frac{I_p}{V_p}$

but $I_p = I_1 + I_2 + I_3 \ldots$ *

$\therefore \frac{1}{R_p} = \frac{I_1 + I_2 + I_3 \ldots}{V_p}$

but $V_p = V_1 = V_2 = V_3 \ldots$ *

$\frac{1}{R_p} = \frac{I_1}{V_p} + \frac{I_2}{V_p} + \frac{I_3}{V_p} \ldots$

$= \frac{I_1}{V_1} + \frac{I_2}{V_2} + \frac{I_3}{V_3} \ldots$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$$

What is the total resistance when a 100Ω, 50Ω and 30Ω resistor are added in parallel?

$\frac{1}{R_p} = \frac{1}{100} + \frac{1}{50} + \frac{1}{30}$

$= \frac{3 + 6 + 10}{300}$

$\frac{1}{R_p} = \frac{19}{300}$

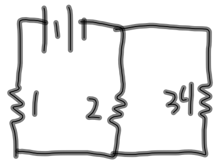
$R_p = \frac{300}{19}$

$= 15.8\Omega$

Combination Circuits

$R_4 = 40\Omega$

$R_3 = 30\Omega$



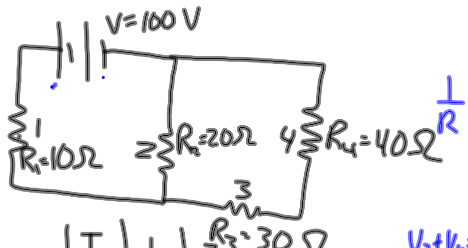
What is R_T?

$R_{34} = R_3 + R_4$
$= 30 + 40$
$= 70\Omega$

$\frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_{34}}$
$= \frac{1}{20} + \frac{1}{70}$
$= \frac{7 + 2}{140}$
$= \frac{9}{140}$

$R_{234} = \frac{140}{9} = 15.6\Omega$

$R_T = R_1 + R_{234}$
$= 10 + 15.6$
$R_T = 25.6\Omega$



$\frac{1}{R} = 25$

	T	1	2	3	4
V(V)	100	39.1	60.9	25.8	34.4
I(A)	3.91	3.91	3.05	0.86	0.86
R(Ω)	25.6	10	20	30	40

$V_3 + V_4 = 25.8 + 34.4$
$= 60.2$

① $R = \frac{V}{I}$ $\therefore I_T = \frac{V_T}{R_T} = \frac{100}{25.6} = 3.91$

② $I_T = I_1$ (KCL)

③ $V = IR$
$= 39.1\,V$

④ $V_T = V_1 + V_2$ (KVL)
$V_2 = V_T - V_1$
$= 60.9\,V$

⑤ $I_2 = \frac{V_2}{R_2}$
$= \frac{60.9}{20}$
$= 3.05$

⑥ $I_T = I_2 + I_{3\text{ or }4}$
$\therefore I_4 = 3.91 - 3.05$
$= 0.86\,A$

⑦ $V_3 = I_3 R_3$
$= (0.86)(30)$
$= 25.8\,V$

⑧ $V_4 = 34.4\,V$

Power & Electrical Cost

We know $P = \frac{\Delta E}{t}$

but $V = \frac{\Delta E}{Q}$ so $\Delta E = VQ$

$\therefore P = \frac{VQ}{t} = V\left(\frac{Q}{t}\right) = VI$

$$P = VI$$

Eg. $P = 32\ W$
$V = 120\ V$
$I = ?$

$P = VI$
$I = \frac{P}{V}$
$= \frac{32}{120}$
$= 0.27\ A$

Cost of Electricity

We pay for the energy we use.

Different units can be used...

$P \Rightarrow kW$
$t \Rightarrow h$

$E = Pt$ → kWh, kW, h
kWh → kilowatt hours

1 kWh is the energy used by a 1000 W device in 1 h.

rate $6 \frac{¢}{kWh} \rightarrow 12 \frac{¢}{kWh}$

Eg. → 100 W bulb
→ on 24 h/day for 30 days

$P = 100\ W$
$= 0.1\ kW$
$t = 24 \times 30$
$= 720\ h$
rate ~ $8 \frac{¢}{kWh}$

$E = Pt$
$= (0.1)(72)$
$= 72\ kWh$
cost = E × rate
$= (72)(0.08)$
$= \$5.76$

$C = Pt(\text{rate})$