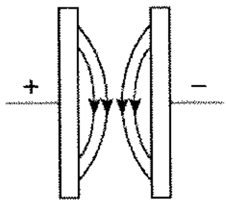
Answers

ELECTRICITY

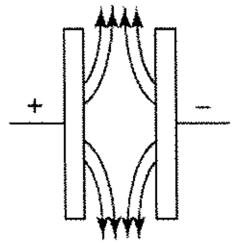
1.

Which diagram best illustrates the electric field between oppositely charged parallel plates?

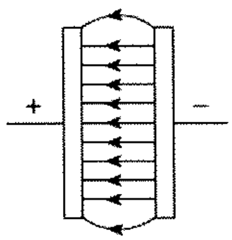
A.



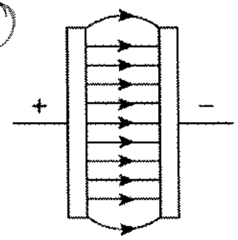
B.



C.



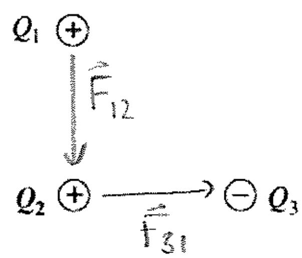
D.

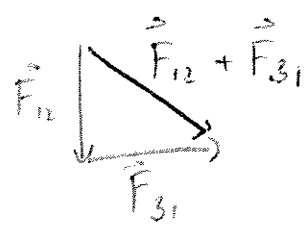


· electric current flows from ⊕ to ⊖ by convention

2.

Three charges of identical magnitude are arranged as shown.





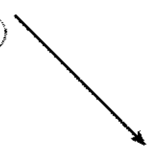
What is the direction of the electric force on Q_2?

A.

B.

C.

D.

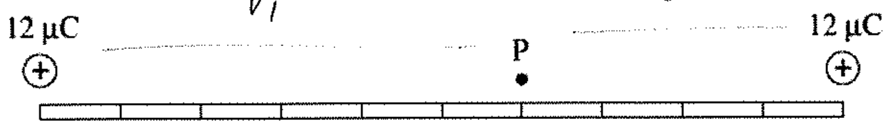


3.

12×10^{-6} C $\quad$ $r = 1.0$ m $\quad$ $V = \frac{kq}{r}$

Identical $12\,\mu C$ charges are placed at the ends of a metre stick.

V_1 $\quad$ V_2



$V_{tot} = V_1 + V_2$

$r_1 = 0.6$ m $\quad$ $r_2 = 0.4$ m

What is the electric potential at point P at the 60 cm mark on the metre stick?

A. 9.0×10^4 V
B. 3.8×10^5 V
C. 4.5×10^5 V
D. 9.8×10^5 V

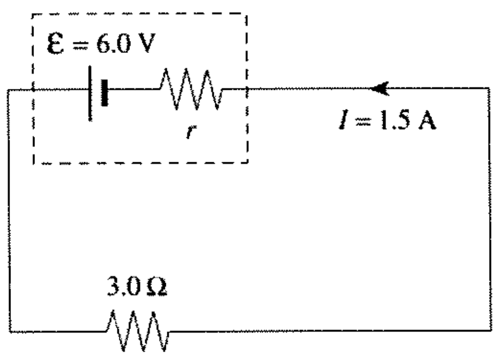
$$V_{tot} = \frac{(9.00 \times 10^9)(12 \times 10^{-6})}{0.6} + \frac{(9.00 \times 10^9)(12 \times 10^{-6})}{0.4}$$

$V_{tot} = 450\,000$ V

$V_{tot} = 4.5 \times 10^5$ V

4.

What is the internal resistance of the battery if it delivers 1.5 A when connected to a 3.0 Ω external load?



$V_{term} = IR$

$= (1.5)(3.0)$

$= 4.5$ V

A. 1.0 Ω
B. 3.0 Ω
C. 4.0 Ω
D. 7.0 Ω

$V_{term} = \mathcal{E} - Ir$

$$r = \frac{-V_{term} + \mathcal{E}}{I}$$

$$r = \frac{-4.5 + 6.0}{1.5}$$

$r = 1.0\ \Omega$

$R_{eq} = R_{loop} + r$

$\frac{1}{R_{loop}} = \frac{1}{2} + \frac{1}{6}$

5.

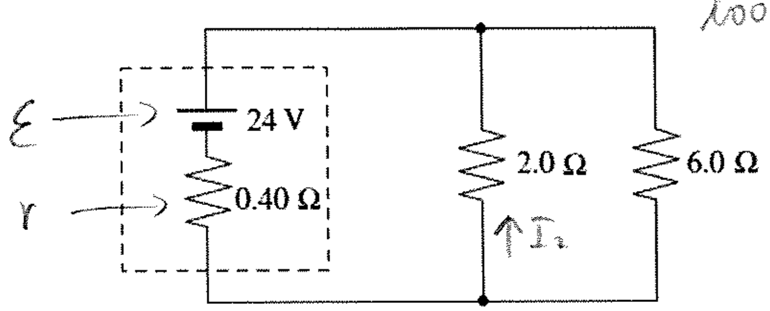
$= 1.5 + 0.40$

$= 1.9\,\Omega$

$= \frac{4}{6} \rightarrow R_{loop} = \frac{3}{2}\,\Omega$

$= \frac{2}{3}$ loop

In the circuit below, what is the current through the 2.0 Ω resistor?



A. 9.5 A
B. 10 A
C. 12 A
D. 13 A

$I = \frac{V}{R_{eq}} = \frac{\mathcal{E}}{R_{eq}}$

$= \frac{24}{1.9}$

$= 12.6316\ A$

$V_{term} = \mathcal{E} - Ir$

$= 24 - (12.6316)(0.40)$

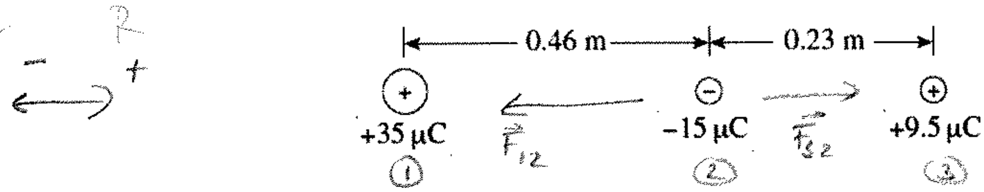
$= 18.9474\ V$

$I_2 = \frac{V_{term}}{R_2}$

$= \frac{18.9474}{2.0} = 9.4737\ A$

6.

Three point charges are arranged as shown below.



$\vec{F}_{e_2} = \vec{F}_{12} + \vec{F}_{32}$

$F_e = \frac{k|q_1||q_2|}{r^2}$

What are the magnitude and direction of the electric force on the −15 μC charge due to the other two point charges?

	Magnitude of Electric Force	Direction of Electric Force
A.	1.9 N ✓	right ✓
B.	1.9 N ✓	left
C.	47 N	right ✓
D.	47 N	left

$F = -22.3299 + 24.243$

$F = 1.9\ N$

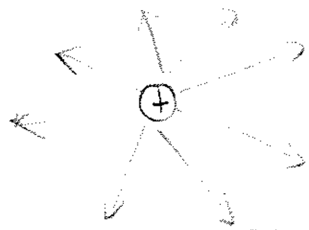
positive ⇒ Right

$\vec{F}_{12} = -\frac{(9.00\times10^9)(35\times10^{-6})(15\times10^{-6})}{0.46^2}$

$= -22.3299\ N$

$\vec{F}_{32} = \frac{(9.00\times10^9)(15\times10^{-6})(9.5\times10^{-6})}{0.23^2}$

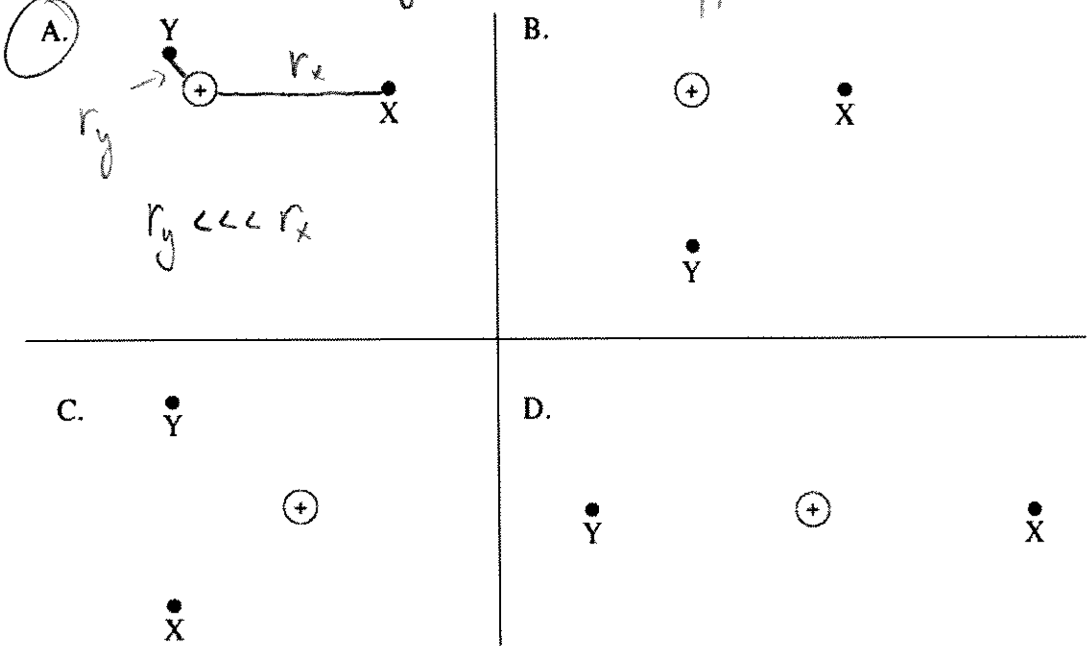
$= 24.2439\ N$



· the greater the r, the weaker the field

7.

Each diagram shows two points X and Y in the electric field near a positive charge. In which case is the difference in the magnitudes of the electric field strengths for the two points greatest? → greatest difference in "r"



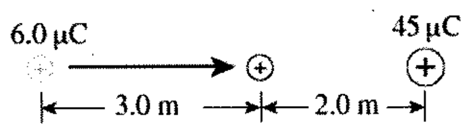
8.

. What is the change in potential energy of a 6.0 μC charge when it is moved 3.0 m closer to a 45 μC charge as shown?

! $r_i = 2.0 + 3.0 = \underline{5.0\,m}$

$EPE = E_p = \frac{kq_1q_2}{r}$

$\Delta EPE = EPE_f - EPE_i$



A. 0.49 J
B. 0.73 J
C. 1.2 J
D. 1.7 J

$\Delta EPE = \frac{(9.00\times10^9)(6.0\times10^{-6})(45\times10^{-6})}{2.0} - \frac{(9.00\times10^9)(6.0\times10^{-6})(45\times10^{-6})}{5.0}$

$= 1.215 - 0.4860$

$= \underline{0.729\ J}$

$m_{e^-} = 9.11 \times 10^{-31}$ kg

$q_{e^-} = -1.6 \times 10^{-19}$ C

* The direction of an electric field is determined by its effect on a positive particle.

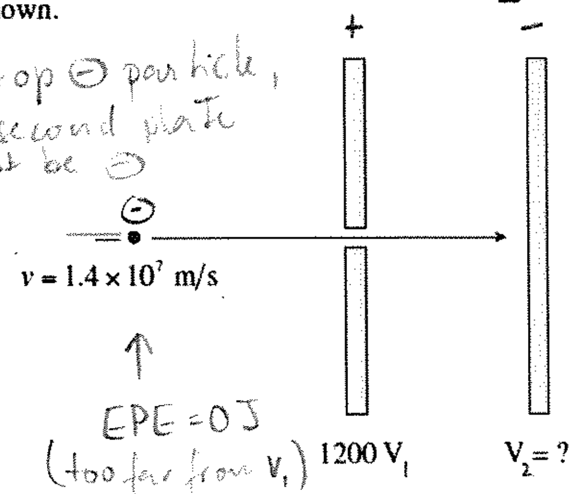
9.

Voltage drop

An electron travelling at 1.4×10^7 m/s enters the region between two charged parallel plates as shown.

- to stop ⊖ particle, the second plate must be ⊖

- $\Delta V = V_2 - V_1$
- $V_2 = \Delta V + V_1$



EPE = 0 J

(too far from V_1)

What voltage applied to the second plate would result in the electron just reaching this plate $\left(v_f = 0 \text{ at second plate}\right)$ and what is the direction of the electric field between the plates?

	VOLTAGE APPLIED TO SECOND PLATE	DIRECTION OF E-FIELD *
A.	640 V ✓	right ✓
B.	640 V ✓	left
C.	1800 V	right ✓
D.	1800 V	left

positive particle would be attracted to the second plate

- All KE goes into EPE → ($E_i = E_f$)

$|\Delta KE| = |\Delta EPE|$ and $\Delta V = \dfrac{\Delta EPE}{q} = \dfrac{|\Delta KE|}{q}$

$\Delta KE = KE_f - KE_i$

$= 0 - \frac{1}{2}(9.11 \times 10^{-31})(1.4 \times 10^7)^2$

$= -8.9278 \times 10^{-17}$ J

$\Rightarrow \Delta EPE = +8.9278 \times 10^{-17}$ J

$\Delta V = \dfrac{8.9278 \times 10^{-17}}{-1.6 \times 10^{-19}} \doteq -557.9875$ J

- $V_2 = -557.9875 + 1200$

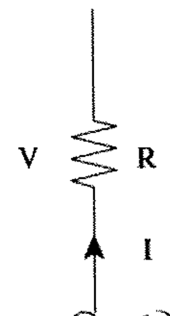
$= 642.0125$

$\doteq 6.40 \times 10^2$ V

10.

Consider the circuit element shown below.

(1) Before I_1 V_1 R_1 = (2) After I_2 $V_2 = 2V_1$ $R_2 = ?$



(1) (2) $I_1 = I_2$

The voltage across the resistor increases from V to 2V. The current remains the same. By what factor has the resistance changed?

A. $\frac{1}{4}$

B. $\frac{1}{2}$

C. 2

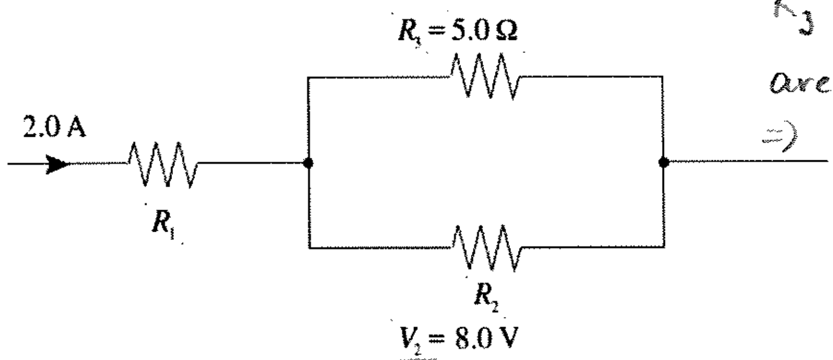
D. 4

$$R_1 = \frac{V_1}{I_1}$$

$$R_2 = \frac{V_2}{I_2} = \frac{2V_1}{I_1} = 2 \cdot \frac{V_1}{I_1} = 2 \cdot R_1$$

11.

A current of 2.0 A flows through resistor R_1 as shown below.



• R_3 and R_2 are in parallel $\Rightarrow V_3 = V_2$

What is the current flowing through the 5.0 Ω resistor? (R_3)

A. 0.40A
B. 1.0 A
C. 1.2 A
D. 1.6 A

$$I_3 = \frac{V_3}{R_3} = \frac{V_2}{R_3} = \frac{8.0}{5.0} = 1.6\ V$$

12.

An electric motor is being supplied with 4.2 A of current at 120 V. The resistance of the motor is $8.0\,\Omega$. How much power is the motor dissipating as heat?

A. 15 W

B. 1.4×10^2 W

C. 5.0×10^2 W

D. 1.8×10^3 W

internal resistance

$V_{lost} = I r$

$= (4.2)(8.0)$

$= 33.6\ V$

$P_{lost} = I \cdot V_{lost}$

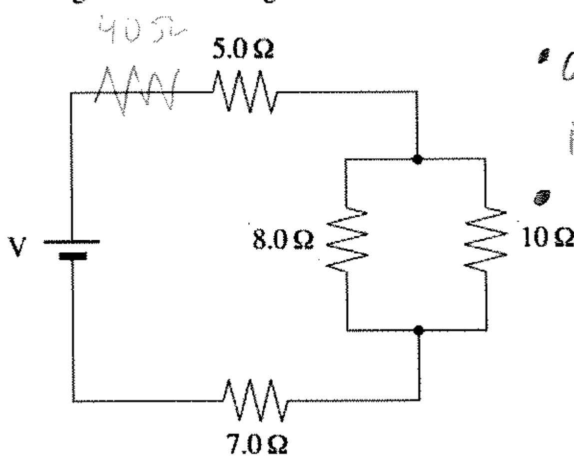
$= (4.2)(33.6)$

$= 141.12\ W$

$\doteq 1.4\times10^2\ W$

13.

A power source is providing a constant voltage V to the circuit shown below.



- adding a resistor in series will increase R_{eq}
- adding a resistor in parallel will decrease R_{eq}

If a $4.0\,\Omega$ resistor is added to the circuit in series with the $5.0\,\Omega$ what happens to the equivalent resistance of the circuit and the current through the $7.0\,\Omega$ resistor?

	EQUIVALENT RESISTANCE OF THE CIRCUIT	CURRENT THROUGH 7.0 Ω RESISTOR
A.	increases ✓	decreases ✓
B.	decreases	increases
C.	increases ✓	increases
D.	decreases	decreases ✓

$R_{eq} \uparrow$

V is constant

$I = \frac{V}{R} \Rightarrow \frac{V}{R\uparrow} \Rightarrow I\downarrow$ (R and I are inversely proportional).

• both particles are ⊕

→ they repel each other

→ they will stop when their KE transfers into EPE

14.

Alpha particles with a mass of 6.6×10^{-27} kg and a charge of 3.2×10^{-19} C are fired towards each other from a great distance.

• $-\Delta KE = \Delta EPE$

$m = 6.6\times10^{-27}$ kg	$m = 6.6\times10^{-27}$ kg
⊕ ⟶	⟵ ⊕
$Q = 3.2\times10^{-19}$ C	$Q = 3.2\times10^{-19}$ C

a) If they each have a speed of 2.5×10^{6} m/s to start with, what will be their minimum separation distance? **(4 marks)**

↑ r

$$EPE = E_p = \frac{k q_1 q_2}{r} \rightarrow r = \frac{k q_1 q_2}{EPE^*} = \frac{(9.00\times10^{9})(3.2\times10^{-19})(3.2\times10^{-19})}{2\left[\frac{1}{2}(6.6\times10^{-27})(2.5\times10^{6})^{2}\right]}$$

two particles

$$r \doteq 2.2\times10^{-14}\ \text{m}$$

∴ The minimum separation distance is 2.2×10^{-14} m.

b) Using energy principles, explain why the particles do not come any closer than this minimum separation distance. **(2 marks)**

When all KE of the particles is transferred into EPE, they can't move any closer as they do not have any more energy left to overcome the repulsive electric force stemming from their like charge.

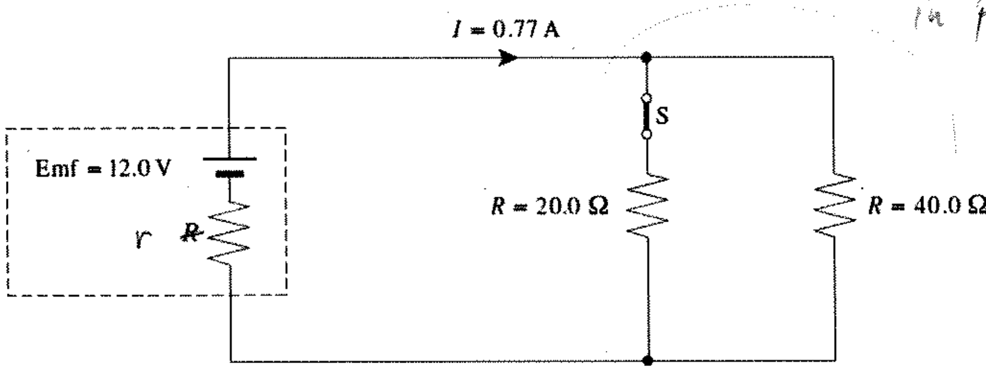
- Find r
- Find V_{term}

15.

3. **(6 marks)** $\mathcal{E}$

A battery having an emf of 12.0 V is connected to the circuit as shown.

loop with resistors in parallel



$$\frac{1}{R_{loop}} = \frac{1}{20.0} + \frac{1}{40.0}$$

$$\frac{1}{R_{loop}} = \frac{3}{40}$$

$$R_{loop} = \frac{40}{3}\ \Omega$$

What is the terminal voltage of the battery?

$R_{eq} = r + R_{loop}$

$r = R_{eq} - R_{loop}$

$= 15.5844 - \frac{40}{3}$

$\doteq \underline{2.25\ \Omega}$

$R_{eq} = \frac{\mathcal{E}}{I}$

$= \frac{12.0}{0.77}$

$= 15.5844\ \Omega$

- $V_{term} = \mathcal{E} - Ir$

$= 12.0 - (0.77)(2.25)$

$\doteq 10.27\ V$

$\therefore$ The terminal voltage $1.03 \times 10^1\ V$.

Explain what happens to the terminal voltage of this battery when switch S is opened. ! $\mathcal{E}$ is constant

→ no current throug $R = 20.0\ \Omega \Rightarrow R_{eq} = r + 40.0$
So R_{eq} is greater than before as the resistors are now in series only. $R_{eq}\uparrow$ and $\mathcal{E}$ is constant leads to $I\downarrow$ (*). With less current going through the battery the voltage at the terminals will increase because (Ir) decreases and $\mathcal{E}$ is constant

(*) $I_i = \frac{\mathcal{E}}{R_{eq_i}} \Rightarrow I_f = \frac{\mathcal{E}}{R_{eq_f}}$ → greater R_{eq} yields smaller I

$I_f < I_i$ because $R_{eq_i} < R_{eq_f}$

$\therefore V_{term}$ increases.

- $\vec{F}_1 = \vec{F}_{21} + \vec{F}_{31}$
$\doteq 15.9499\ N$
positive ⇒ Right

- $\vec{F}_{21} = \dfrac{(9.0\times10^{9})(15\times10^{-6})(25\times10^{-6})}{0.23^2} \doteq 63.7996\ N$
- $\vec{F}_{31} = -\dfrac{(9.0\times10^{9})(15\times10^{-6})(75\times10^{-6})}{0.46^2} \doteq -47.8497\ N$

16.

Three point charges are arranged as shown below.

← − + →

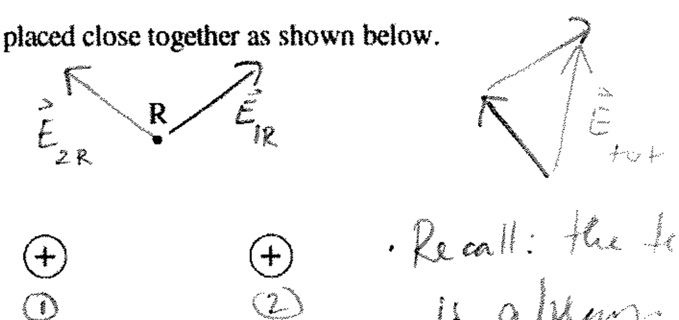
← 0.23 m →	← 0.23 m →	
⊖	⊕	⊖
−15 μC	+25 μC	−75 μC
(1)	(2)	(3)

What are the magnitude and direction of the electric force on the −15 μC charge due to the other two point charges?

	Magnitude of Electric Force	Direction of Electric Force
A.	16 N ✓	Right ✓
B.	16 N ✓	Left
C.	110 N	Right
D.	110 N	Left

17.

Two equally charged particles are placed close together as shown below.



- Recall: the test particle is always ⊕

Which of the following shows the net electric field due to these two particles at point R?

A. →

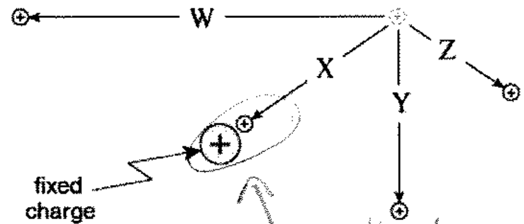
B. ←

C. ↓

D. ↑

18.

A small test charge is moved to several different locations near a larger fixed charge as shown.



smallest separation distance

Which change in position of the smaller charge would require the most work?

$W = \Delta EPE$

A. W
B. X
C. Y
D. Z

$EPE = \frac{k q_1 q_2}{r}$

→ the smaller the r, the greater the EPE

19.

A proton initially held at rest 2.0 m away from a fixed 25 μC charge is released. The proton accelerates to the right as shown.

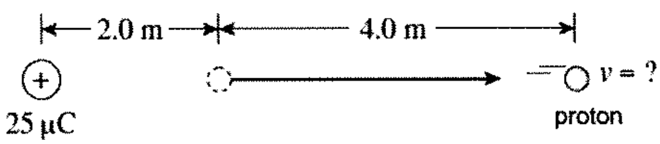
• $KE_i + EPE_i = KE_f + EPE_f$

$0 + EPE_i = \frac{1}{2} m v^2 + EPE_f$

• $v_i = 0\ m/s$

→ $KE_i = 0\ J$

• $m = 1.67 \times 10^{-27}\ kg$



→ $v = \sqrt{\frac{EPE_i - EPE_f}{\frac{1}{2} m}}$

What is the speed of the proton when it is 6.0 m away from the 25 μC charge?

A. 2.7×10^6 m/s
B. 3.3×10^6 m/s
C. 3.8×10^6 m/s
D. 4.6×10^6 m/s

$$v = \sqrt{\frac{\frac{(9 \times 10^9)(25 \times 10^{-6})(1.6 \times 10^{-19})}{2.0} - \frac{(9.00 \times 10^9)(25 \times 10^{-6})(1.6 \times 10^{-19})}{6.0}}{\frac{1}{2}(1.67 \times 10^{-27})}}$$

$v \doteq 3{,}790{,}944\ m/s$

$v \doteq 3.8 \times 10^6\ m/s$

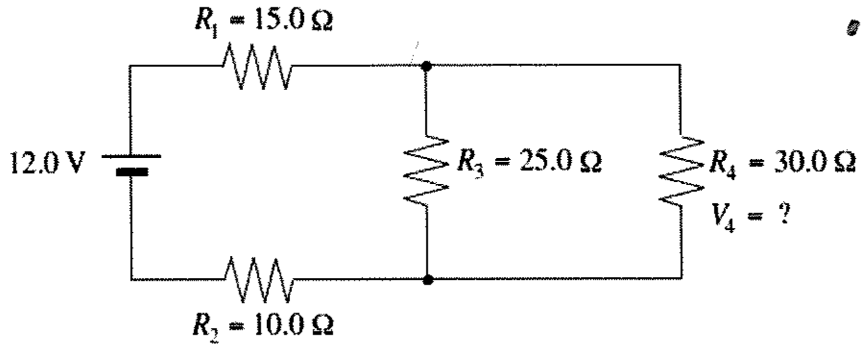
$\frac{1}{R_{loop}} = \frac{1}{25.0} + \frac{1}{30.0} = 0.07\bar{3}$ → $R_{loop} \doteq 13.6364\,\Omega$

$R_{eq} = 15.0 + 10.0 + R_{loop} \doteq 38.6364\,\Omega$

20.

A 12.0 V power supply is connected to 4 resistors as shown.

loop



$V = R \cdot I$

$I = \frac{V}{R_{eq}}$

$I = \frac{12.0}{38.6364}$

$\doteq 0.3106\ A$

What is the potential difference, V_4, across the $30.0\,\Omega$ resistor?

A. 2.12 V
B. 4.24 V
C. 9.32 V
D. 12.0 V

$V_3 = V_4 = V_{loop}$ (parallel resistors)

$V_{battery} = V_1 + V_2 + V_{loop}$

$V_{loop} = 12.0 - 4.659 - 3.106$

$= 4.235$

$\doteq 4.24\,V$

$V_1 = (15.0)(0.3106)$

$\doteq 4.659\,V$

$V_2 = (10.0)(0.3106)$

$= 3.106\ V$

21.

An electric motor is being supplied with 500 W of power at 120 V. The resistance of the motor is $8.0\,\Omega$. What current is being supplied to the motor?

A. 4.2 A
B. 7.9 A
C. 15 A
D. 63 A

$P = IV \rightarrow I = \frac{P}{V}$

$I = \frac{500}{120}$

$I \doteq 4.2\ A$

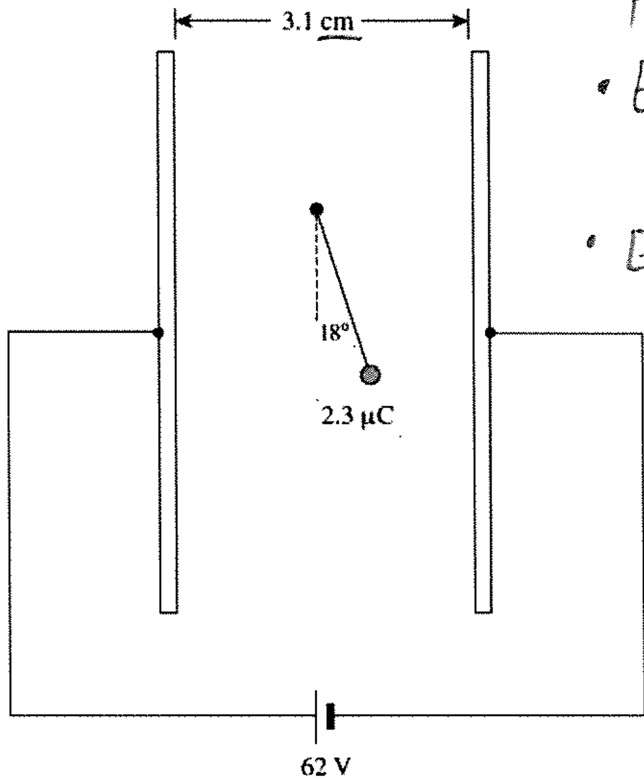
a sphere is at rest

22.

(5 marks)

A small sphere having a charge of $2.3\ \mu C$ is suspended from a thread hanging between two charged plates as shown.

$d = 0.031\ m$



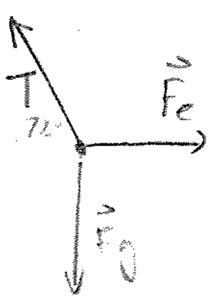
- parallel plates
- $E = \frac{\Delta V}{d} = \frac{62}{0.031} = 2000\ N/C$
- $E = \frac{F}{q} \rightarrow F = Eq$

$\rightarrow \vec{F} = (2000)(2.3 \times 10^{-6})$

$= \underline{0.0046\ N}\ [R]$

What is the mass of the small sphere?

FBD:



$F_{net} = 0\ N$

$[0,0] = [0, -mg] + [F_e, 0] + [-T_x, T_y]$

- $0 = 0 + F_e - T_x$

$0.0046 = T \cdot \cos 72°$

$T = \frac{0.0046}{\cos 72°}$

$\underline{T = 0.014885912\ N}$

- $0 = -mg + T_y$

$m = \frac{T_y}{g}$

$= \frac{T \cdot \sin 72°}{9.8}$

$\doteq \underline{0.001445\ kg}$

∴ The mass of the sphere is $\underline{1.4 \times 10^{-3}\ kg}$.