# Review for Exam II


- **Topics from …**
  - **Electric Potential Energy: "U"**
  - **Electric Potential Difference: "V" (or $\Delta$V)**
- **… to …**
  - **Kirchoff's Loops Laws, Power and Internal Resistance**
    - » **(and everything in between)**
- **No RC circuits this time**

**Phys 122 Lecture 16**
**G. Rybka**

# Today

- Plan
  - *Wild & fast review of main points from this Unit*
  - *Some problems from a different older exam*

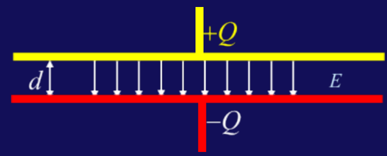
- Suggest that you …(read it later)
  - *Go back and flip through slides (and Clicker questions) to make sure you understand them.*
  - *Look over classic HW problems in SP or Webassign*
  - *Make sure you can do the types of calculations on the practice exam.*
    - » *Solutions will be posted*

# What did we learn?

- **Physics & Relations**
  - Electrical Potential Energy: U (or ΔU) — Joules
  - Electrical Potential: V (or ΔV) — Joules / Coulomb
  - Energy density in E field: $u = \frac{1}{2} \varepsilon_0 E^2$ — Joules / volume
  - V from E: $$\Delta V_{a \to b} - \int_a^b \vec{E} \cdot d\vec{l}$$ The Difference matters
  - E from V: $$\vec{E} = -\vec{\nabla} V$$
- **Some Consequences**
  - E = 0 inside a conductor (or wires)
  - V = constant in conductor (or wires)
  - E field perpendicular to conductor surface
  - Equipotential V values orthogonal to E field

# What did we learn?

- **Practical Use** (but <u>not new</u> stuff)
  - Devices for electronic circuits introduced
  - Batteries*, Resistors, Capacitors, switches, …
  - Capacitors:




$$E = \frac{\sigma}{\varepsilon_o} \qquad V = Ed = \frac{Q}{\varepsilon_o A} d \qquad \therefore C = \frac{\varepsilon_0 A}{d}$$

    - » Value depends on geometry
      - If a dielectric material is between plates, $C' = \kappa C_0$
    - » "in series" same Q on all plates
    - » "in parallel" same ΔV across elements
  - Resistors: control rate of current: $I = dq/dt$ in circuits
    - » Value depends on shape and stuff it's made from
    - » "Voltage across" or "Voltage Drop" between two ends of a resistor is proportional to the current: $V = IR$ (it's a difference)
    - » "in series" same current goes through both
    - » "in parallel" same ΔV across elements

* We often assume that batteries maintain a constant ΔV from + to - terminal

# Now, many examples

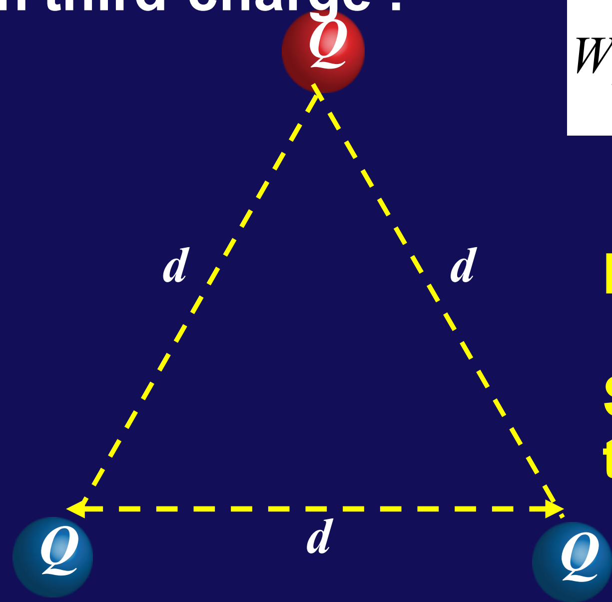
# Work to assemble set of charges

$$W = \sum W_i = +\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{d}$$

Work to bring in first charge: $W_1 = 0$

Work to bring in second charge : $W_2 = +\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{d}$

Work to bring in third charge : $W_3 = +\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{d} - \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{d} = 0$



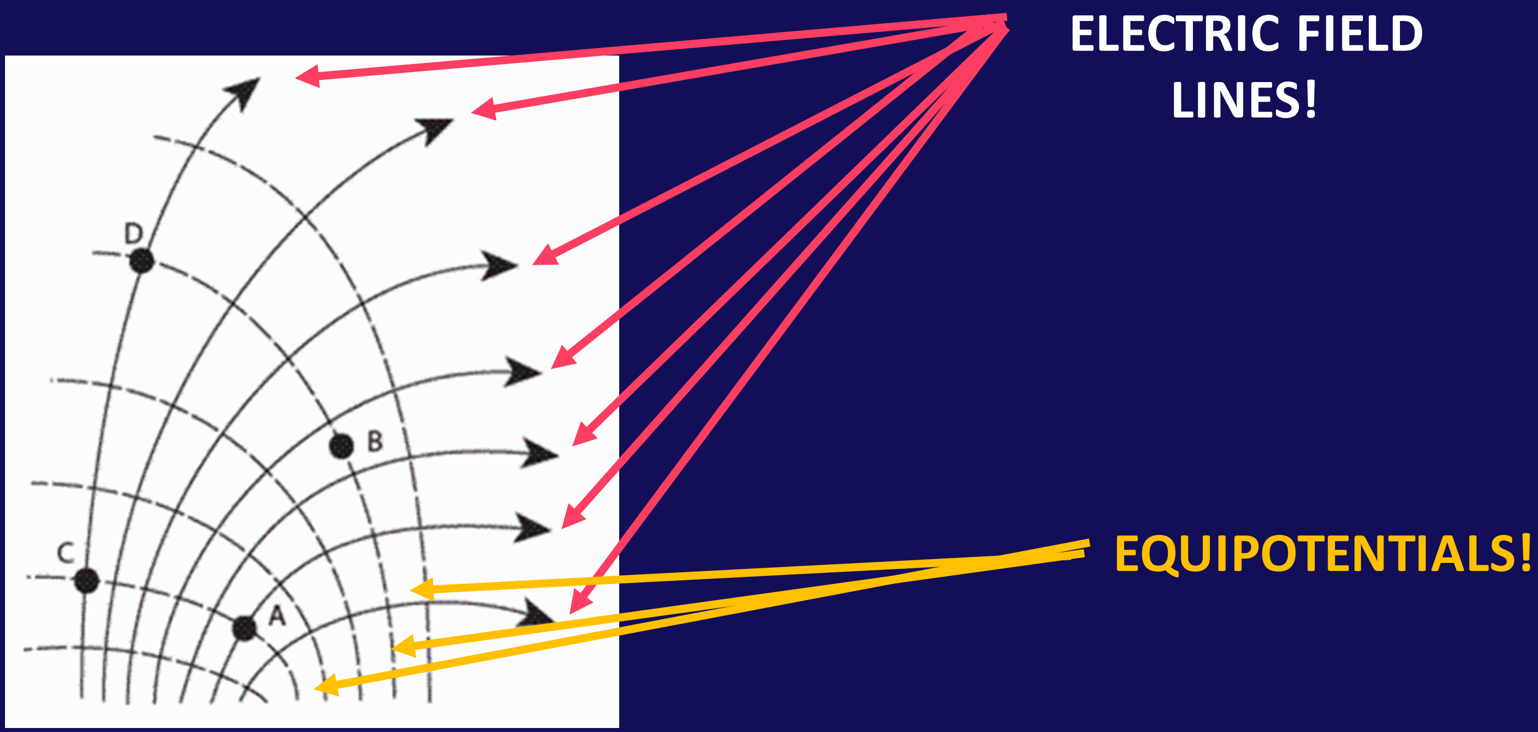

PE is sum of P.E.s for each pair

Sign positive if + is moved toward another + charge

Potential energy is negative the Work required to build it

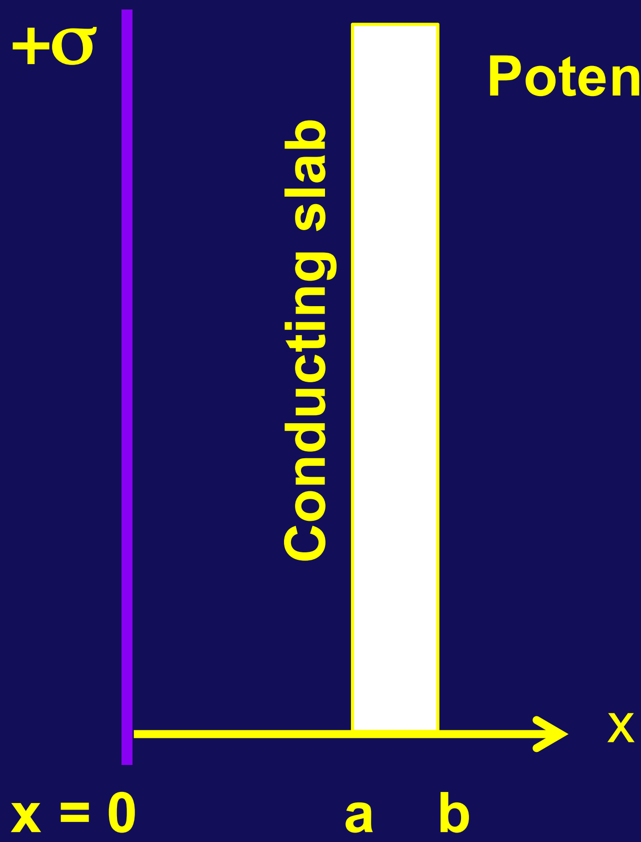
$$\Delta U = -\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{d}$$

# Field Lines and Equipotentials

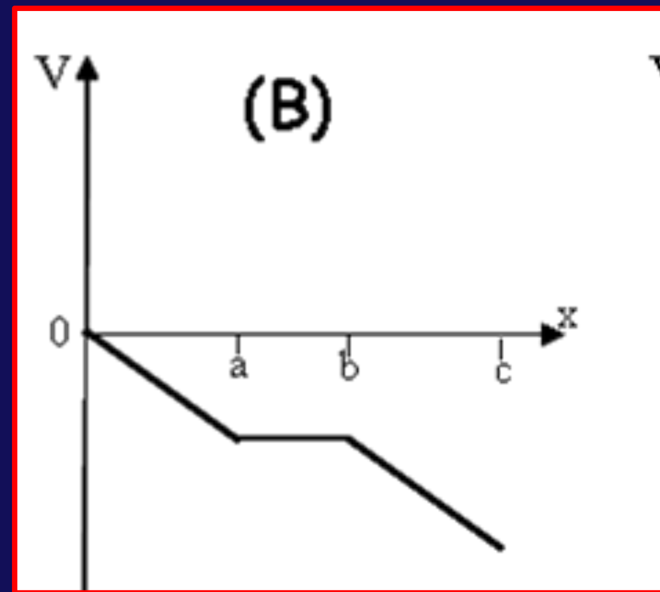



**Points:**

- Density of E
- Orthogonal E to V
- Work to move along




# Potential in the positive x direction

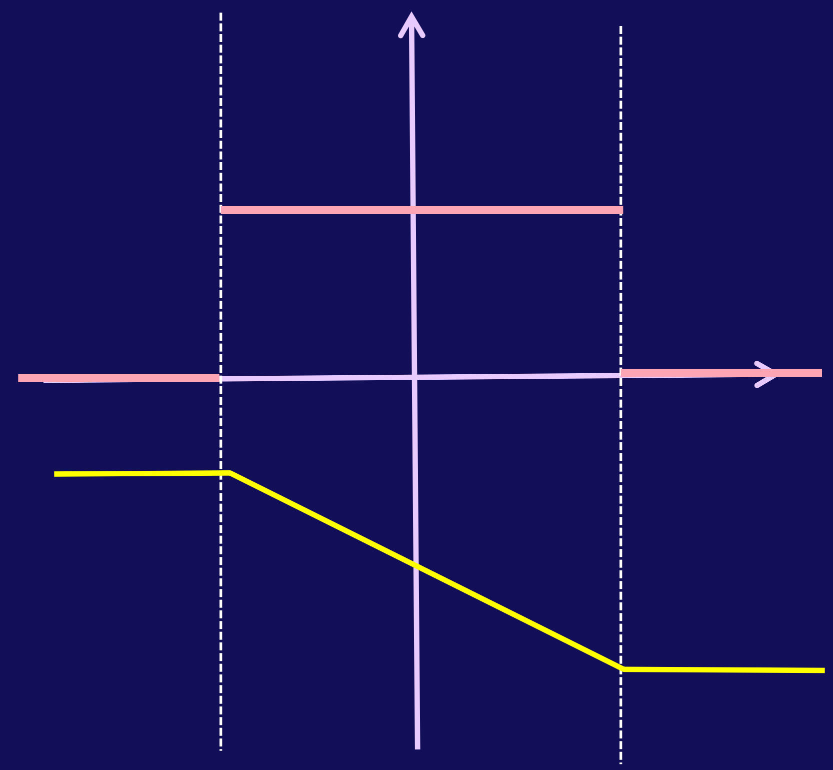



- E is constant between x = 0 and x = a
  - V must be a linear function of x, downward since sigma is positive
- E = 0 in conductor
  - V = constant
- E has same value to right of conductor
  - V continues downward with same slope

# Toward a capacitor

+σ −σ

**Two "infinite" oppositely charged parallel plates are located at –d and +d on the x axis. Which graphs best represent the Electric Field and the Potential Difference vs x ?**



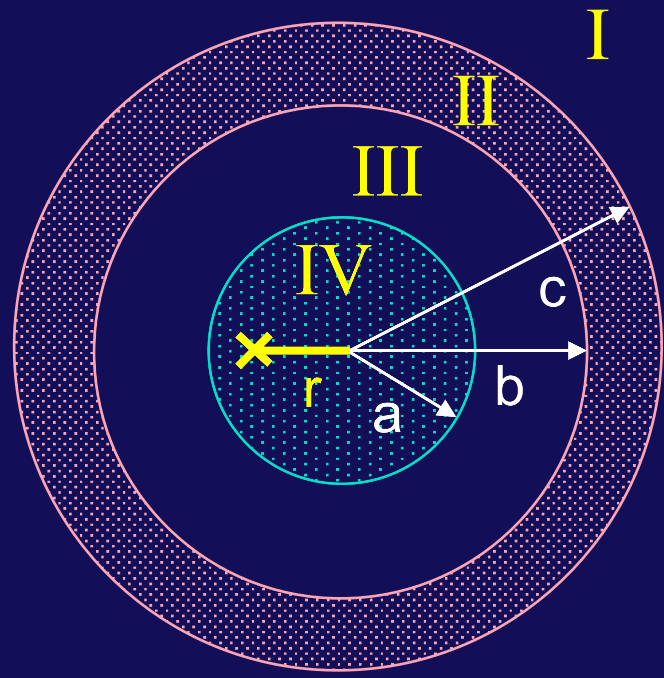
# E and V with spheres and cylinders

- Determine **E(r)** everywhere from Gauss's Law

$$\vec{E}_I(r) = \frac{kQ}{r^2}\hat{r} \qquad \vec{E}_{III}(r) = \frac{kQ}{r^2}\hat{r}$$

$$\vec{E}_{II}(r) = 0 \qquad \vec{E}_{IV}(r) = \frac{kQr}{a^3}\hat{r}$$

Depends on problem of course



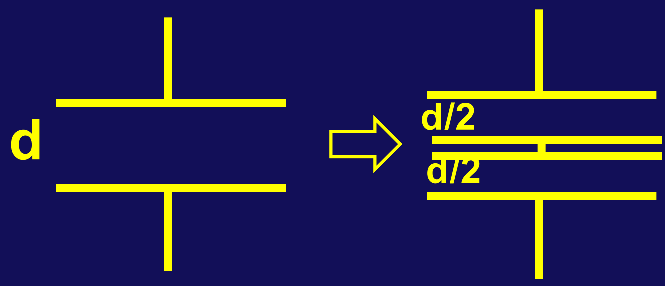

- Determine **ΔV** for each region by integration

$$V(r) = V_\infty + \Delta V_{\infty \to c} + \Delta V_{c \to b} + \Delta V_{b \to a} + \Delta V_{a \to r}$$

- When plotting, recall
  - E can be discontinuous (e.g, E = 0 in the conductors)
  - V must be continuous (and have a V = 0 defined somewhere)

**(Let's assume just positive charges here)**

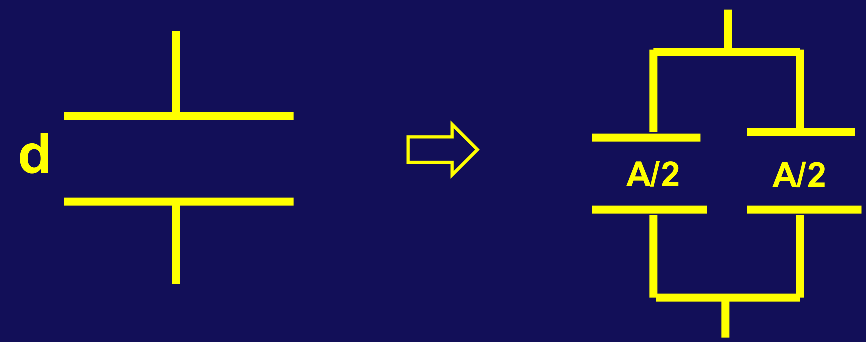
# Capacitors in Series and Parallel & Dielectrics




$C_0$

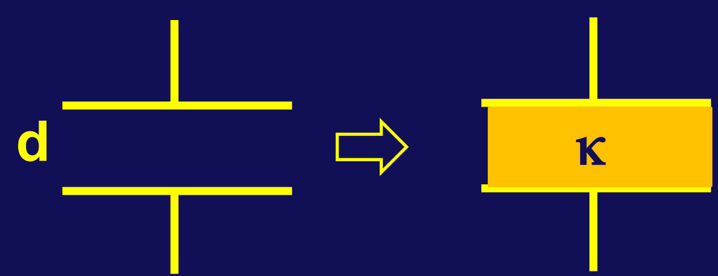
$$C' = \left( \frac{1}{2C_0} + \frac{1}{2C_0} \right)^{-1} = C_0$$

Or, two in series with d/2 separation ☺




$C_0$

$C' = C_0/2 + C_0/2 = C_0$



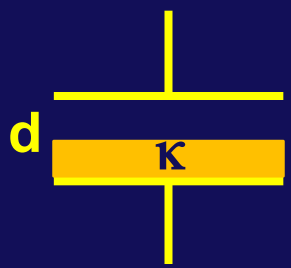

$C_0$

$C' = \kappa C_0$

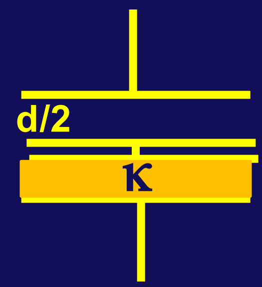
original

adding dielectric

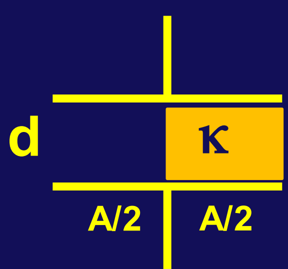
# Capacitors in Series and Parallel & Dielectrics




What is this?




Think about this

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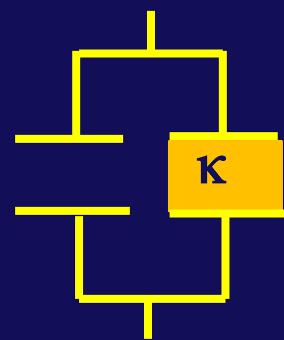


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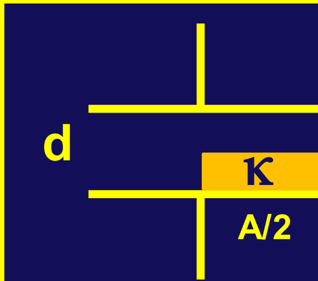
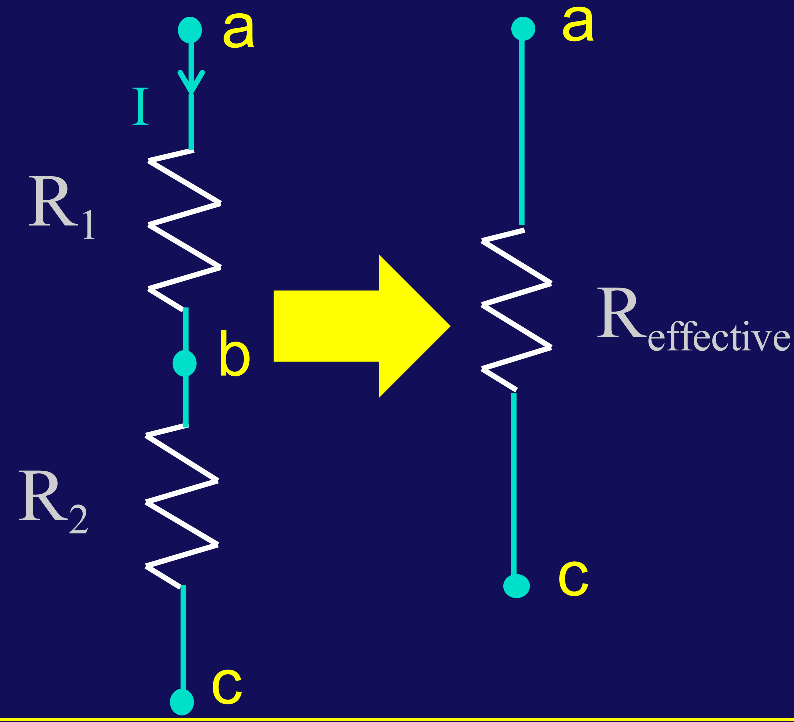



Now, could you do this?

# Resistors in Series & Parallel

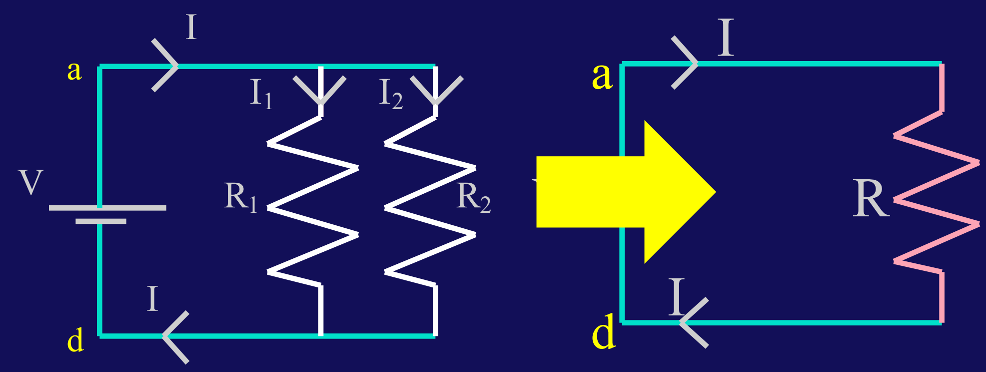
**The current is the same for devices in SERIES,**

$$R_{effective} = (R_1 + R_2)$$




**The voltage drop is the same for devices in PARALLEL**

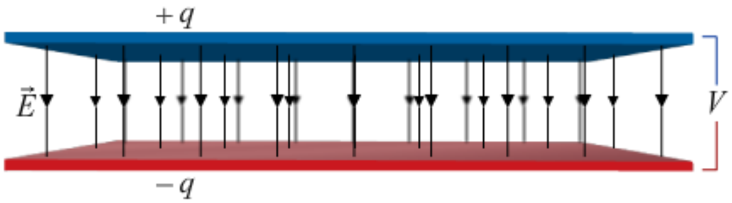
Þ $$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$



# Energy and Power in Devices

**Energy is stored in the electric field between plates of a Capacitor**

$$U=\frac{1}{2}QV \quad \text{or} \quad U=\frac{1}{2}\frac{Q^2}{C} \quad \text{or} \quad U=\frac{1}{2}CV^2$$



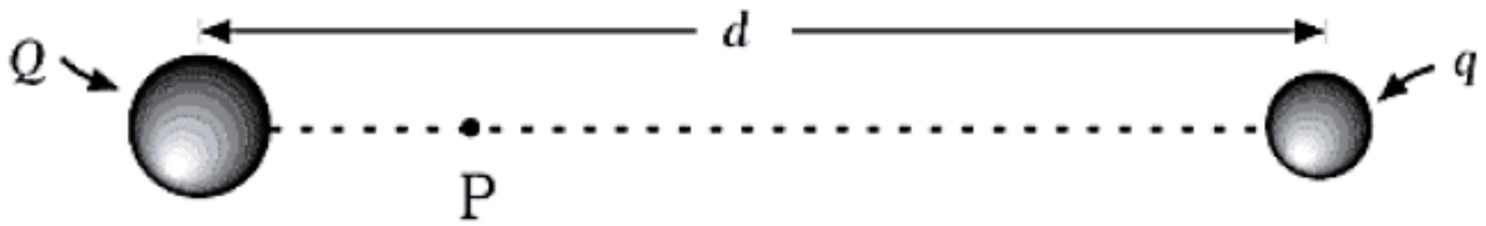

**Rate of Energy expended in a resistor with current running through**

$$P=VI$$

$$P=(IR)I=I^2R$$

$$\frac{\text{Joule}}{\text{Coulomb}}\times\frac{\text{Coulomb}}{\text{second}}=\frac{\text{J}}{\text{s}}=\text{Watt}$$

# Now some problems from the past

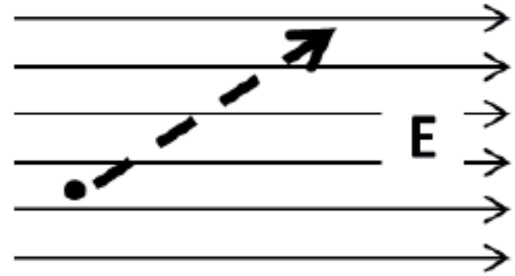



1. (4 pts.) Charges Q and q (Q > q), separated by a distance d, produce a potential $V_P = 0$ at point P. This means that

A) no force is acting on a test charge placed at point P.
B) Q and q must have the same sign.
C) the electric field must be zero at point P.
D) the net work in bringing Q to distance d from q is zero.
E) the net work needed to bring a charge from infinity to point P is zero.

- **Take V = 0 at infinity**
- **Then, $\Delta U = q\Delta V = 0 = -W$ to go to point P**

2. (4 pts.) A charge of 5.0 μC is located in a uniform electric field of intensity $3.5 \times 10^5$ N/C. How much work is required to move this charge at constant speed 50 cm along a path making an angle of 33° with respect to the electric field direction?

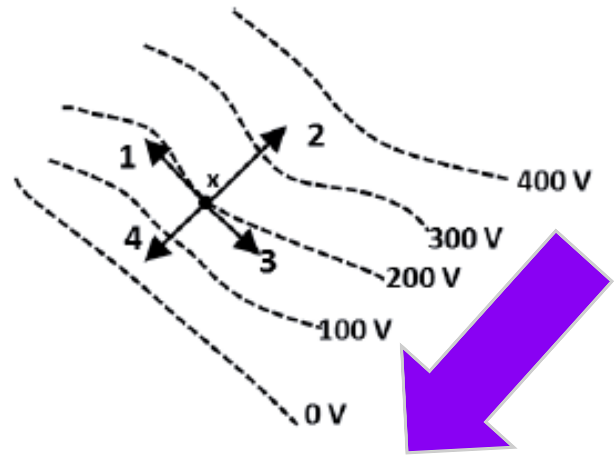



A) 0.16 J
B) 0.27 J
C) 0.54 J
D) 0.73 J
E) 7.3 mJ

- $W = \int qE \cdot dl$
- → $W = q \int E \cdot dl = E \cos \Theta \int dl$
- → $W = qLE \cos \Theta$

4. (3 pts.) The vector that best represents the direction of the electric field at point **x** on the 200 V equipotential line is

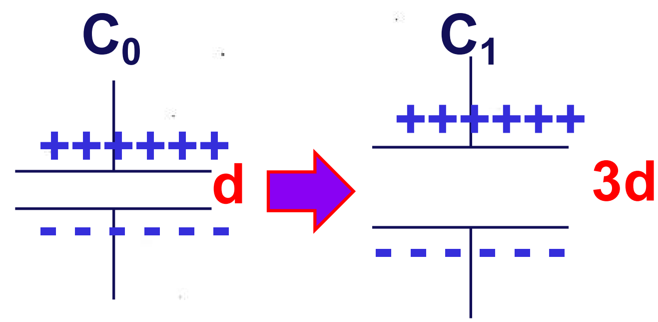
A) 1
B) 2
C) 3
D) 4
E) None of these is correct.




- $\vec{E} = -\vec{\nabla} V$
- **E then points toward DECREASING potential**

Two plates of a parallel plate capacitor are separated by distance $d$, and each has area $A$. The capacitor is charged to a potential difference $V_0$ and then disconnected from the voltage source. The plates are then pulled apart until the separation becomes $3d$.

4. What is the new potential difference between the plates of the capacitor? (Express your answer in terms of the original potential difference, $V_0$.)




A. $V_0$
B. $3V_0$
C. $9V_0$
D. $0.33V_0$
E. $0.11V_0$

1. $C_0 = A\varepsilon/d$
2. $C_1 = A\varepsilon/3d$

3. $V_0 = Q/C_0$
4. $V_1 = Q/C_1$ (same Q)

5. $V_1 = 3V_0$

5. How much work was required in order to change the plate separation from $d$ to $3d$?

**Looking for the *difference* in stored energy**

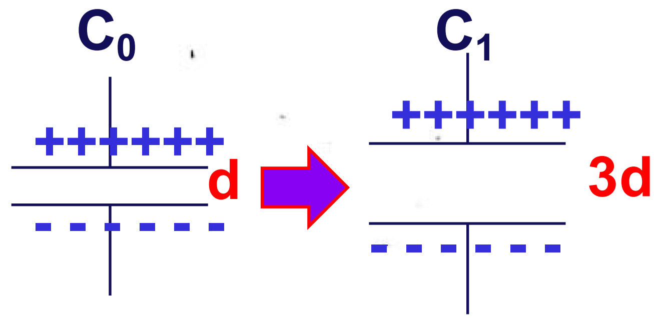
A. $\varepsilon_0 A V_0 / d$

B. $\varepsilon_0 A V_0 / 2d$

C. $\varepsilon_0 A V_0^2 / d$

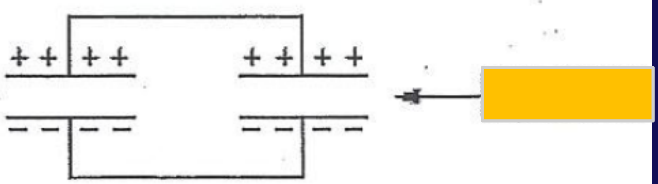
D. $\varepsilon_0 A^2 V_0 / d$

E. $\varepsilon_0 A^2 V_0^2 / 2d$




1. $U_0 = ½ Q^2/C_0$ is original stored energy
2. $U_1 = ½ Q^2/C_1$ is final stored energy
3. $C_1 = C_0/3$ (see previous problem)
4. $U_1 = 3 U_0$
5. $U_1 – U_0$ is the work done (conservative force)
6. $U_1 – U_0 = 2U_0 = 2 (½ CV^2) = \varepsilon AV^2/d$

6. Two capacitors each have two conducting plates of surface area $A$ and an air gap width $d$. They are connected in parallel, as shown in the figure, and each has a charge $Q$ on the positively charged plate. A slab that has a width $d$, area $A$, and a dielectric constant $\kappa$ is then inserted between the plates of *one* of the capacitors. Find the new charge $Q'$ on the positively charged plate of the capacitor with the dielectric. Assume that electrostatic equilibrium has been reestablished.



A. $\kappa Q / (1+\kappa)$

B. $2\kappa Q / (1+\kappa)$

C. $\kappa Q / (1+\kappa)^2$

D. $\kappa Q / (1+2\kappa)$

E. $2\kappa Q / (1+2\kappa)$

**After insertion of dielectric, Q redistributed, but the total Q is the same**

1. $Q_L + Q_R = 2Q$ (they both had Q)
2. $C_R = \kappa C_L$ ( dielectric )
3. $V_L = V_R$ (in parallel)

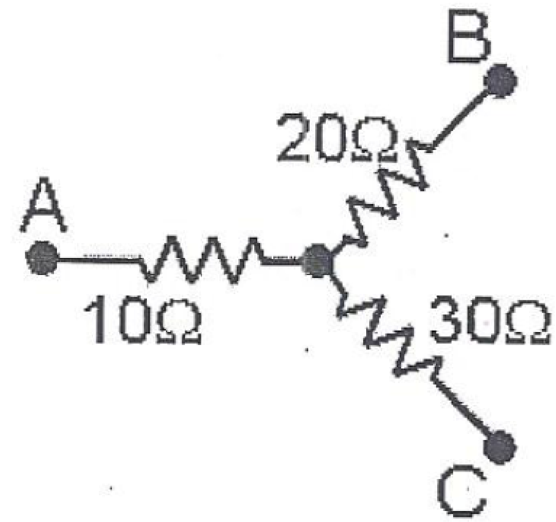
4. $Q_L = C_L V$ &
5. $Q_R = C_R V = \kappa C_L V = \kappa Q_L$
6. $Q_R = \kappa Q_L = \kappa(2Q - Q_R)$
7. $Q_R(1+\kappa) = \kappa 2Q$

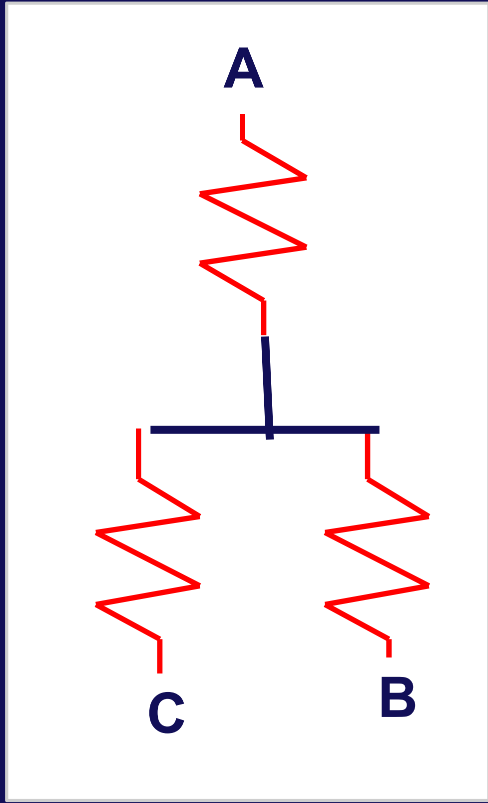
8. $Q_R = 2\kappa Q/(1+\kappa)$

8. The voltages at point A, B, and C, are 10V, 6V, and 5V, respectively. What is the current through the 10Ω resistor?

(a) 0.2 Amps
(b) 0.4
(c) 0.6
(d) 0.8
(e) 1.2

**First thought: What is this?**
**Redraw it perhaps ?**



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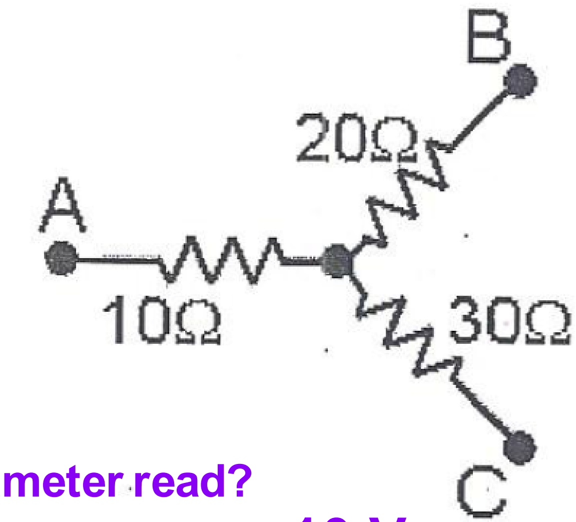



**Now, do Kirchoff's Loops and Junction**

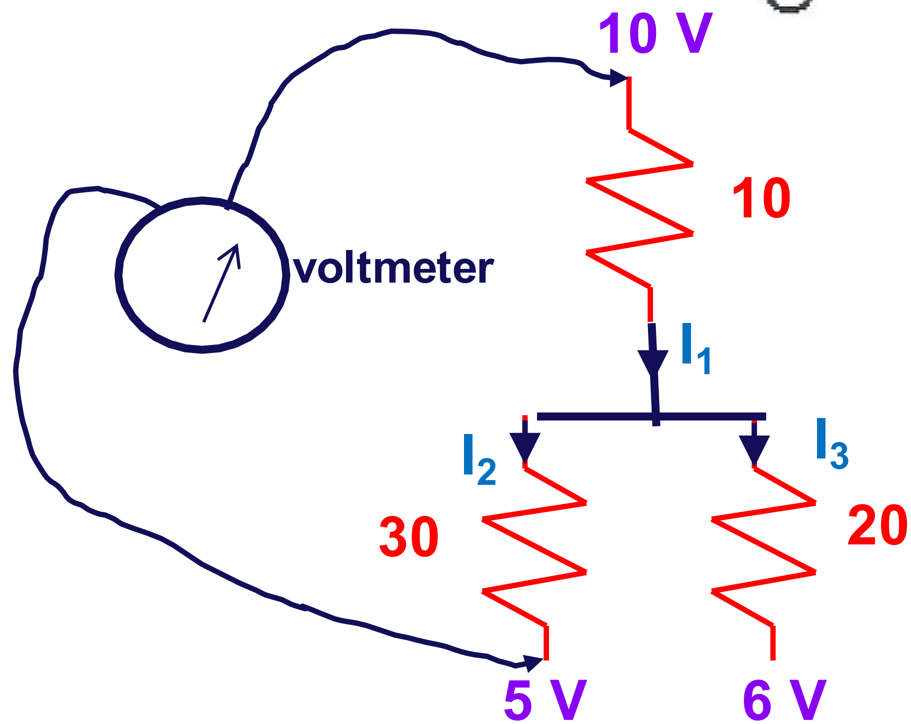
1. $I_1(10) + I_2(30) - 5 = 0$
2. $I_1(10) + I_3(20) - 4 = 0$
3. $I_1 = I_2 + I_3$

4. **Now solve for currents**

5. **Soln: $I_1 = 0.2$ A**

6. **Make sense?**
   1. **V at node is 10 – 2 = 8 V**
   2. **$V_{30} = 3$ V; $I_2 = 0.1$ A**
   3. **$V_{20} = 2$ V; $I_3 = 0.1$ A**
   4. **The currents add up**
   5. **The voltages add up**

**What will voltmeter read?**



Good luck