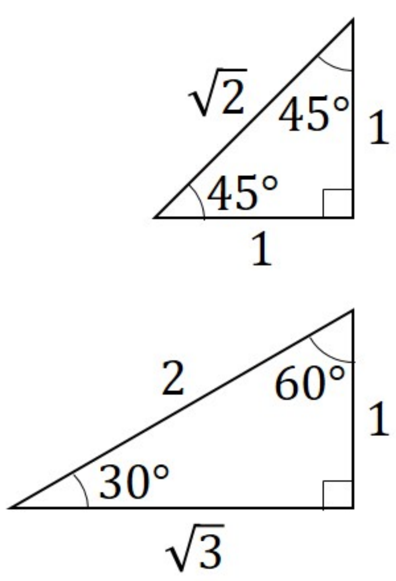
The exam consists of 22 multiple choice questions, worth 4.5 points each, plus 1 point for question 0, for a total of 100 points. Allowed material: Hand-written equation sheet (1 piece, front and back, of letter-sized paper), pencils and erasers. Calculators are allowed, but cell phones are not and must be turned off.

Note: In all questions, unless otherwise stated, neglect air resistance and assume all wires and batteries are ideal. Also, unless otherwise stated, assume all light bulbs and resistors are Ohmic.

Possibly useful information:



$$g = 9.8\ \mathrm{m/s^2}$$
$$e = 1.60 \times 10^{-19}\ \mathrm{C}$$
$$k = 8.99 \times 10^{9}\ \mathrm{N \cdot m^2/C^2}$$
$$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$$
$$m_{e^-} = 9.11 \times 10^{-31}\ \mathrm{kg}$$
$$1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$$

Physics 1 Equations

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$v = v_0 + a\Delta t$$
$$\Delta x = v_0 \Delta t + \frac{1}{2} a (\Delta t)^2$$
$$v^2 = v_0^2 + 2a\Delta x$$
$$W_F = \int \vec{F} \cdot d\vec{r}$$

The last page of this booklet is for scratch work.

0. (1 percent) Ensure that you have printed your full name and student ID number, with **clear and neat handwriting**, on both the front page of this exam **AND** on your bubble sheet. Your student ID number is not written on your BuffOne Card. Bubble in **version (B)** on your bubble sheet. Failure to follow these instructions may result in the loss of this point.

1. If a 2.0 F capacitor is charged (fully) by a 5.0 V battery, how much net charge will be on the positive plate?

   A. 25 C
   B. 2.5 C
   C. 0.40 C
   D. ~~50 C~~
   E. 10 C

$$Q = CV = 2.0\,F \times 5.0\,V = 10\,C$$

2. The battery in your cell phone provides 4 V to the built-in flashlight. If the flashlight bulb has a resistance of 4 ohms, how much power is consumed by the lightbulb when it is on?

   A. 64 W
   B. ~~16 W~~
   C. 4 W
   D. ~~1 W~~
   E. 0.25 W

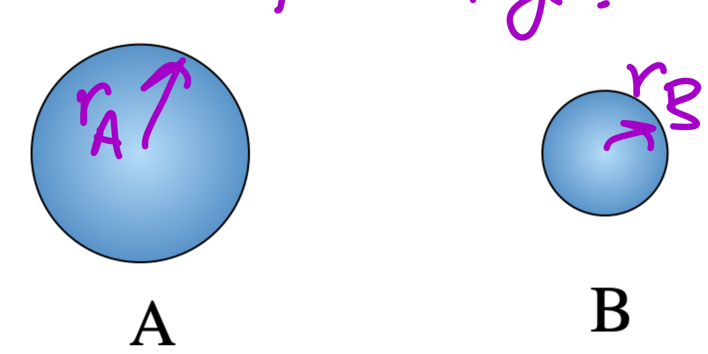
$$P = IV = \frac{V^2}{R} = \frac{(4V)^2}{4\Omega} = 4W$$

3. Two spherical conductors are separated by a large distance. They each carry the same positive net charge $+Q$. Conductor A has a larger radius than conductor B. How does the electrical potential just outside the surface of conductor A compare to the electrical potential just outside the surface of conductor B?

   A. ~~$V_A > V_B$~~
   B. $V_A < V_B$
   C. $V_A = V_B$

From outside, looks like a pt charge.

$$V_{pt} = \frac{kq}{r}$$



$$V_A = \frac{kQ}{r_A} \qquad V_B = \frac{kQ}{r_B}$$

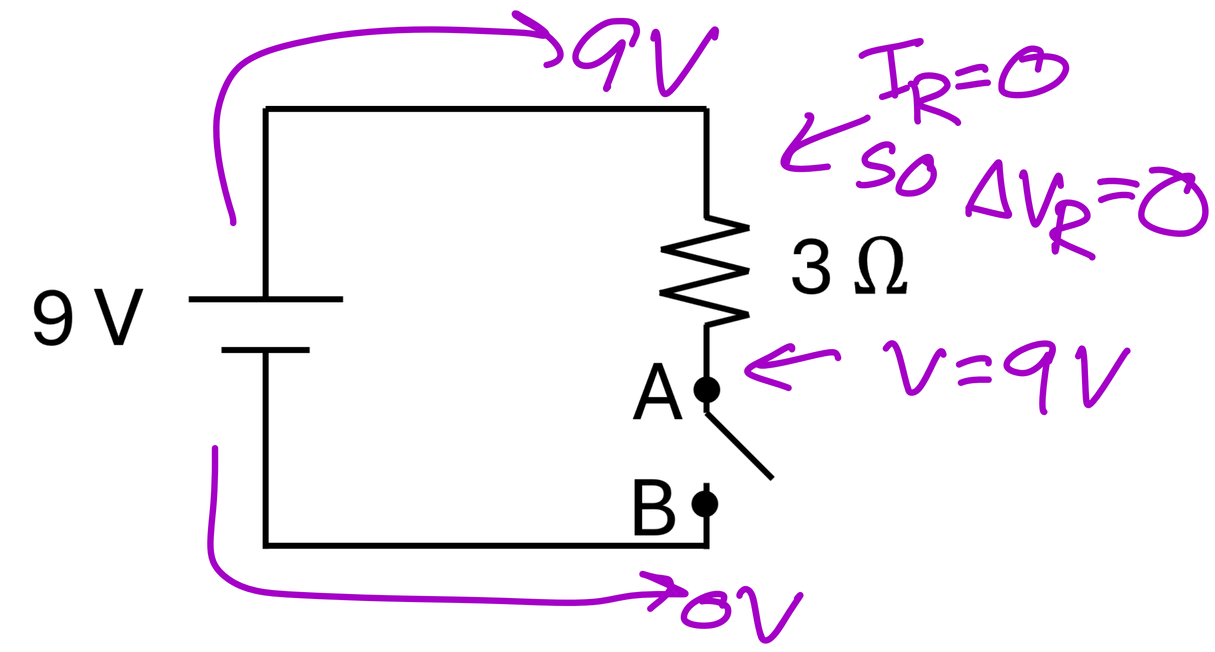
Since $r_A > r_B$, $V_A < V_B$

4. Suppose that the electric potential $V(x)$ in a certain region of space is given by $V(x) = (3\ \mathrm{V/m}) \cdot x + (5\ \mathrm{V})$. What is the x-component of the **electric field** at $x = 2$ m?

   A. +11 N/C
   B. +6 N/C
   C. +3 N/C
   D. −3 N/C
   E. ~~−6 N/C~~

$$E_x = -\left.\frac{dV}{dx}\right|_{x=2m} = -\left(3\frac{V}{m}\right) = -3\frac{N}{C}$$

5. In the circuit shown, the switch is **open and no current flows**. What is the electric potential difference across the switch, $V_A - V_B$?



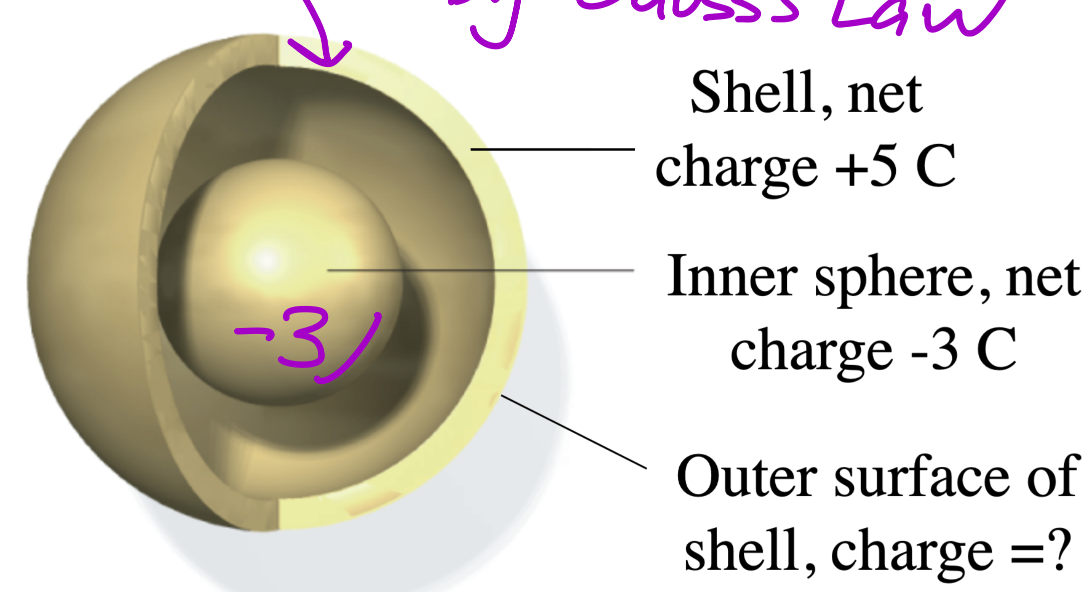
A. 9 V
B. 4.5 V
C. 3 V
D. 0.33 V
E. 0 V

6. Consider two concentric **conducting** spheres. The outer sphere is a hollow shell with a 1 cm thick wall and has a net charge of $+5$ C. The inner sphere is solid and has a net charge of -3 C. Once equilibrium is reached, how much net charge is spread over the **outer surface** of the shell?

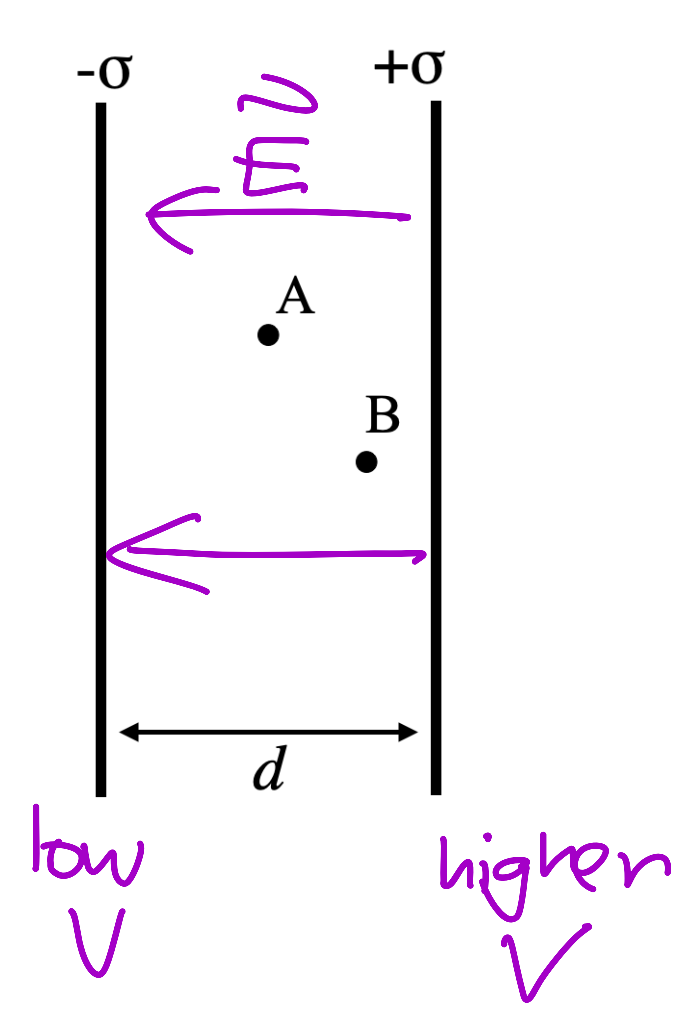
Since $E=0$ in middle of shell, $Q_{inner} = +3$ by Gauss's Law

A. $+5$ C
B. $+3$ C
C. -3 C
D. $+2$ C
E. 0 C

$Q_{outer} = Q_{net} - Q_{inner}$
$= +5C - 3C$
$= +2C$



7. The two infinite metal plates are separated by a distance d as shown. One has a uniform charge density $+\sigma$ and the other has a uniform charge density $-\sigma$. A small test charge is moved from Point A to Point B at uniform speed. What is the change in the electrical potential ($V_B - V_A$)?



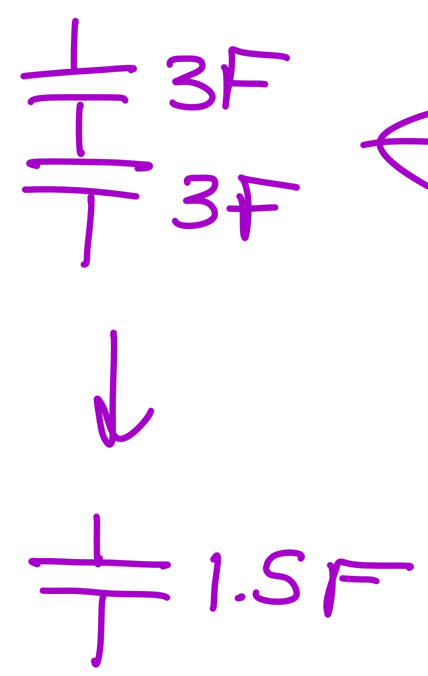
A. Positive
B. Negative
C. Zero
D. Cannot be determined unless the sign of the test charge is known.

V higher on right side.

$V_B - V_A > 0$

8. Three capacitors are arranged as shown on the right. If a voltage of 5.000 V is applied between points A and B, what is the total electrical energy stored in this system of three capacitors (to four significant figures)? (All answers accepted.)

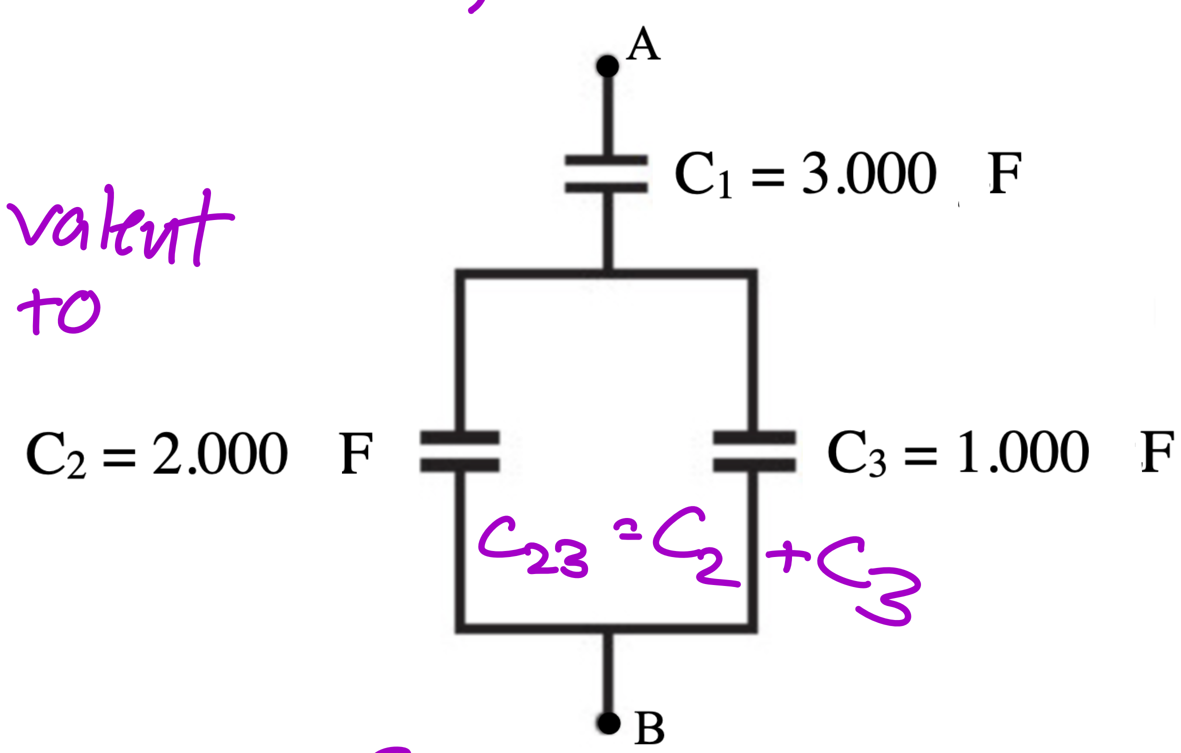
A. 8.333 J
B. 18.75 J
C. 75.00 J
D. 45.96 J
E. 1.500 J



equivalent to

equiv to

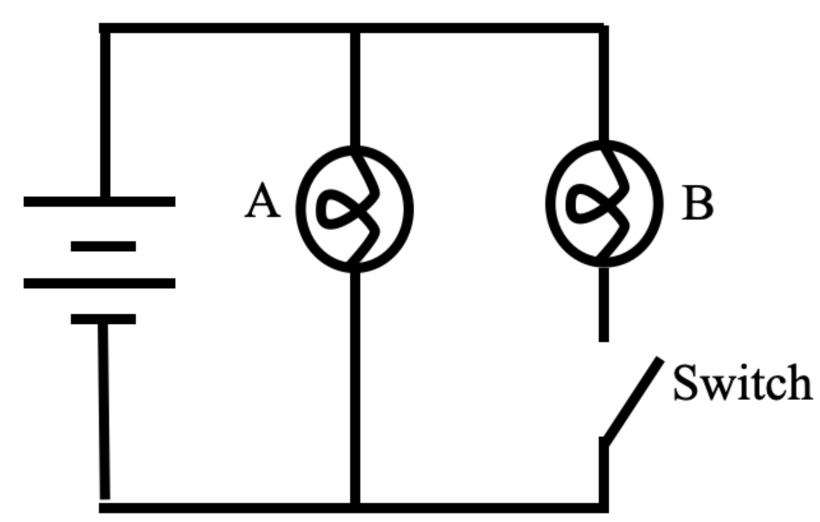
$C_{123} = \left(\frac{1}{C_1} + \frac{1}{C_{23}}\right)^{-1}$



$U = \frac{1}{2} C_{eq} V^2 = \frac{1}{2}(1.5F)(5V)^2 = 18.75J$

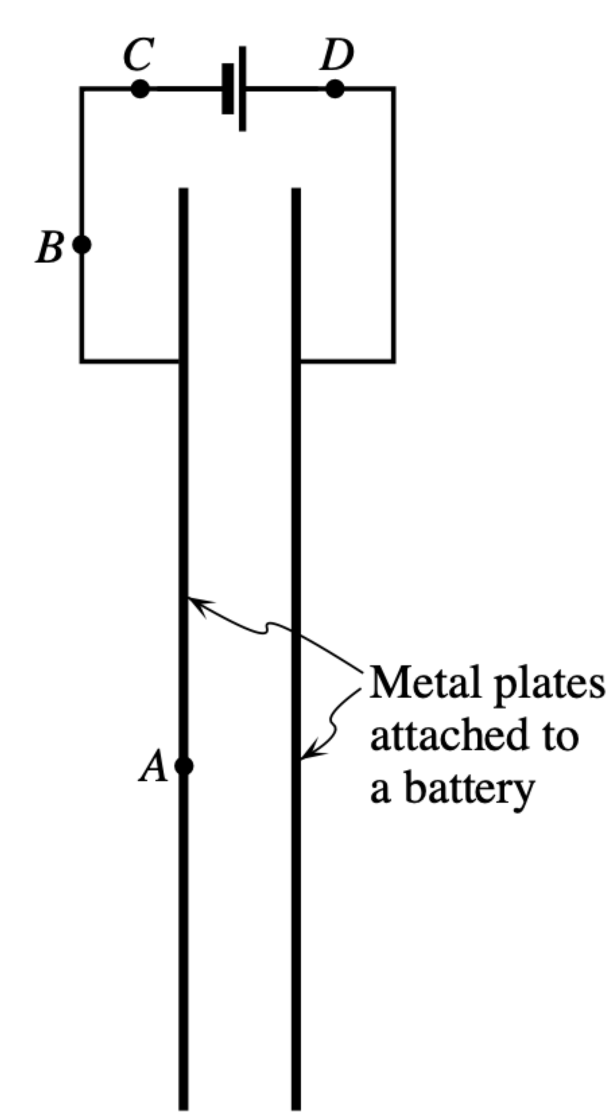
9. A circuit has an ideal battery, two identical ideal light bulbs and a switch. Initially the switch is open as shown in the figure. If the switch is then **closed**, what happens to the **brightness of Bulb A**?

A. Bulb A becomes brighter.
B. Bulb A becomes dimmer, but stays on.
C. Bulb A remains the same.
D. Bulb A goes out.



ΔV over bulb A doesn't change.
Since I_A & V_A are same, brightness = same

10. The two metal plates have been connected to a battery as shown for a long time. Now the two plates are moved **farther apart** (while still connected to the battery) and allowed to reach equilibrium. How did the capacitance and the charge density on the positive plate change (if at all)?



A. The capacitance increased; the charge density remained the same.
B. The capacitance remained the same; the charge density remained the same.
C. The capacitance remained the same; the charge density decreased.
D. The capacitance decreased; the charge density remained the same.
E. The capacitance decreased; the charge density decreased.

$C = \frac{\varepsilon_0 A}{d}$

As $d \uparrow$, $C \downarrow$

$V = \text{const} = Ed = \frac{\sigma}{\varepsilon_0} d$

As $d \uparrow$, $\sigma \downarrow$

11. A carbon resistor and a light bulb are connected to a battery with ideal wire as shown. Compare the **current** I at the three points shown (Point A, Point B, and Point C).

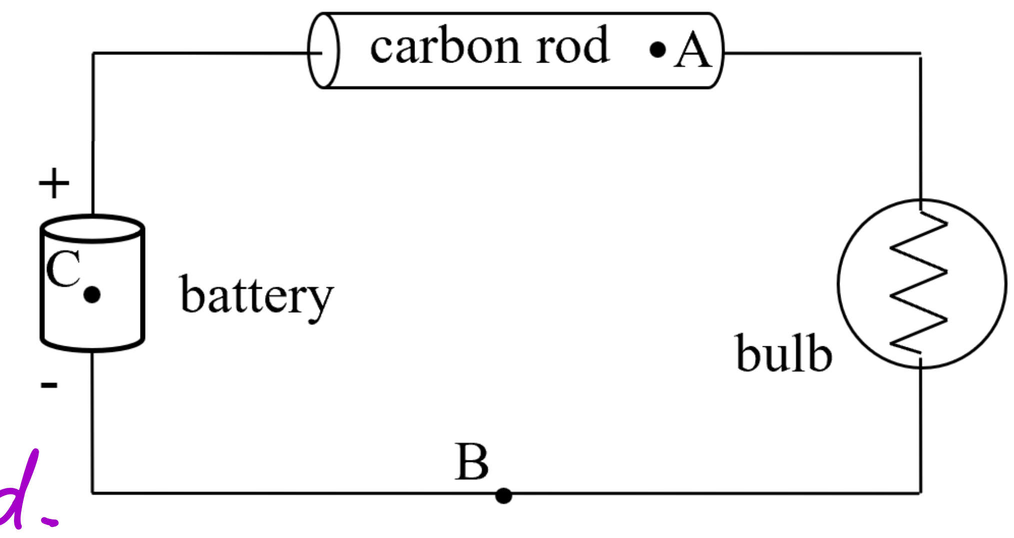
A. $I_C > I_A > I_B$

B. $I_C = I_A > I_B$

C. $I_A = I_B > I_C$

D. $I_A > I_C > I_B$

E. $I_C = I_A = I_B$



For a given loop, current is conserved.

$I_{in} = I_{out}$

12. A honey bee has accumulated a static net charge of $+0.5$ C. The bee flies away from a flower starting at point A (0 m , 0 m) and ending at point B (4 m, 3 m). If the Earth has a uniform electric field near ground level of around 10 N/C pointing **vertically upward**, what is the change in the bee's **electrical potential energy** as it flies from Point A to Point B?

A. +25 J

B. +15 J

C. +30 J

D. −15 J

E. −25 J

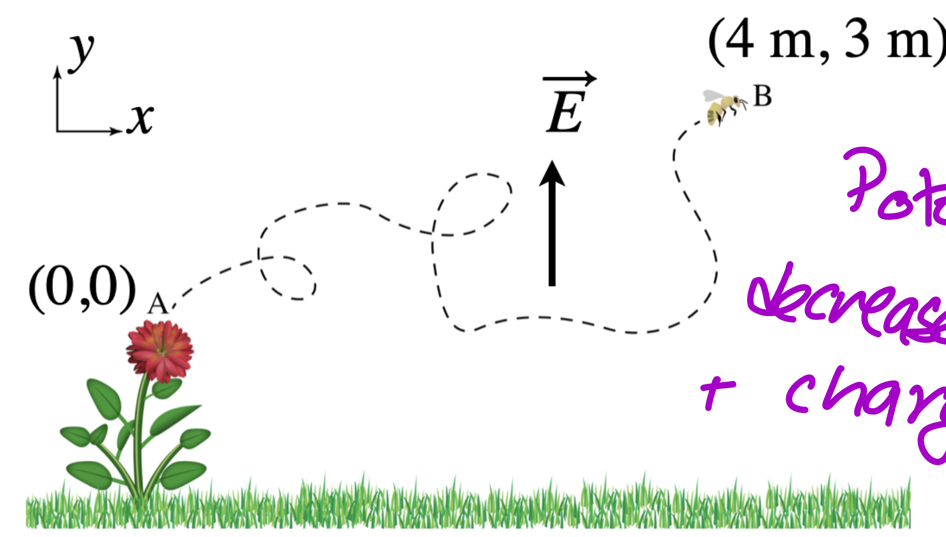
$\Delta V = -\int \vec{E}\cdot d\vec{r} = -E_y \Delta y$

$= -10\frac{N}{C} \cdot 3\,m$

$\Delta V = -30 V/m$

$\Delta U = q\Delta V = (+.5C)(-30\frac{V}{m})$

$= -15 J$



Potential energy decreases as a + charge moves along $\vec{E}$.

13. Four identical ideal light bulbs are connected to an ideal battery with ideal wires as shown. Three students have made statements about the brightness of the bulbs.

Student 1: Bulbs **B and C** have the **same brightness** since they have the same current through them.

Student 2: Bulbs **B and D** have the **same brightness** since they have the same voltage.

$V_B + V_C = V_D$

$V_B \neq V_D$

Student 3: Bulb **A** is the **dimmest** since it has the lowest voltage.

Bulb A has largest I, so it is brightest.

Which students are correct?

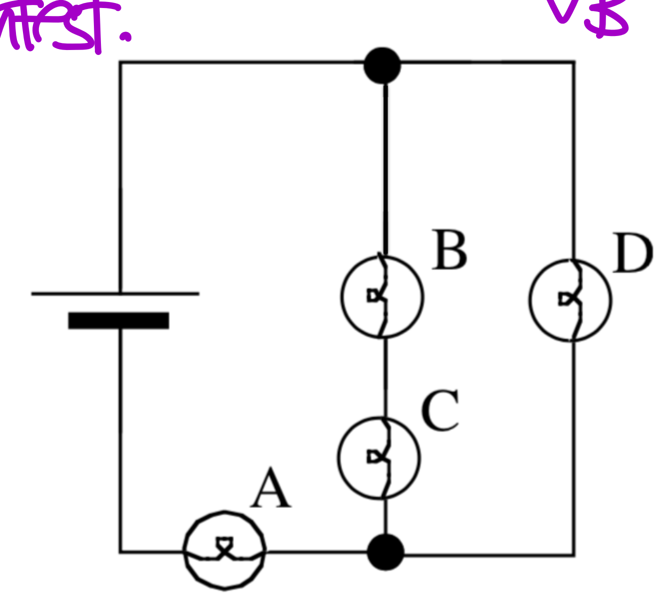
A. Student 1 only

B. Student 1 and 2

C. Student 1 and 3

D. Student 2 only

E. All of the students are correct



14. An electric dipole with charges of magnitude Q and separation $2d$ is oriented as shown in the Figure. Compare V_A, the electric potential at point A, with V_B, the electric potential at point B. There are no other charges nearby and you can take $V = 0$ far away from the dipole.

A. $V_A > V_B$

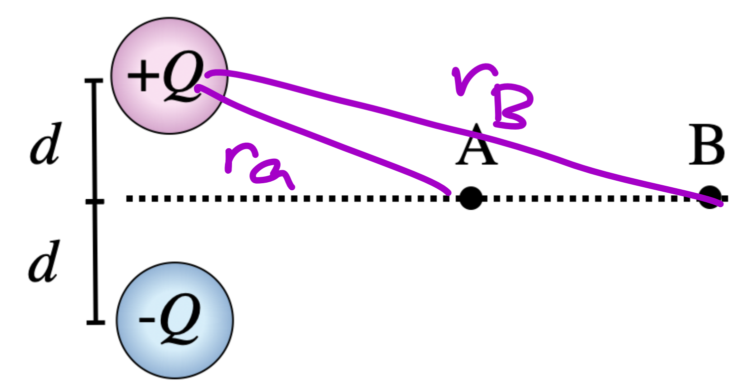
B. $V_A = V_B$

C. $V_A < V_B$

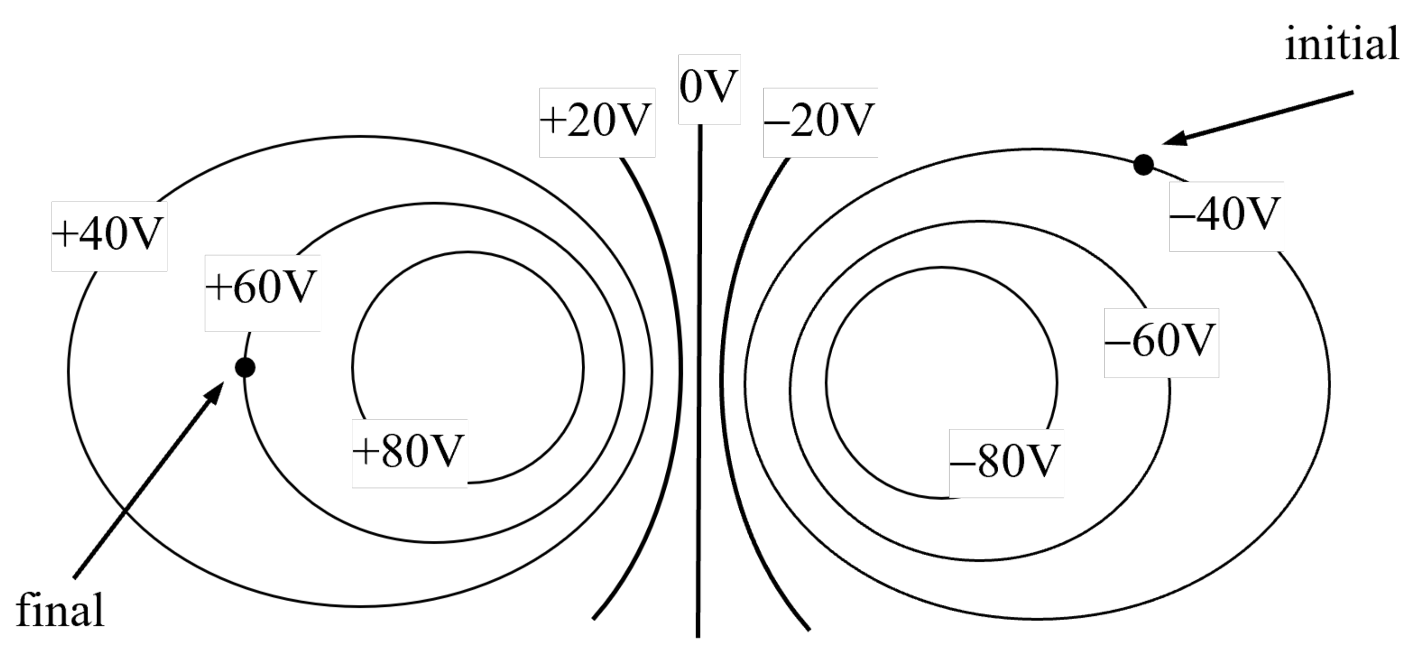
$$V_{point} = \frac{kq}{r}$$

$$V_A = \frac{+kQ}{r_A} + \frac{-kQ}{r_A} = 0$$

$$V_B = \frac{+kQ}{r_B} + \frac{-kQ}{r_B} = 0$$



15. A proton is traveling through the region shown in the figure. At the instant when it is at the position labeled “initial”, it has a kinetic energy of 170 eV. At a later moment, the particle is found to be at the position labeled “final”.



If the only work done on the proton was done by the electric field, what is the proton’s **kinetic energy** at the position labeled “final”? [Recall: An electronvolt (eV) is related to a joule in the following way $1\ \text{eV} = e \cdot (1\ \text{V}) = 1.6 \times 10^{-19}$ J.]

A. 20 eV

B. 70 eV

C. 100 eV

D. 190 eV

E. 270 eV

Since no external forces $\Delta Energy = \Delta U + \Delta K = 0$

$$\Delta K = -\Delta U = -(q\Delta V)$$

$$\Delta K = -(e(60V - -40V)) = -e(100V) = -100eV$$

$$K_{ef} = K_{ei} + \Delta K = 170\ eV - 100\ eV = 70\ eV$$

16. A cylindrical rod of carbon with length L and diameter d acts as a resistor in a circuit. The carbon rod is in series with a light bulb and a battery, as shown. If the rod is replaced with a new carbon rod that is half as long ($L \to L/2$) and twice the diameter ($d \to 2d$), what is the resistance of the new rod?

A. $R \to 8R$

B. $R \to 4R$

C. $R \to 2R$

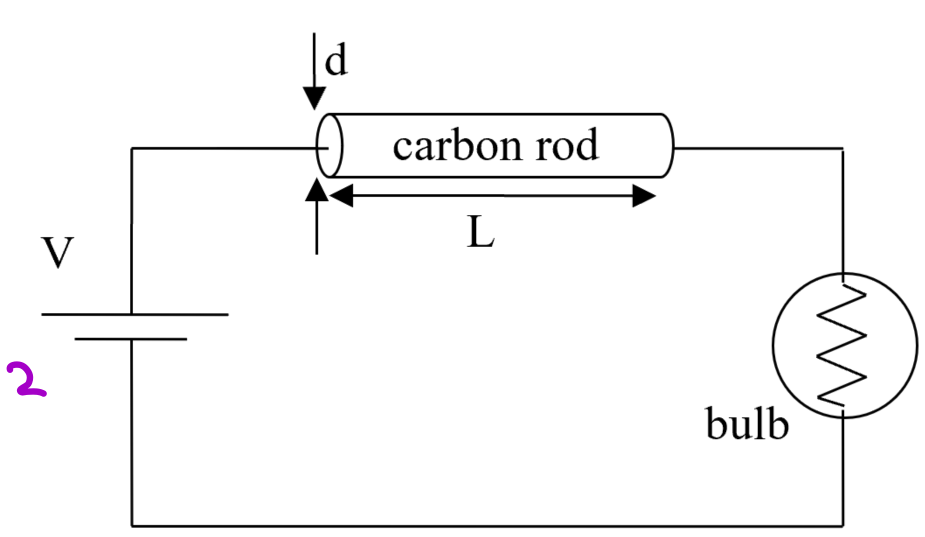
D. $R \to R$

E. $R \to R/8$

$$R_1 = \frac{\rho L_1}{A_1} = \frac{\rho L_1}{\pi (d_1/2)^2}$$

$$R_2 = \frac{\rho L_2}{A_2} = \frac{\rho L_2}{\pi (d_2/2)^2} = \frac{\rho L_1/2}{\pi \left(\frac{2d_1}{2}\right)^2}$$

$$= \frac{1}{8}\frac{\rho L_1}{\pi (d_1/2)^2} = R_1/8$$



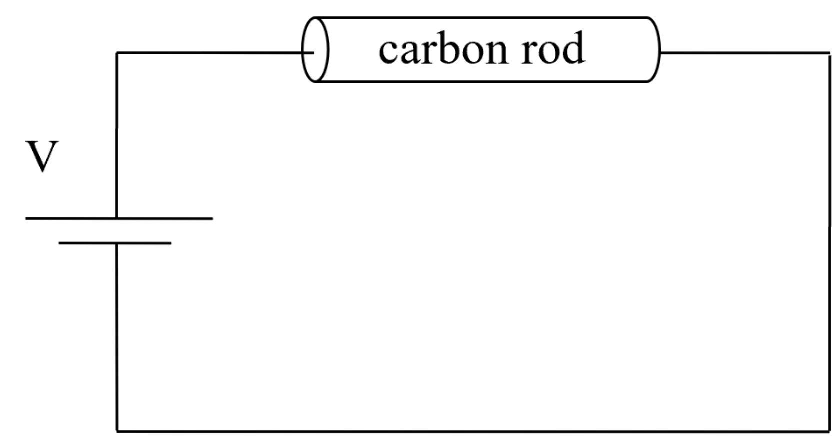
17. A resistor is made from a carbon rod and connected with ideal wires to an ideal battery as shown. The drift speed is v_d. Now, the battery voltage is doubled from V to $2V$. What is the new **drift speed**?

$I = \frac{V}{R} = JA = nqAv_d$

A. $4\,v_d$
B. $2\,v_d$
C. v_d
D. $v_d/2$
E. $v_d/4$

$v_{drift} = \frac{V}{\underbrace{RnqA}_{\text{not changing}}}$

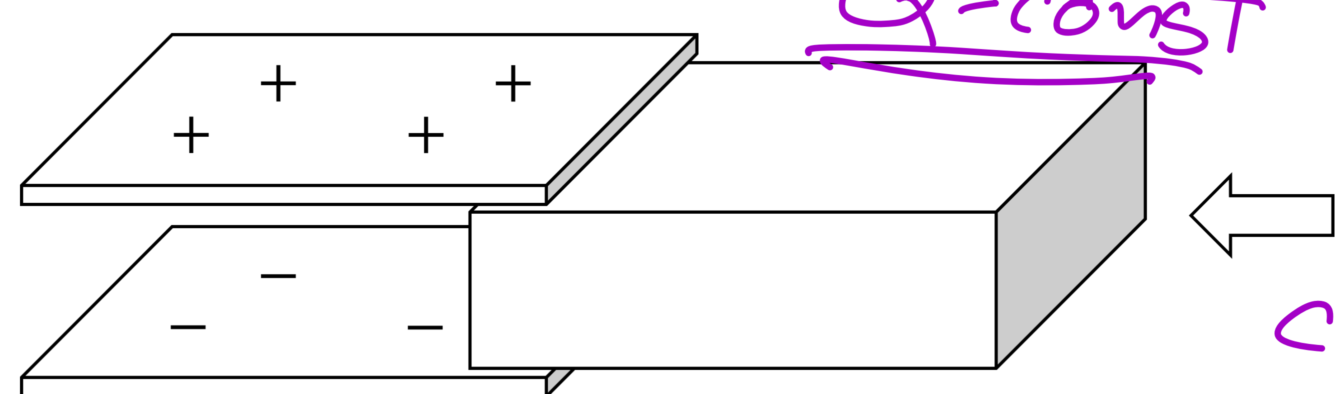
So as $V \to 2V$, $v_d \to 2v_d$



18. A dielectric ($\kappa > 1$) is being inserted between the plates of an isolated parallel-plate capacitor (which had been previously charged up by a battery, but is now isolated). While the dielectric is being inserted, what is happening to the potential difference between the capacitor plates (ΔV) and the electric potential energy stored in the capacitor (U)?

$Q = \text{const}$

A. ΔV is decreasing; U is decreasing.
B. ΔV is decreasing; U is increasing.
C. ΔV is constant; U is decreasing.
D. ΔV is constant; U is constant.
E. ΔV is decreasing; U is increasing.



$C = Q/\Delta V$

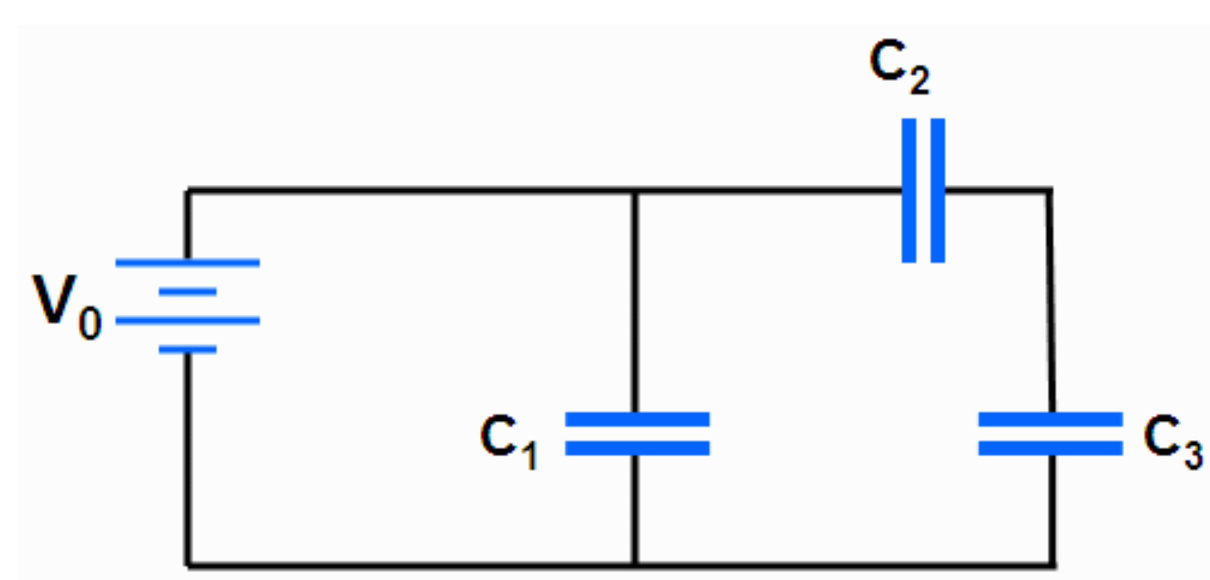
$C = \frac{\varepsilon_0 KA}{d}$ so as $K\uparrow$, $C\uparrow$. $U = \frac{1}{2}\frac{Q^2}{C}$ so $U\downarrow$. $\Delta V = \frac{Q}{C}$ so $\Delta V \downarrow$

19. A circuit consists of three identical capacitors $C_1 = C_2 = C_3 = C$, which are connected to a battery of voltage V_0 as shown. Evaluate the following statements as true/false.

× I. The voltage across C_1 is equal to the voltage across C_3. $V_1 = V_2 + V_3$
× II. The charge on C_1 is equal to the charge on C_2.

$Q = C\Delta V$ Since $V_1 \neq V_2$, $Q_1 \neq Q_2$

A. Both statements are true.
B. Statement I is true. Statement II is false.
C. Statement I is false. Statement II is true.
D. Both statements are false.



20. Three charges $+Q$, $-Q$, and $-Q$ form an equilateral triangle. The total **electrostatic energy** of this charge configuration is …

A. zero.

B. positive.

C. negative.

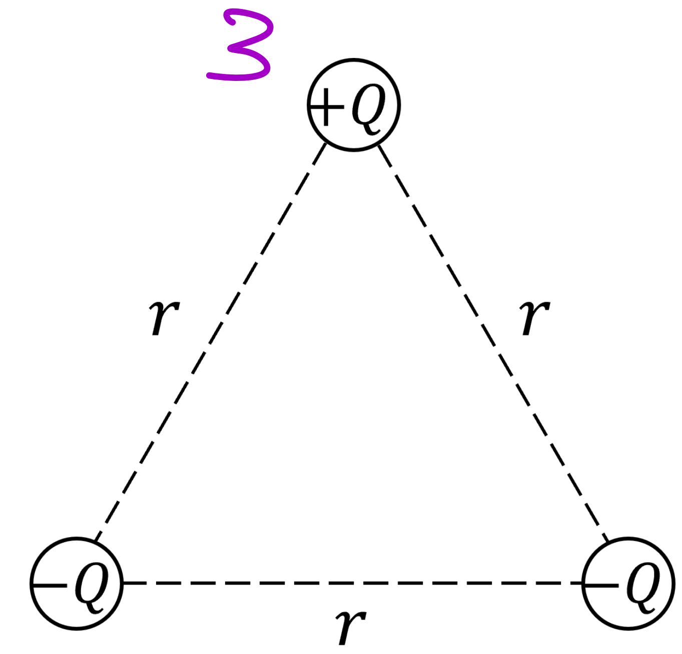
$U_{pair} = \frac{kq_1q_2}{r}$

$U_{tot} = U_{12} + U_{23} + U_{13}$

$= \frac{kQ^2}{r} - \frac{kQ^2}{r} - \frac{kQ^2}{r}$

$= -\frac{kQ^2}{r} < 0$

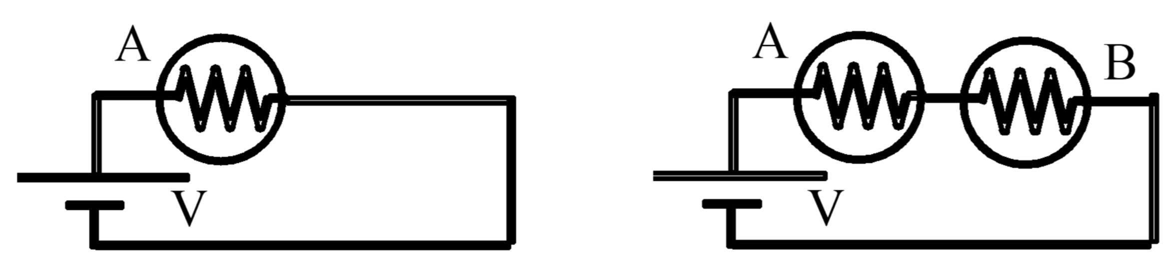
3



1 2

21. We start with Circuit 1, containing bulb A (with nonzero resistance). Circuit 2 is then made by adding a second identical bulb B as shown. In which circuit is the power supplied by the battery greater?

$I_1 = V/R$ $\qquad I_2 = \frac{V}{2R}$



$R_{eq} = 2R$

Circuit 1 Circuit 2

$P_1 = I_1^2 R = \frac{V^2}{R}$ $\qquad P_2 = I_2^2 R + I_2^2 R = \frac{V^2}{4R} + \frac{V^2}{4R} = \frac{V^2}{2R}$

A. The power supplied by the battery is greater in Circuit 1.

B. The power supplied by the battery is greater in Circuit 2.

C. The power supplied by the battery is the same in both circuits.

$P_2 < P_1$

22. A small ball of mass m has acquired a small net charge. The ball is then placed halfway between two very large (nearly infinite) parallel plates spaced a distance y apart, which have a potential difference of V applied across them. In this configuration, the ball is motionless floating in between the plates. What is the **electric charge** on the ball?

A. $+\frac{m|g|y}{2V}$

B. $-\frac{m|g|y}{2V}$

C. $+\frac{m|g|y}{V}$

D. $-\frac{m|g|y}{V}$

E. $-\frac{m|g|}{V}$

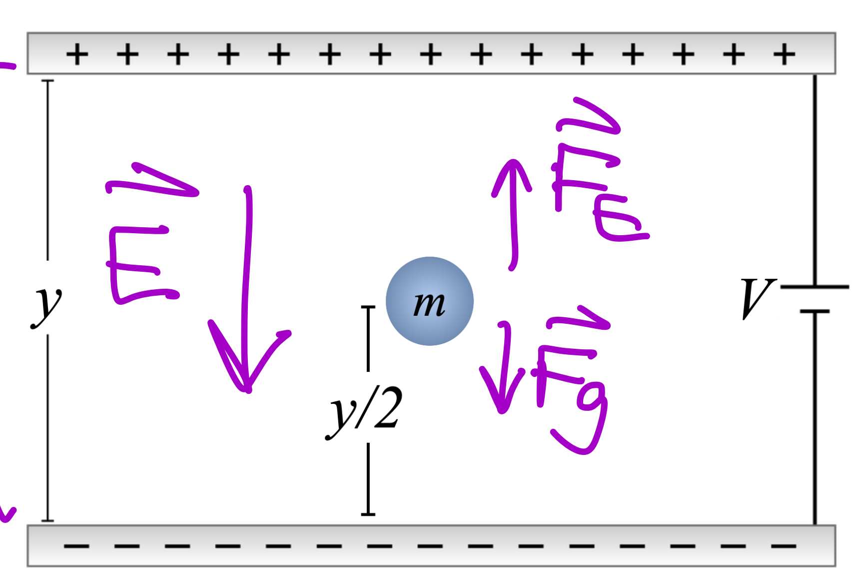
$|\vec{F}_E| = |\vec{F}_g|$

$|q||\vec{E}| = mg$

$|q|\frac{V}{y} = mg$

$|q| = \frac{mgy}{V}$

$V = |\vec{E}|y$



$\vec{F}_E$ is opposite $\vec{F}_g$, so $\vec{F}_E$ must be up.

Since $\vec{F}_E = q\vec{E}$, q must be negative.

(Use this page if you need extra space for your calculations.)