The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Science A Physics

Lectures 13-22:

Additional Problems: Electric Fields, Electric Potential, Current, Resistance, and Capacitance

Discovering Electricity

Q.1 Charged glass and plastic rods hang by threads. An object attracts the glass rod. If this object is then held near the plastic rod, it will

a) Attract the plastic rod.

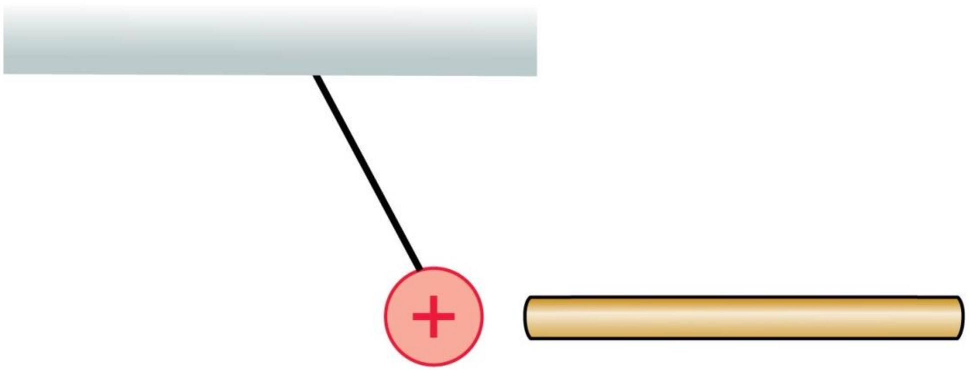
b) Repel the plastic rod.

c) Not affect the plastic rod.

d) Either A or B. There's not enough information to tell.

Charge

Q.2 A rod attracts a positively charged hanging ball. The rod is



a) Positive.

b) Negative.

c) Neutral.

d) Either A or C.

e) Either B or C.

Coulomb's law:

1. If two charged particles having charges q_1 and q_2 are a distance r apart, the particles exert forces on each other of magnitude

$$F_{1\text{ on }2} = F_{2\text{ on }1} = \frac{K|q_1||q_2|}{r^2}$$

where K is called the **electrostatic constant.** These forces are an action/reaction pair, equal in magnitude and opposite in direction.

2. The forces are directed along the line joining the two particles. The forces are *repulsive* for two like charges and *attractive* for two opposite charges.

In SI units $K = 8.99 \times 10^9$ N m^2/C^2.

PROBLEM-SOLVING STRATEGY 25.1

Electrostatic forces and Coulomb's law

MODEL Identify point charges or objects that can be modeled as point charges.

VISUALIZE Use a *pictorial representation* to establish a coordinate system, show the positions of the charges, show the force vectors on the charges, define distances and angles, and identify what the problem is trying to find. This is the process of translating words to symbols.

PROBLEM-SOLVING STRATEGY 25.1

Electrostatic forces and Coulomb's law

SOLVE The mathematical representation is based on Coulomb's law:

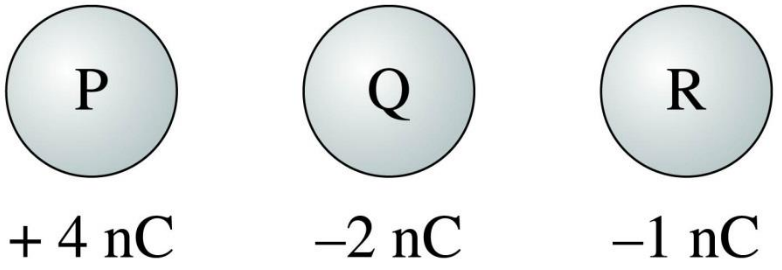
$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{K|q_1||q_2|}{r^2}$$

- Show the directions of the forces—repulsive for like charges, attractive for opposite charges—on the pictorial representation.
- When possible, do graphical vector addition on the pictorial representation. While not exact, it tells you the type of answer you should expect.
- Write each force vector in terms of its x- and y-components, then add the components to find the net force. Use the pictorial representation to determine which components are positive and which are negative.

ASSESS Check that your result has the correct units, is reasonable, and answers the question.

Charge

Q.3 Identical metal spheres are initially charged as shown. Spheres P and Q are touched together and then separated. Then spheres Q and R are touched together and separated. Afterward the charge on sphere R is



a) –1 nC or less.

b) –0.5 nC.

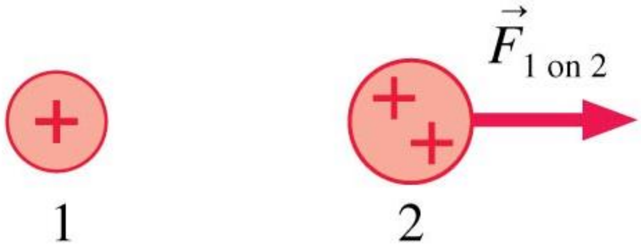
c) 0 nC.

d) +0.5 nC.

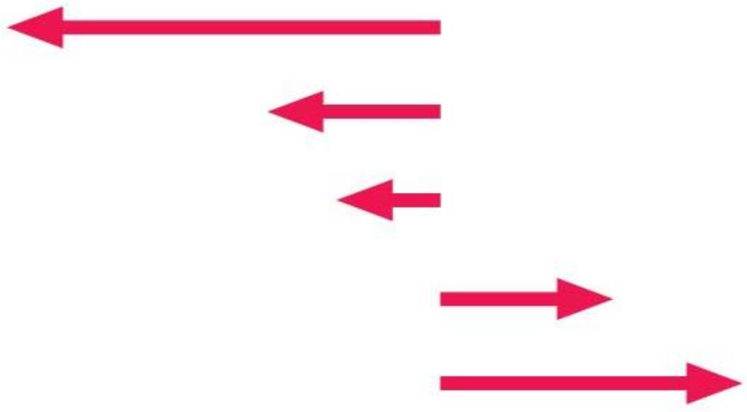
e) +1.0 nC or more.

Coulomb's Law

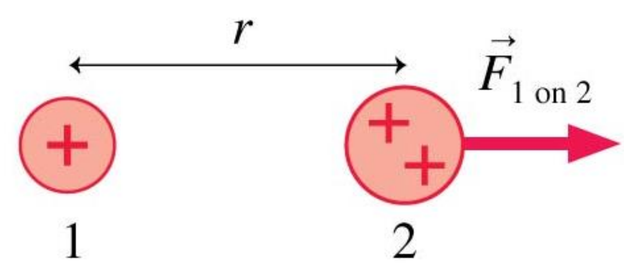
Q.4 The charge of sphere 2 is twice that of sphere 1. Which vector below shows the force of 2 on 1?



a)
b)
c)
d)
e)



Coulomb’s Law



Q.5 The charge of sphere 2 is twice that of sphere 1. Which vector below shows the force of 1 on 2 if the distance between the spheres is reduced to $r/2$?

a) 

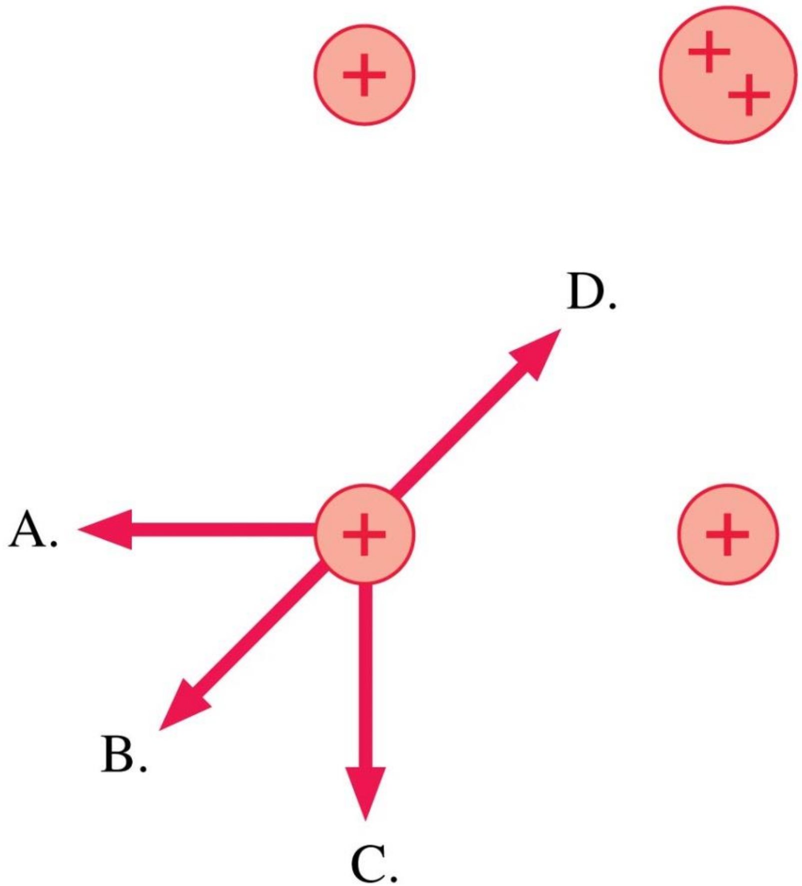
b) 

c) 

d) None of the above.

Electric Force

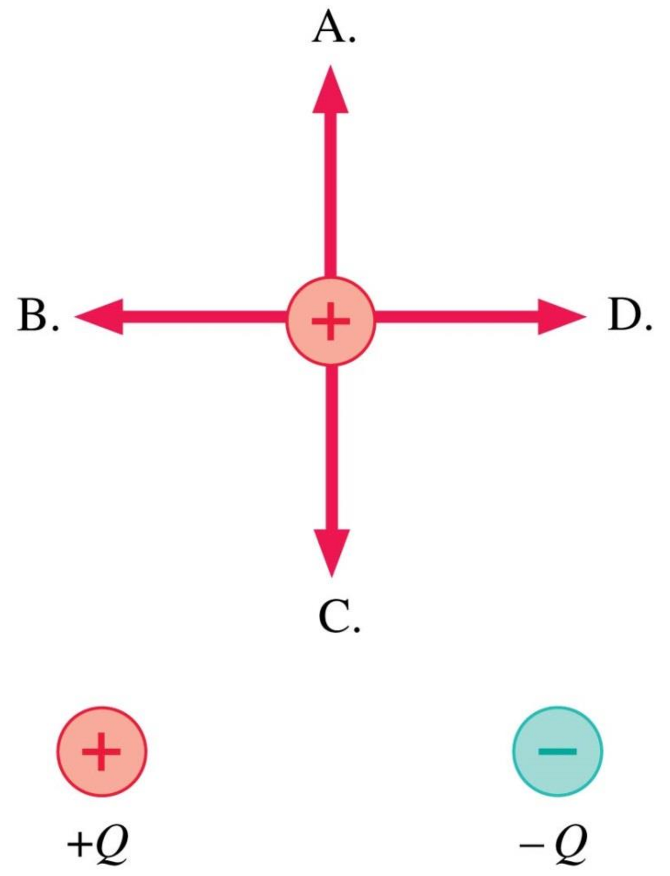
Q.6 Which is the direction of the net force on the charge at the lower left?



E. None of these.

Electric Force

Q.7 Which is the direction of the net force on the charge at the top?



E. None of these.

Lifting a Glass Bead

Q.8 A small plastic sphere charged to – 10 nC is held 1.0 cm above a small glass bead at rest on a table. The bead has a mass of 15 mg and a charge of + 10 nC. Will the glass bead 'leap up' to the plastic sphere?

Electric Force

Q.9 The direction of the force on charge $-q$ is

a) Up.

b) Down.

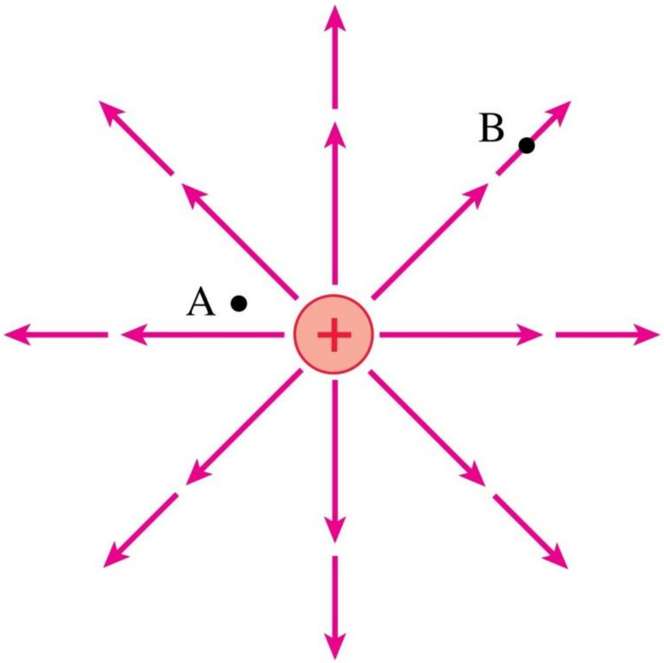
c) Left.

d) Right.

e) The force on $-q$ is zero.

Electric Field

Q.10 At which point is the electric field stronger?



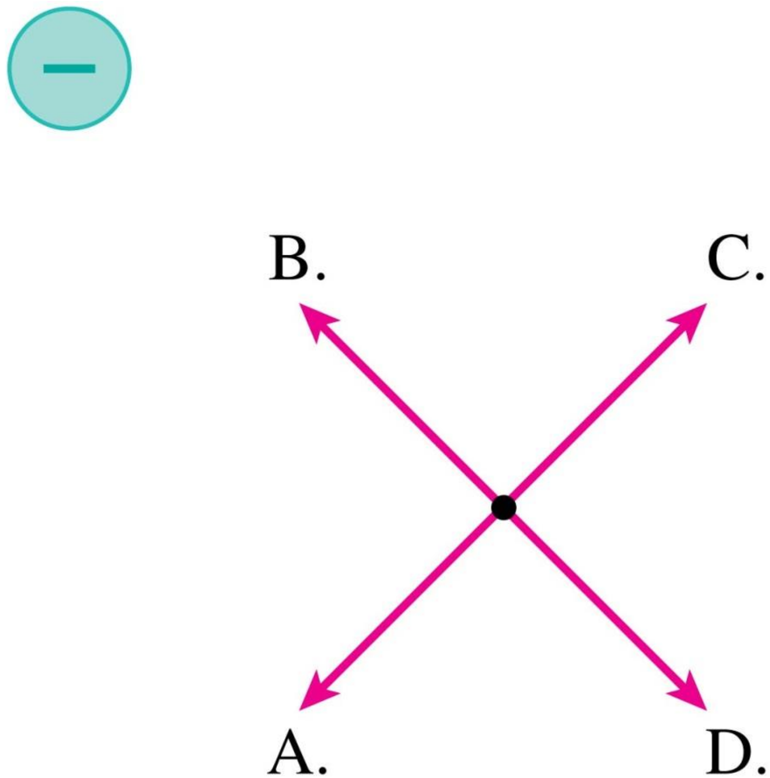
a) Point A.

b) Point B.

c) Not enough information to tell.

Electric Field

Q.11 Which is the electric field at the dot?



E. None of these.

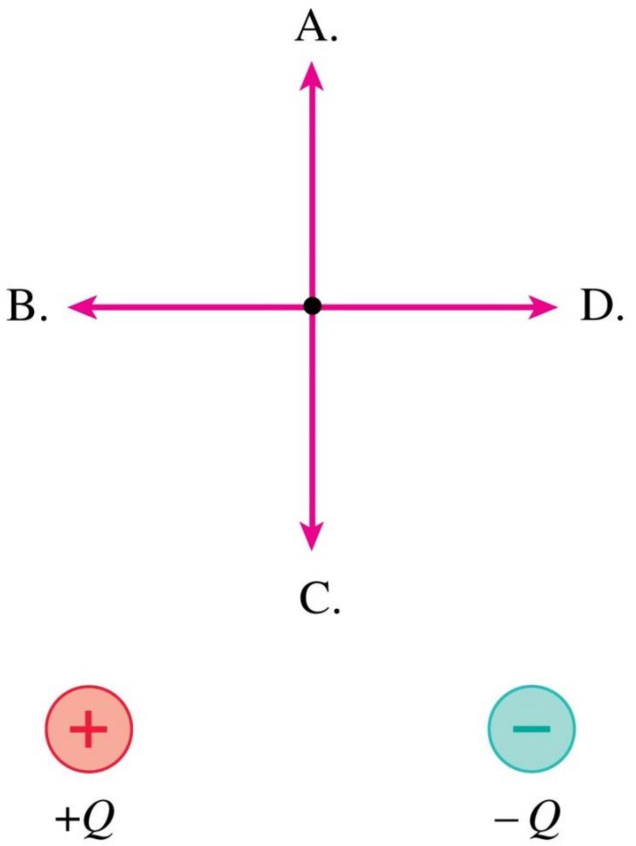
The Electric Field of a Proton

Q.12 The electron in a hydrogen atom orbits the proton at a radius of 0.053 nm.

a. What is the proton's electric field strength at the position of the electron?
b. What is the magnitude of the electric force on the electric force on the electron?

Electric Field

Q.13 What is the direction of the electric field at the dot?



E. None of these.

PROBLEM-SOLVING STRATEGY 26.1

The electric field of multiple point charges

MODEL Model charged objects as point charges.

VISUALIZE For the pictorial representation:

- Establish a coordinate system and show the locations of the charges.
- Identify the point P at which you want to calculate the electric field.
- Draw the electric field of each charge at P.
- Use symmetry to determine if any components of $\vec{E}_{net}$ are zero.

PROBLEM-SOLVING STRATEGY 26.1

The electric field of multiple point charges

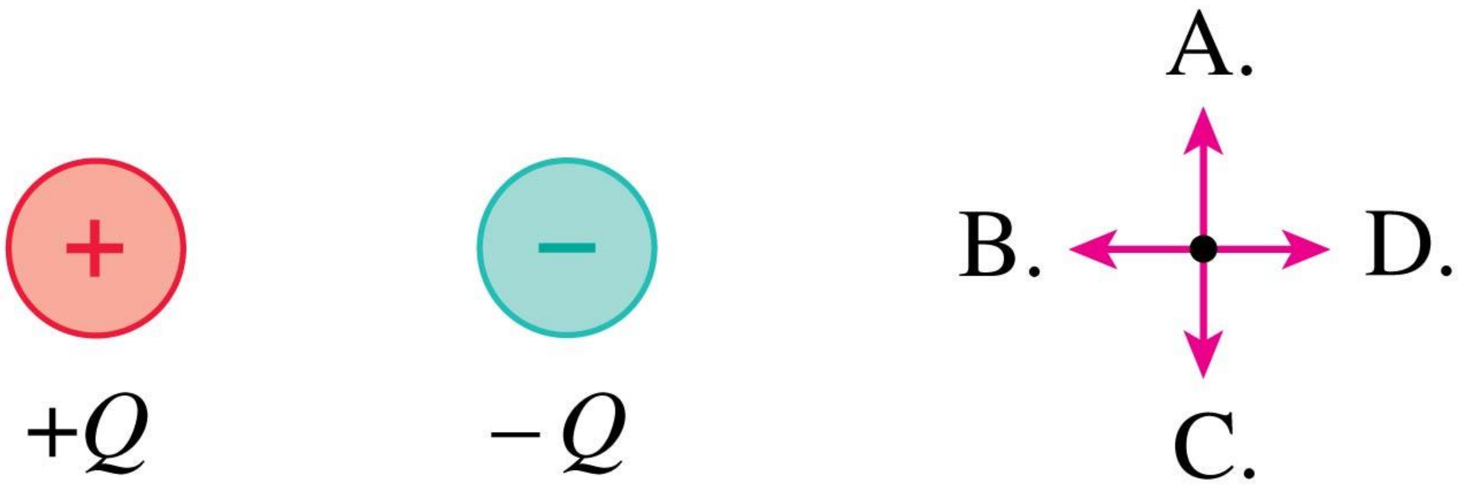
SOLVE The mathematical representation is $\vec{E}_{\text{net}} = \sum \vec{E}_i$.

- For each charge, determine its distance from P and the angle of $\vec{E}_i$ from the axes.
- Calculate the field strength of each charge's electric field.
- Write each vector $\vec{E}_i$ in component form.
- Sum the vector components to determine $\vec{E}_{\text{net}}$.
- If needed, determine the magnitude and direction of $\vec{E}_{\text{net}}$.

ASSESS Check that your result has the correct units, is reasonable, and agrees with any known limiting cases.

Electrical Field of Multiple Point Charges

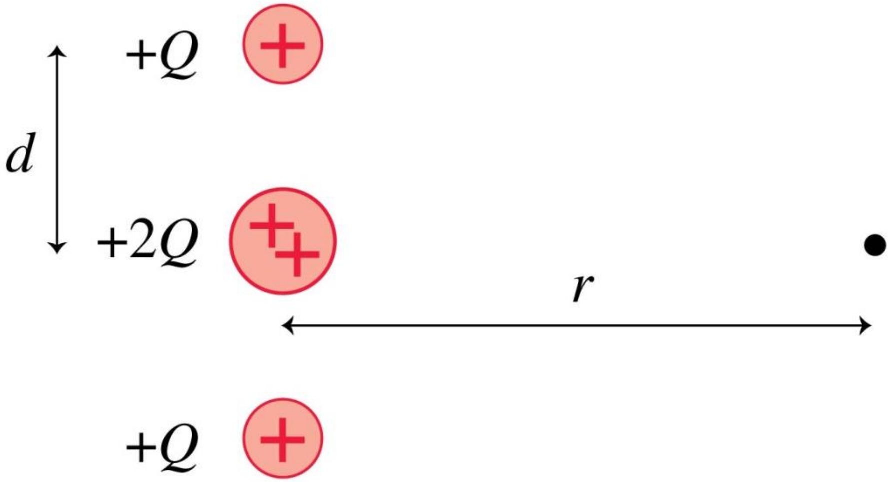
Q.14 What is the direction of the electric field at the dot?



E. The field is zero.

Electrical Field of Multiple Point Charges

Q.15 When $r >> d$, the electric field strength at the dot is



A. $\dfrac{Q}{4\pi\epsilon_0 r^2}$

B. $\dfrac{2Q}{4\pi\epsilon_0 r^2}$

C. $\dfrac{4Q}{4\pi\epsilon_0 r^2}$

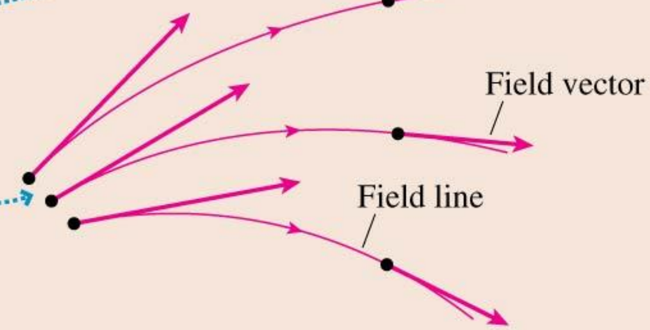
D. $\dfrac{4Q}{4\pi\epsilon_0 (r^2 + d^2)}$

E. $\dfrac{4Q}{4\pi\epsilon_0 r}$

TACTICS BOX 26.1 **Drawing and using electric field lines**

❶ Electric field lines are continuous curves drawn tangent to the electric field vectors. Conversely, the electric field vector at any point is tangent to the field line at that point.

❷ Closely spaced field lines represent a larger field strength, with longer field vectors. Widely spaced lines indicate a smaller field strength.

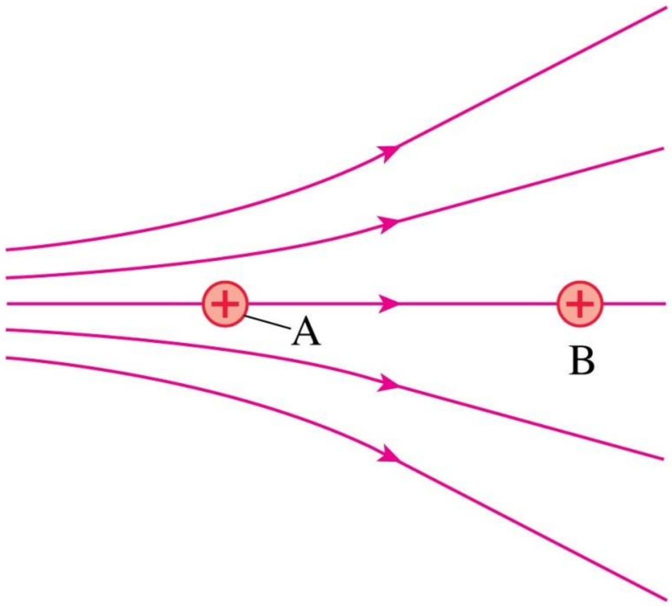


❸ Electric field lines never cross.

❹ Electric field lines start from positive charges and end on negative charges.

Electrical Field

Q.16 Two protons, A and B, are in ar
electric field. Which proton ha
the larger acceleration?



a) Proton A.

b) Proton B.

c) Both have the same acceleration.

The Parallel Plate Capacitor

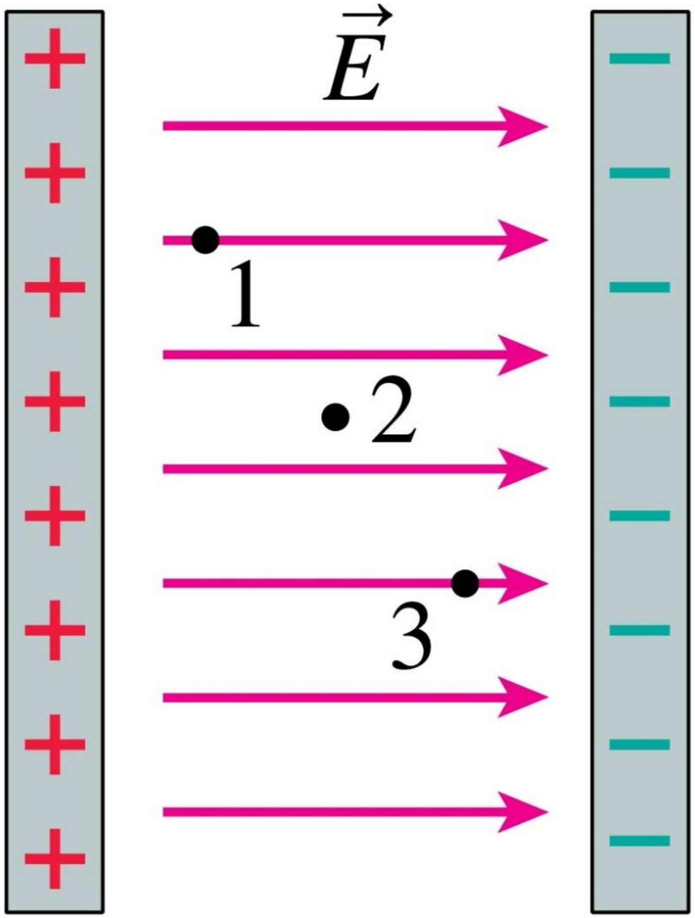
Q.17 Three points inside a parallel-plate capacitor are marked. Which is true?

a) $E_1 > E_2 > E_3$

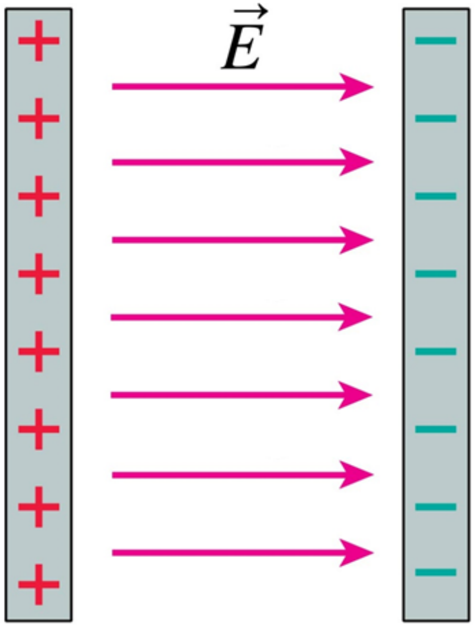
b) $E_1 < E_2 < E_3$

c) $E_1 = E_2 = E_3$

d) $E_1 = E_3 > E_2$



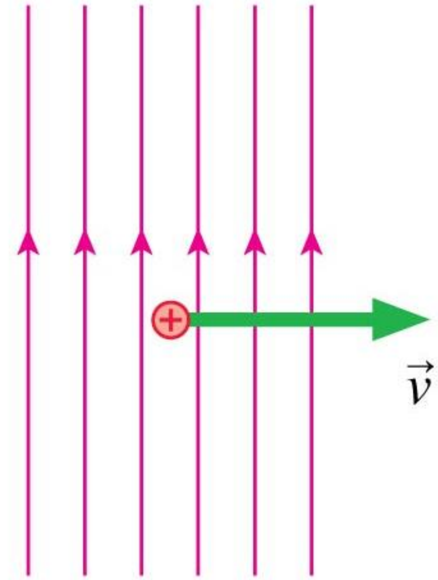
The Electric Field Inside a Capacitor

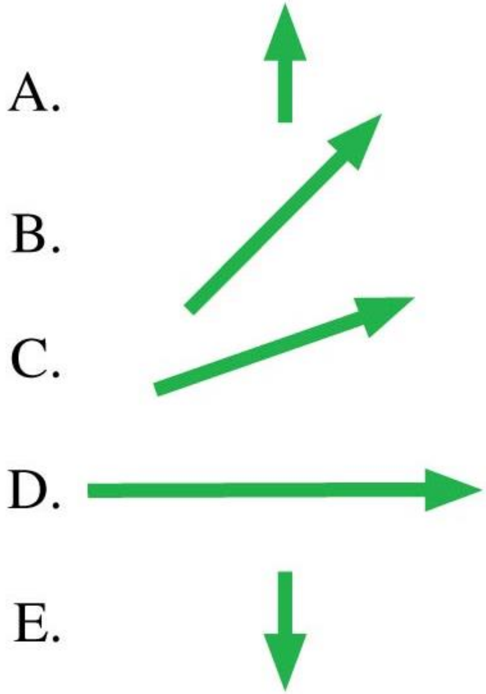


Q.18 Two 1.0 cm × 2.0 cm rectangular electrodes are 1.0 cm apart. What charge must be placed on each electrode to create a uniform electric field of strength 2.0×10^6 N/C? How many electrons must be moved from one electrode to the other to accomplish this?

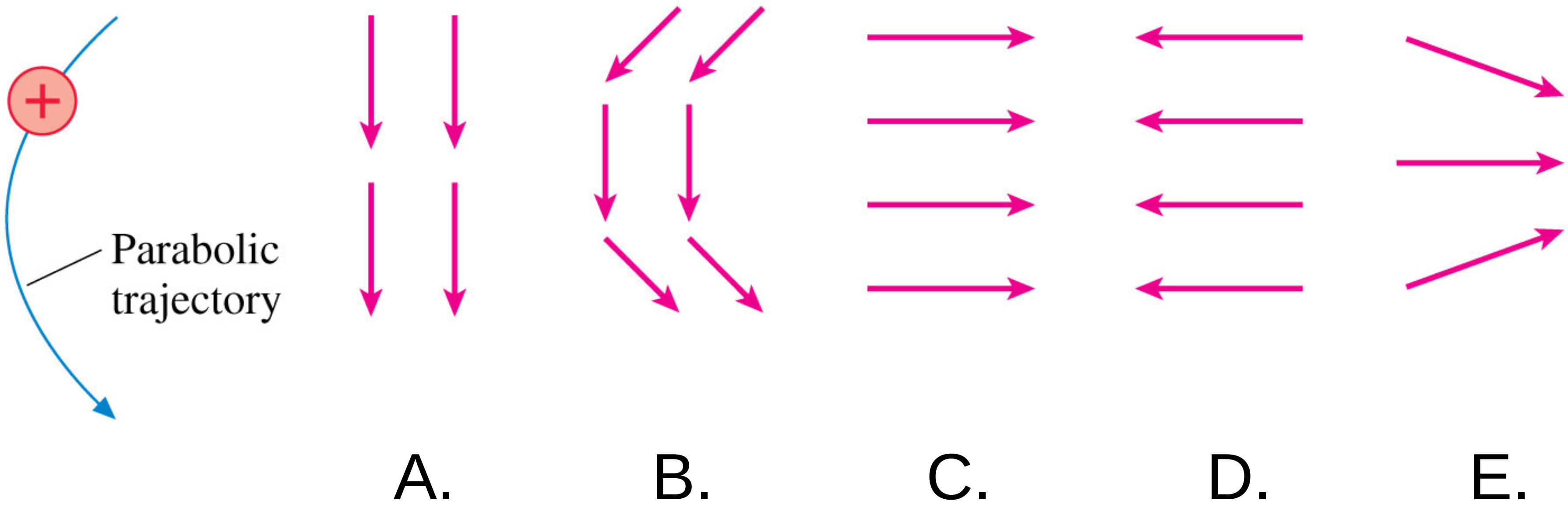
Motion of a Charged Particle in an Electric Field

Q.19 A proton is moving to the right in a vertical electric field. A very short time later, the proton's velocity is





Motion of a Charged Particle in an Electric Field



Q.20 Which electric field is responsible for the proton's trajectory?

Electric Flux

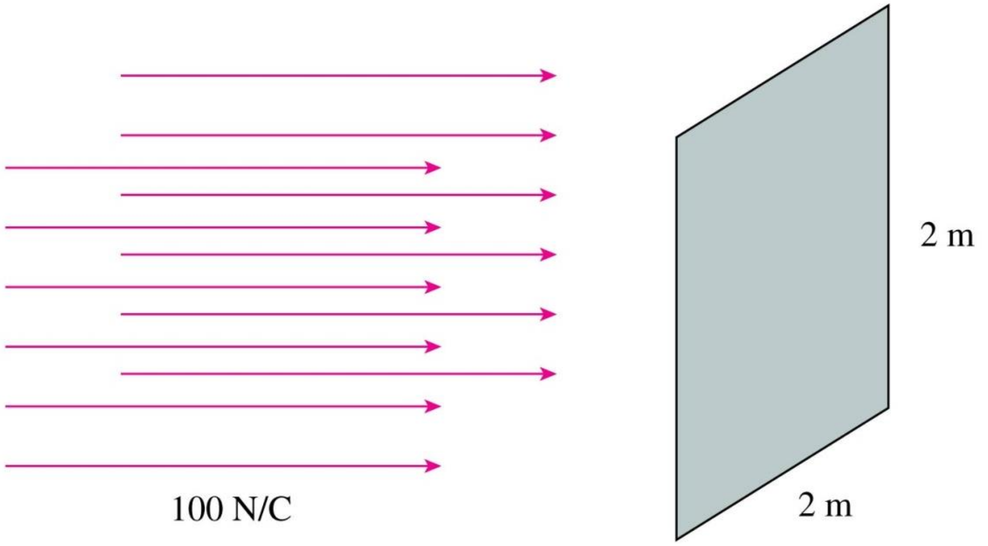
Q.21 The electric flux through the shaded surface is

a) 0.

b) 200 N m/C.

c) 400 N m^2/C.

d) Flux isn't defined for an open surface.



Electric Flux

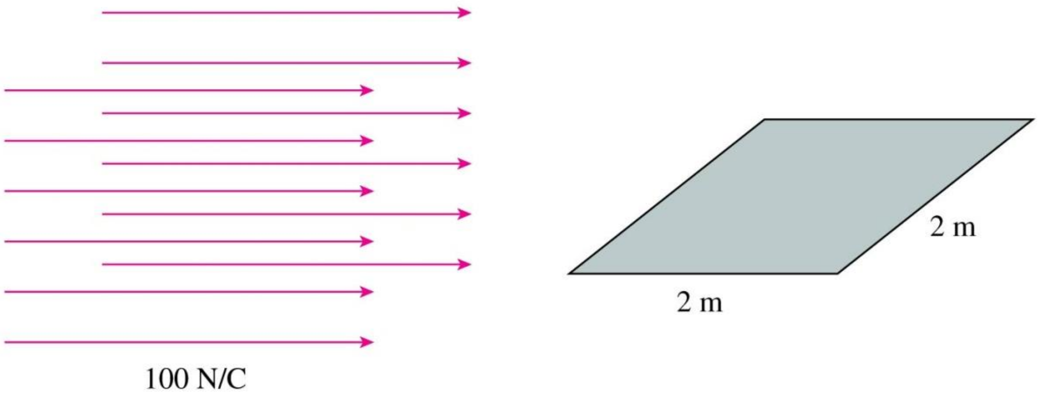
Q.22 The electric flux through the shaded surface is

a) 0.

b) 200 N m/C.

c) 400 N m^2/C.

d) Some other value.



Electric Flux

Q.23 The electric flux through the shaded surface is

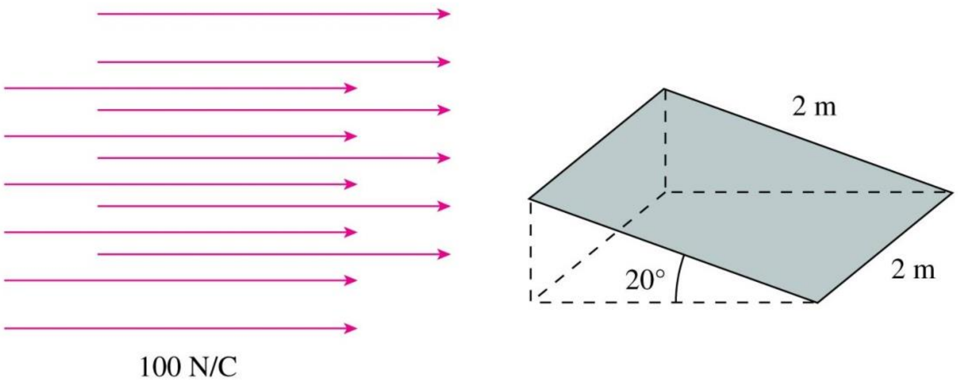
a) 0.

b) $400\cos 20°$ N m^2/C.

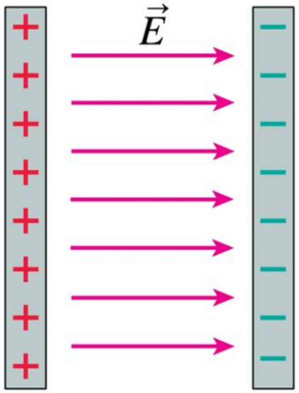
c) $400\cos 70°$ N m^2/C.

d) 400 N m^2/C.

e) Some other value.



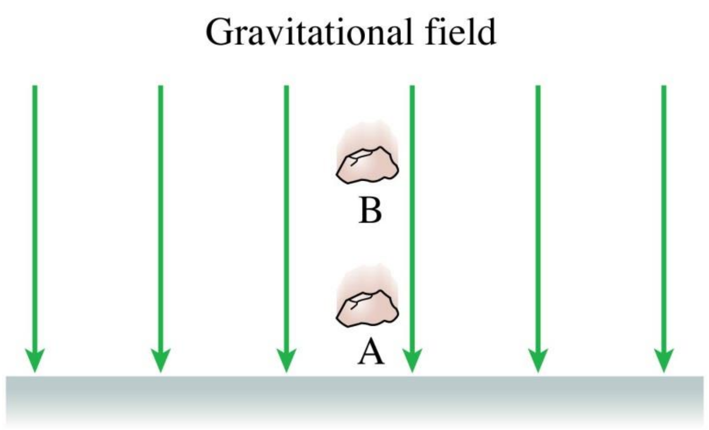
The Electric Flux Inside a Parallel-Plate Capacitor



Q.24 Two 100 cm^2 parallel electrodes are 2.0 cm apart. One is charged to +5.0 nC, the other to -5.0 nC. A 1.0 cm $\times$ 1.0 cm surface between the electrodes is tilted to where its normal makes a 45° angle with the electric field. What is the electric flux through this surface?

Gravitational Potential

Q.25 Two rocks have equal mass. Which has more gravitational potential energy?



a) Rock A.

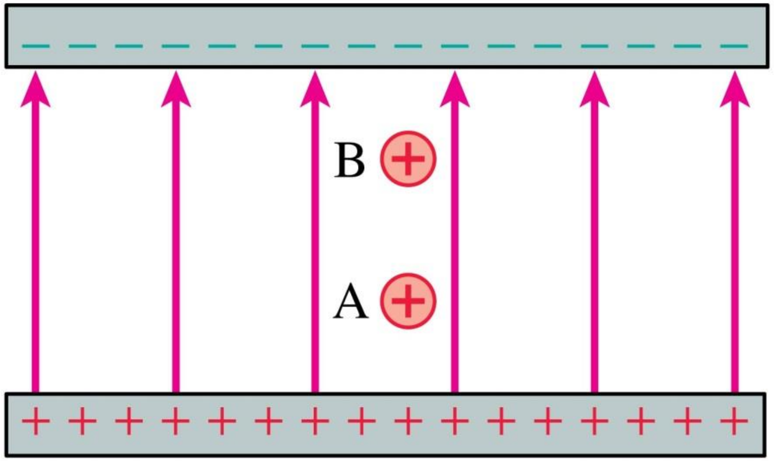
b) Rock B.

c) They have the same potential energy.

d) Both have zero potential energy.

Electric Potential Energy

Q.26 Two positive charges are equal. Which has more electric potential energy?



a) Charge A.

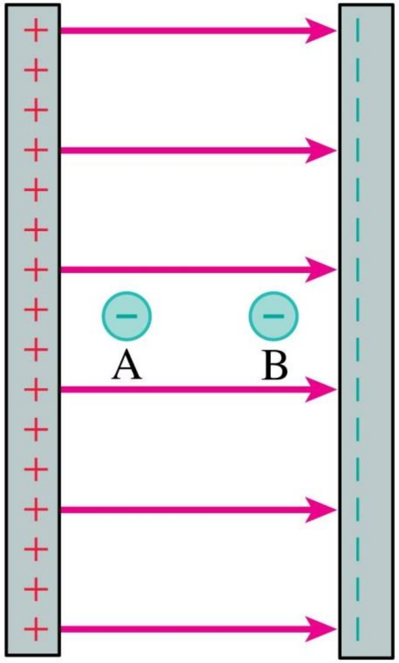
b) Charge B.

c) They have the same potential energy.

d) Both have zero potential energy.

Electric Potential Energy

Q.27 Two negative charges are equal. Which has more electric potential energy?



a) Charge A.

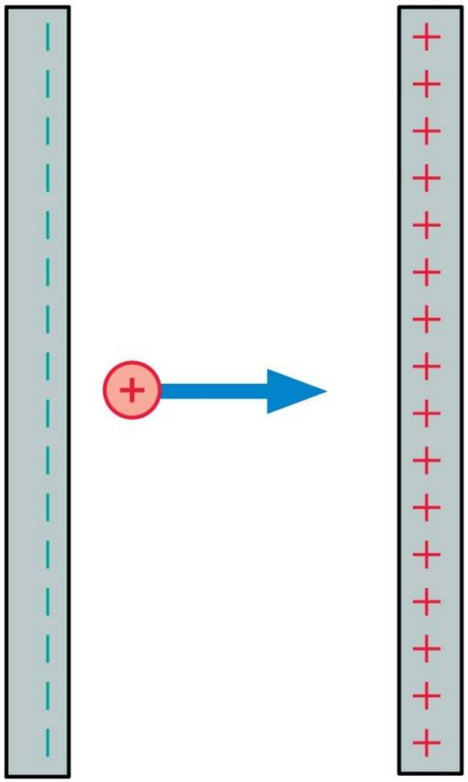
b) Charge B.

c) They have the same potential energy.

d) Both have zero potential energy.

Electric Potential Energy

Q.28 A positive charge moves as shown. Its kinetic energy



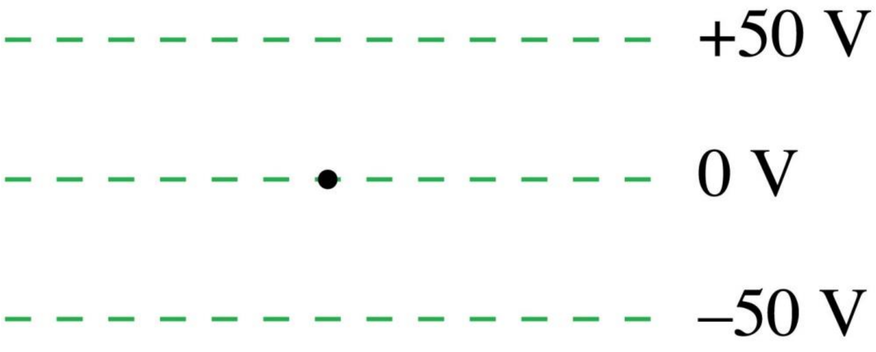
a) Increases.

b) Remains constant.

c) Decreases.

Electric Potential

Q.29 A proton is released from rest at the dot. Afterward, the proton



a) Remains at the dot.

b) Moves upward with steady speed.

c) Moves upward with an increasing speed.

d) Moves downward with a steady speed.

e) Moves downward with an increasing speed.

Electric Potential

Q.30 If a positive charge is released from rest, it moves in the direction of

a) A stronger electric field.
b) A weaker electric field.
c) Higher electric potential.
d) Lower electric potential.
e) Both B and D.

PROBLEM-SOLVING STRATEGY 28.1 Conservation of energy in charge interactions

MODEL Check whether there are any dissipative forces that would keep the mechanical energy from being conserved.

VISUALIZE Draw a before-and-after pictorial representation. Define symbols that will be used in the problem, list known values, and identify what you're trying to find.

PROBLEM-SOLVING STRATEGY 28.1

Conservation of energy in charge interactions

MP

SOLVE The mathematical representation is based on the law of conservation of mechanical energy:

$$K_f + qV_f = K_i + qV_i$$

- Is the electric potential given in the problem statement? If not, you'll need to use a known potential, such as that of a point charge, or calculate the potential using the procedure given later, in Problem-Solving Strategy 28.2.
- K_i and K_f are the sums of the kinetic energies of all moving particles.
- Some problems may need additional conservation laws, such as conservation of charge or conservation of momentum.

ASSESS Check that your result has the correct units, is reasonable, and answers the question.

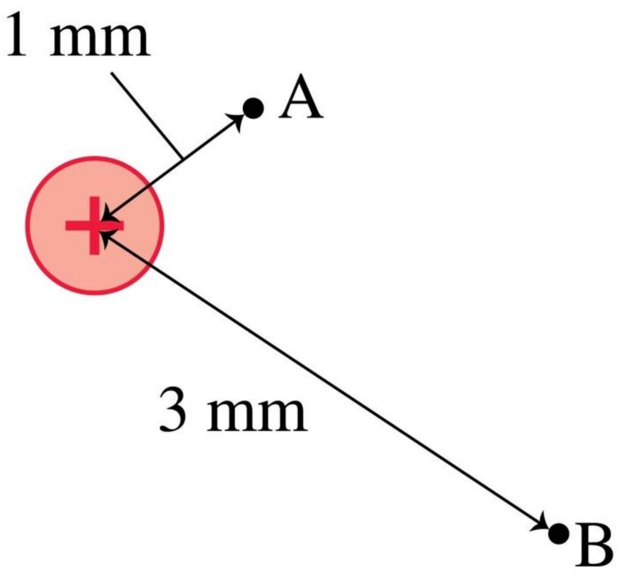
Exercise 22

Moving through a Potential Difference

Q.31 A proton with a speed of 2.0×10^5 m/s enters a region of space in which source charges have created an electric potential. What is the proton's speed after it moves through a potential difference of 100 V? What will be the final speed if the proton is replaced by an electron?

Electric Potential

Q.32 What is the ratio V_B/V_A of the electric potentials at the two points?



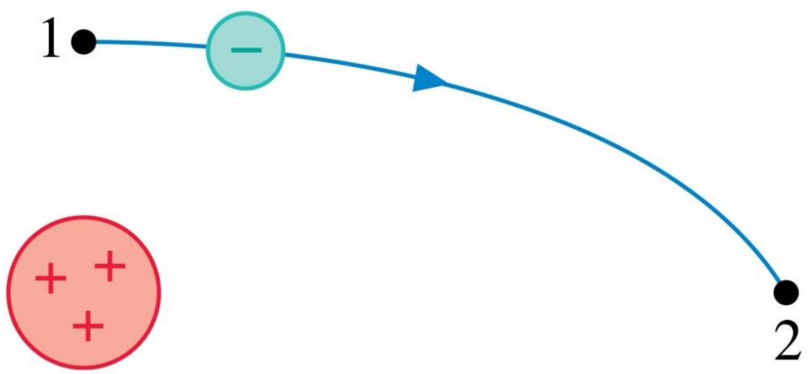
a) 9.
b) 3.
c) 1/3.
d) 1/9.
e) Undefined without knowing the charge.

Calculating the Potential of a Point Charge

Q.33 What is the electric potential 1.0 cm from a +1.0 nC charge? What is the potential difference between a point 1.0 cm away and a second point 3.0 cm away?

Electric Potential

Q.34 An electron follows the trajectory shown from point 1 to point 2. At point 2,



a) $v_2 > v_1$.

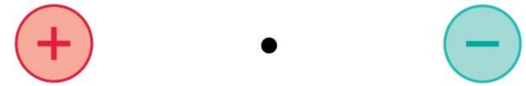
b) $v_2 = v_1$.

c) $v_2 < v_1$.

d) Not enough information to compare the speeds at these points.

Electric Potential

Q.35 At the midpoint between these two equal but opposite charges,



a) $\vec{E} = \vec{0}$; $V = 0$.

b) $\vec{E} = \vec{0}$; $V > 0$.

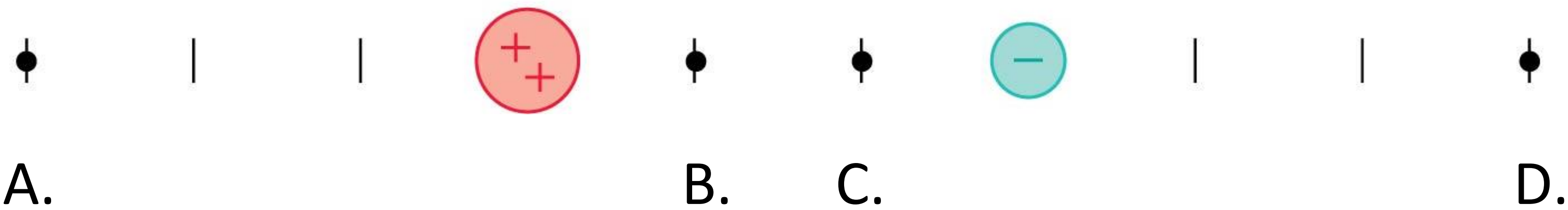
c) $\vec{E} = \vec{0}$; $V < 0$.

d) $\vec{E}$ points right; $V = 0$.

e) $\vec{E}$ points left; $V = 0$.

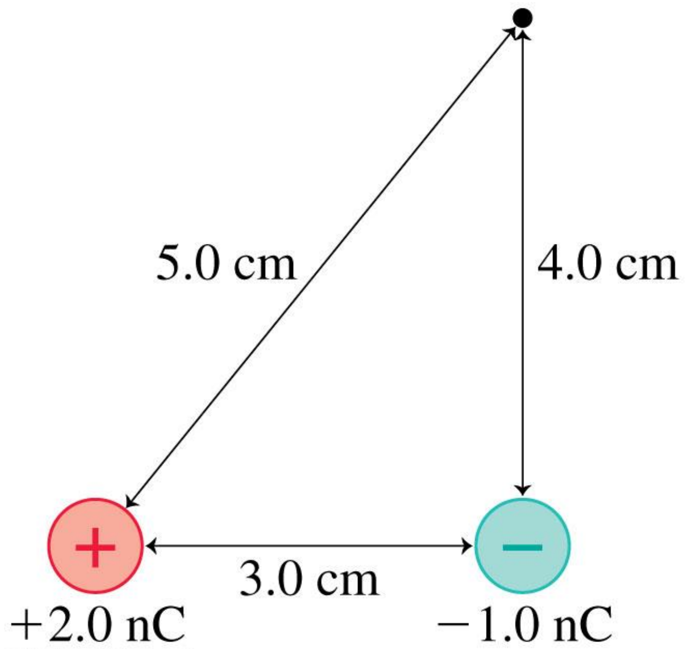
Electric Potential

Q.36 At which point or points is the electric potential zero?



E. More than one of these.

The Potential of Two Charges



Q.37 What is the electric potential at the point indicated in the figure?

Batteries

Q.38 The charge escalator in a battery does 4.8×10^{-19} J of work for each positive ion that it moves from the negative to the positive terminal. What is the battery's Voltage?

a) 9 V.

b) 4.8 V.

c) 3 V.

d) 4.8×10^{-19} V.

e) I have no idea.

Electric Potential

Q.39 Which set of equipotential surfaces matches this electric field?

A.

B.

C.

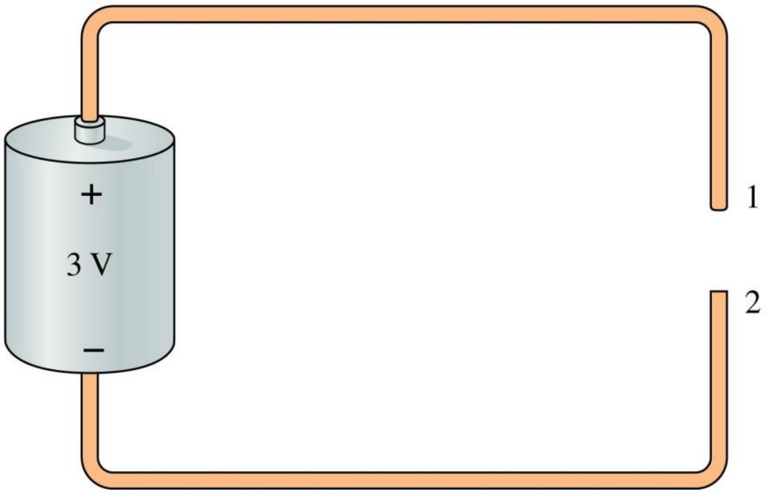
D.

E.

F.

Potential Difference

Q.40 Metal wires are attached to the terminals of a 3 V battery. What is the potential difference between points 1 and 2?



a) 6 V.

b) 3 V.

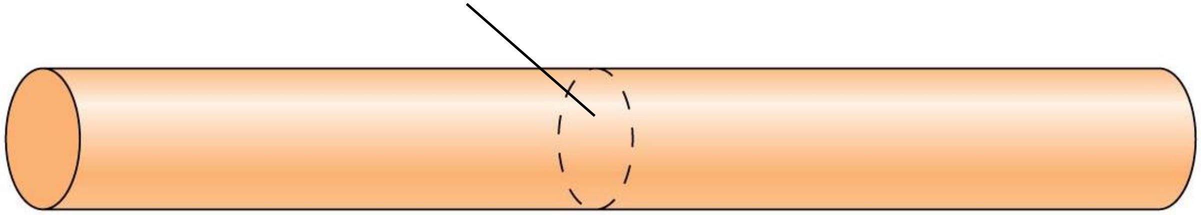
c) 0 V.

d) Undefined.

e) Not enough information to tell.

Current

Q.41 Every minute, 120 C of charge flow through this cross section of the wire.



The wire's current is

a) 240 A.

b) 120 A.

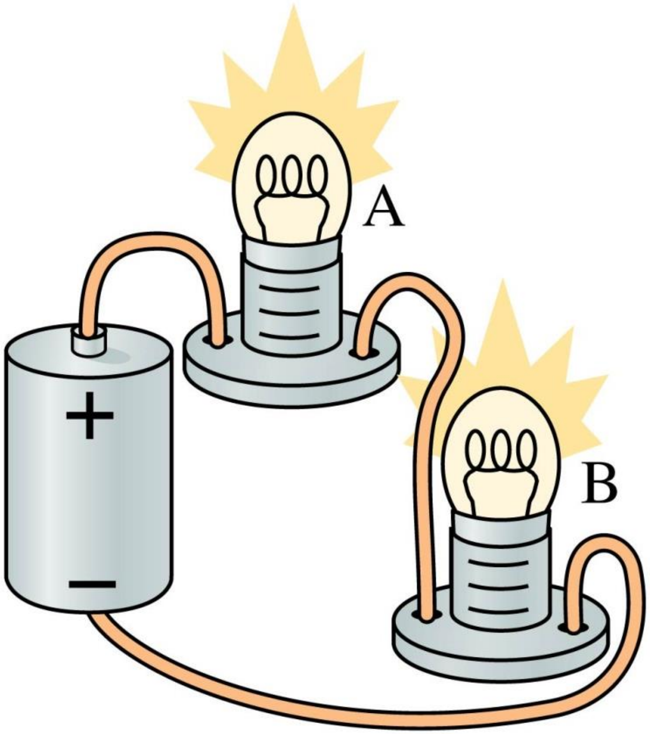
c) 60 A.

d) 2 A.

e) Some other value.

Conservation of Current

Q.42 A and B are identical lightbulbs connected to a battery as shown. Which is brighter?



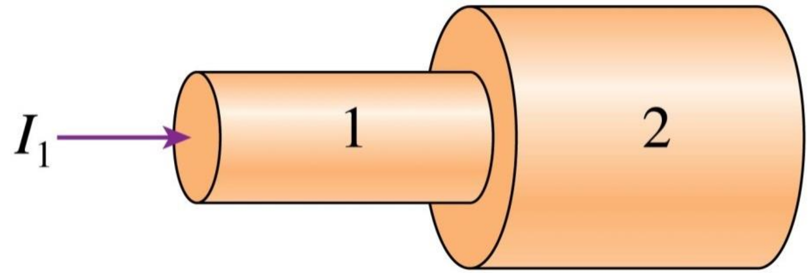
a) Bulb A.

b) Bulb B.

c) The bulbs are equally bright.

Conservation of Current

Q.43 Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left. How does current I_1 in segment 1 compare to current I_2 in segment 2?



a) $I_1 > I_2$.

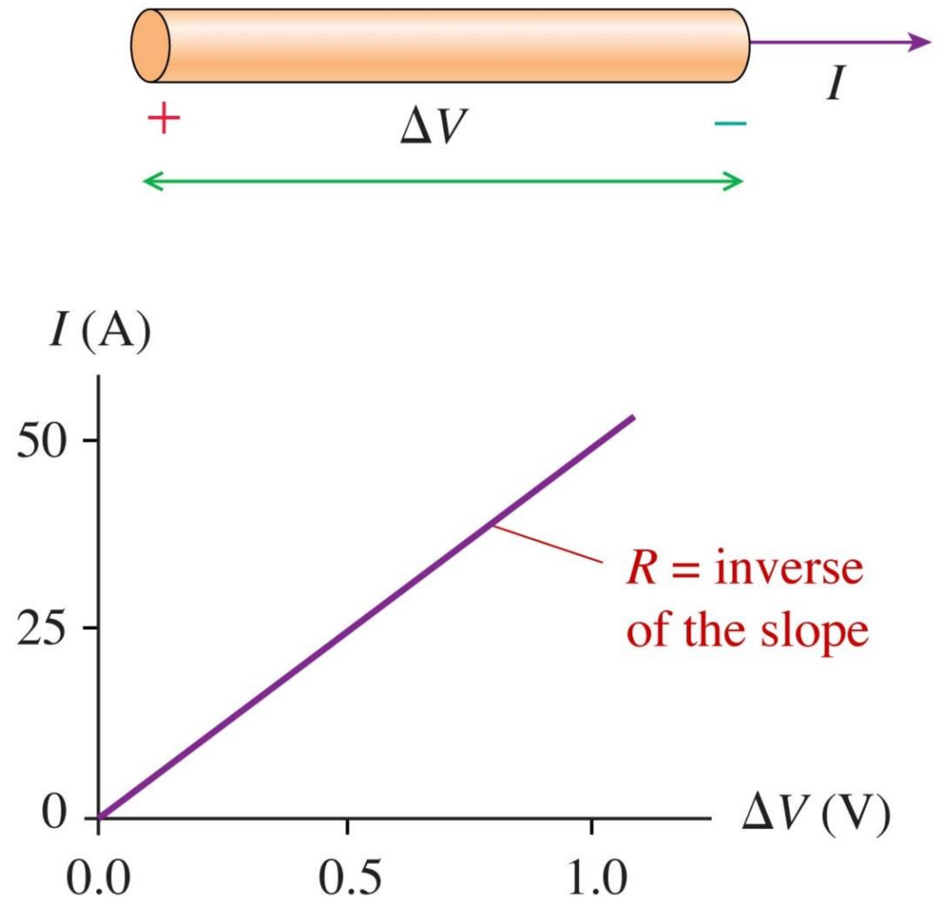
b) $I_1 = I_2$.

c) $I_1 < I_2$.

d) There's not enough information to compare them.

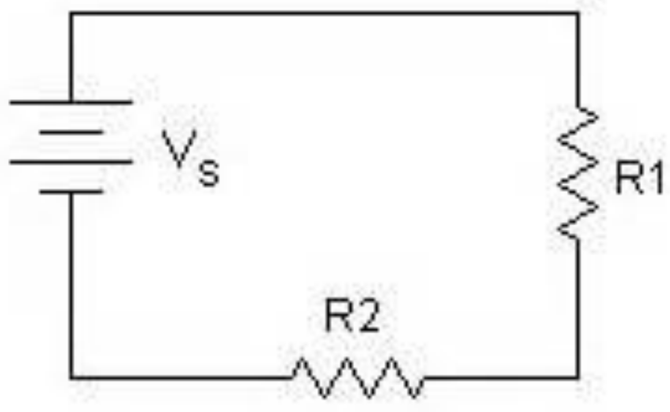
Ohm's Law

Q.44 The current through a wire is measured as the potential difference ΔV is varied. What is the wire's resistance?



A. 0.01 Ω.
B. 0.02 Ω.
C. 50 Ω.
D. 100 Ω.
E. Some other value.

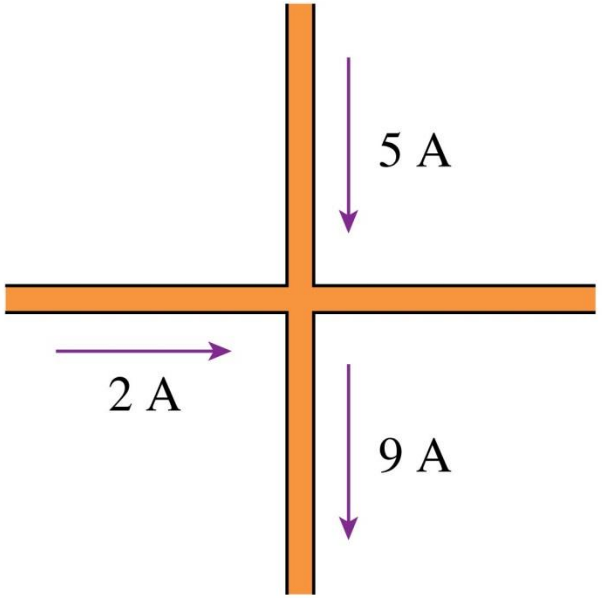
A Battery and a Resistor



Q.45 What resistor would have a 15 mA current if connected across the terminals of a 9.0 V battery?

Kirchoff's Junction Law

Q.46 The current in the fourth wire is



a) 16 A to the right.

b) 4 A to the left.

c) 2 A to the right.

d) 2 A to the left.

e) Not enough information to tell.

TACTICS BOX 31.1 Using Kirchhoff's loop law

❶ **Draw a circuit diagram.** Label all known and unknown quantities.

❷ **Assign a direction to the current.** Draw and label a current arrow I to show your choice.

- If you know the actual current direction, choose that direction.
- If you don't know the actual current direction, make an arbitrary choice. All that will happen if you choose wrong is that your value for I will end up negative.

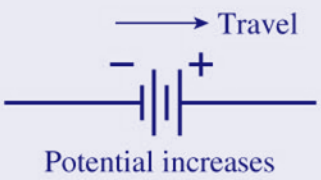
TACTICS BOX 31.1 **Using Kirchhoff's loop law**

❸ **"Travel" around the loop.** Start at any point in the circuit, then go all the way around the loop in the direction you assigned to the current in step 2. As you go through each circuit element, ΔV is interpreted to mean

$$\Delta V = V_{\text{downstream}} - V_{\text{upstream}}$$

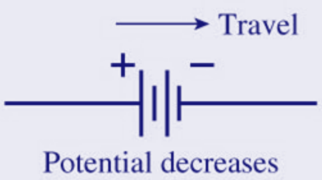
- For an ideal battery in the negative-to-positive direction:

$$\Delta V_{\text{bat}} = +\mathcal{E}$$

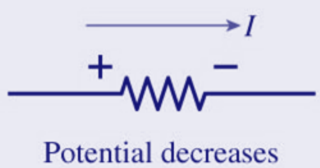


- For an ideal battery in the positive-to-negative direction:

$$\Delta V_{\text{bat}} = -\mathcal{E}$$



- For a resistor: $\Delta V_{\text{res}} = -\Delta V_{\text{R}} = -IR$



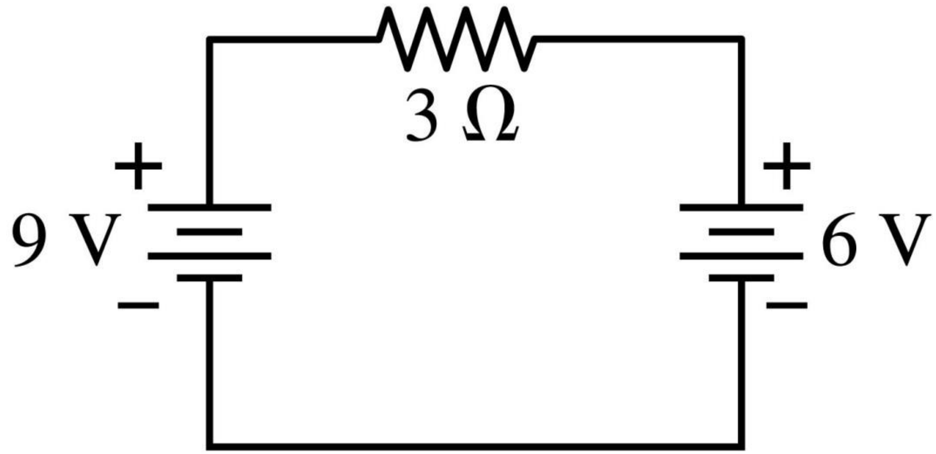
❹ **Apply the loop law:** $\sum (\Delta V)_i = 0$

Exercises 4–7

Using Kirchoff's Loop Law

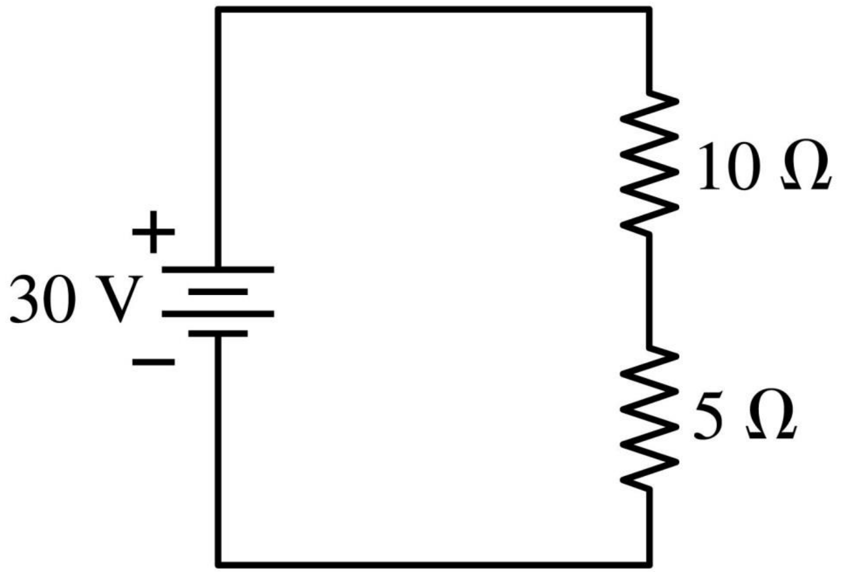
Q.47 The current through the 3 Ω resistor is

a) 9 A.
b) 6 A.
c) 5 A.
d) 3 A.
e) 1 A.



Resistors in Series

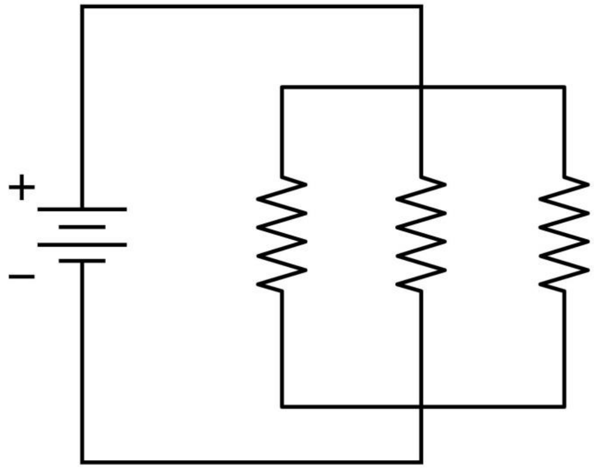
Q.48 The potential difference across the 10 resistor is



a) 30 V.
b) 20 V.
c) 15 V.
d) 10 V.
e) 5 V.

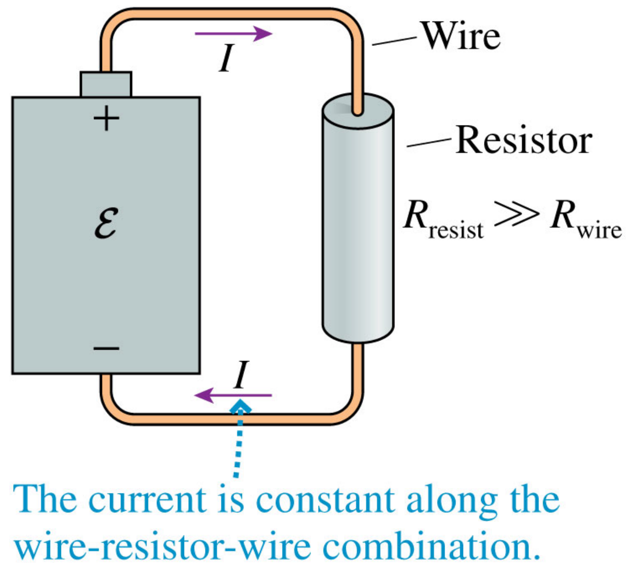
Resistors in Parallel

Q.49 What things about the resistors in this circuit are the same for all three?



a) Current *I*.
b) Potential difference ΔV.
c) Resistance *R*.
d) A and B.
e) B and C.

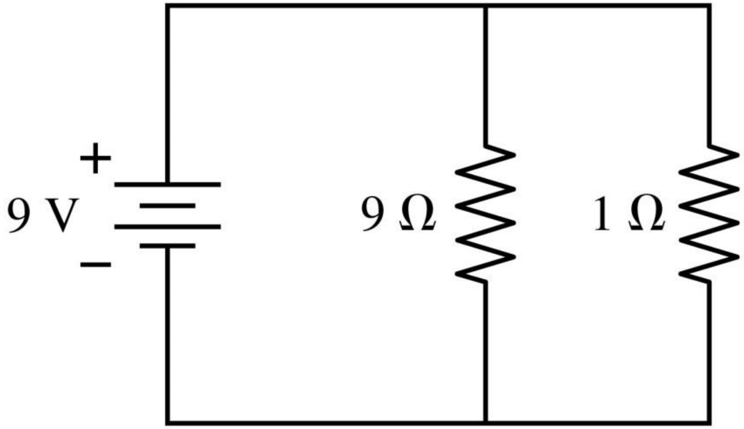
Delivering Power



Q.50 A 90 Ω load is connected to a 120 V battery. How much power is delivered by the battery?

Power Dissipation

Q.51 Which resistor dissipates more power?



a) The 9 Ω resistor.

b) The 1 Ω resistor.

c) They dissipate the same power.

Power Dissipation

Q.52 Which has a larger resistance, a 60 W lightbulb or a 100 W lightbulb?

a) The 60 W bulb.
b) The 100 W bulb.
c) Their resistances are the same.
d) There's not enough information to tell.

Power Dissipation

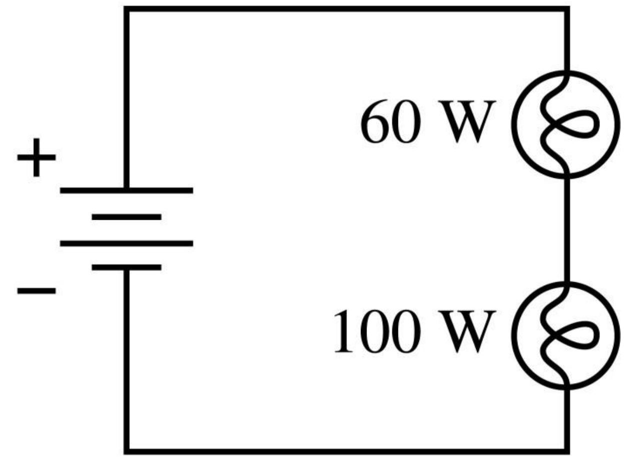
Q.53 Which bulb is brighter?

a) The 60 W bulb.

b) The 100 W bulb.

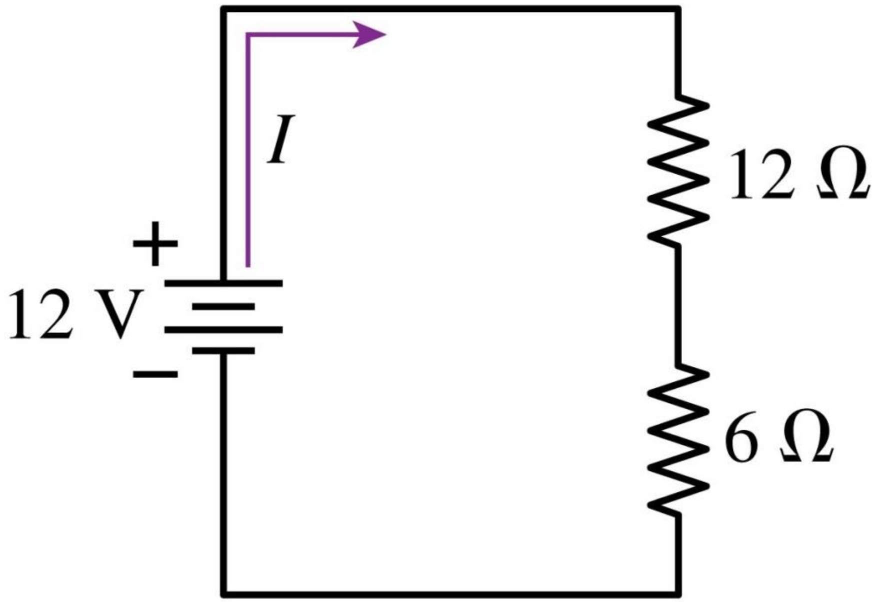
c) Their brightnesses are the same.

d) There's not enough information to tell.



Series Resistors

Q.54 The battery current *I* is



a) 3 A.

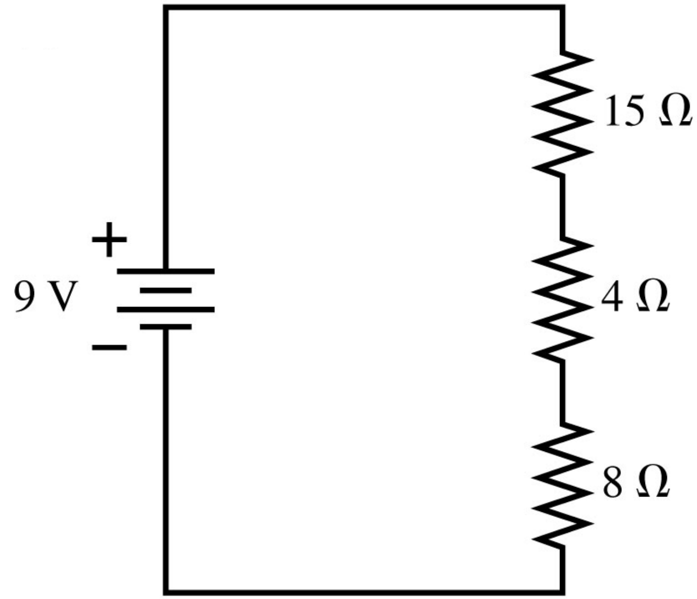
b) 2 A.

c) 1 A.

d) 2/3 A.

e) 1/2 A.

A Series Resistor Circuit



Q.55

a. What is the current in the circuit below?

b. Draw a graph of potential versus position in the circuit, going cw from $V = 0$ V at the battery's negative terminal.

Lighting Up a Flashlight

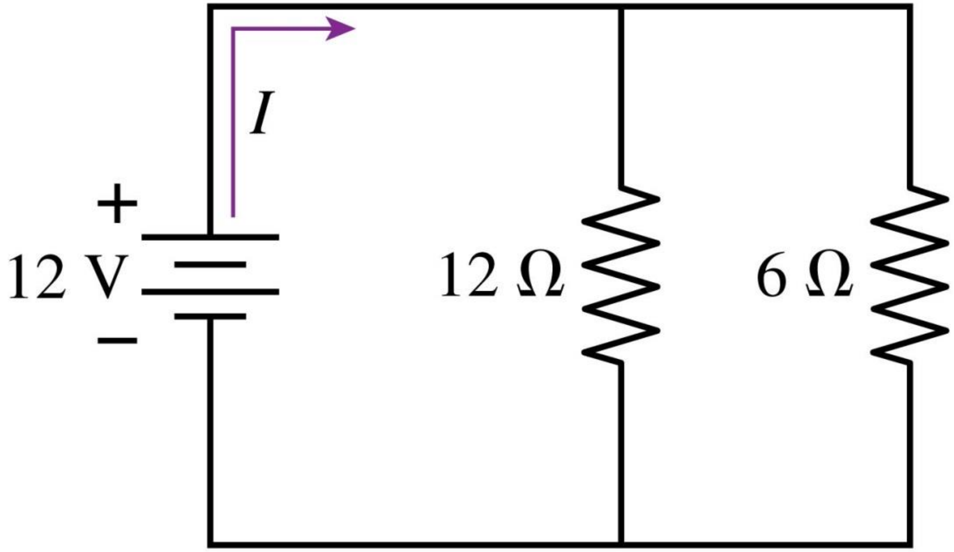
Q.56 A 6 Ω flashlight bulb is powered by a 3 V battery with an internal resistance of 1 Ω. What are the power dissipation of the bulb and the terminal voltage of the battery?

A Short-Circuited Battery

Q.57 What is the short-circuit current of a 12 V car battery with an internal resistance of 0.020 Ω? What happens to the power supplied by the battery?

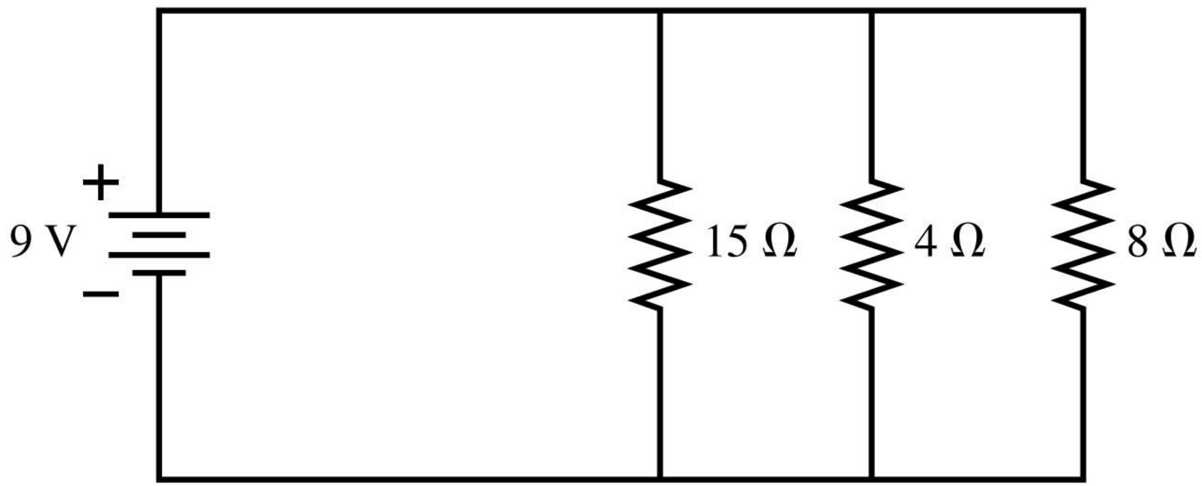
Parallel Resistors

Q.58 The battery current *I* is



a) 3 A.
b) 2 A.
c) 1 A.
d) 2/3 A.
e) 1/2 A.

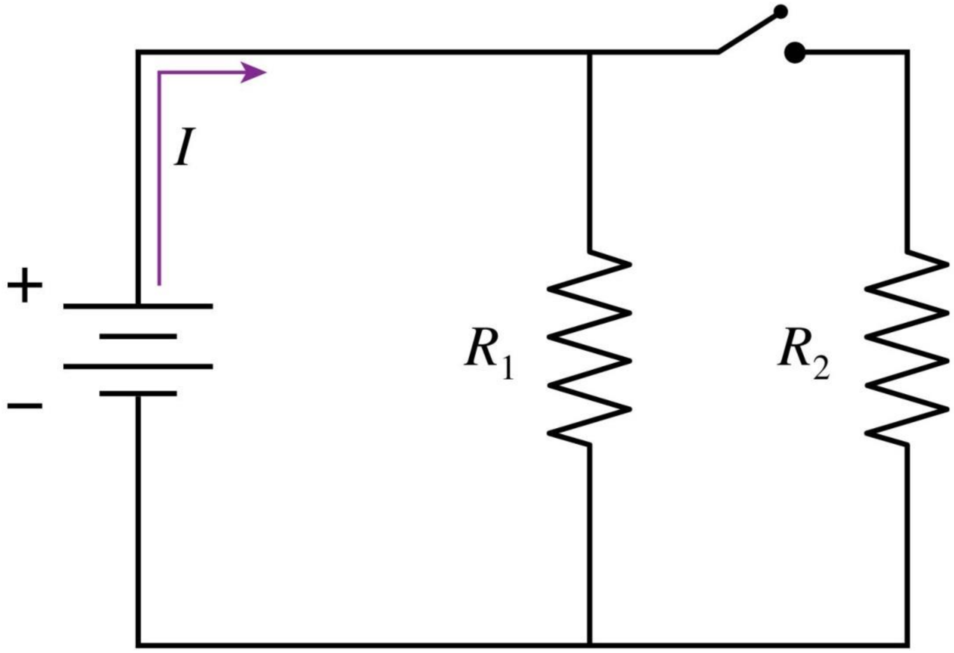
A Parallel Resistor Circuit



Q.59 The three resistors above are connected to a 9 V battery. Find the potential difference across and the current through each resistor.

Parallel Resistors

Q.60 When the switch closes, the battery current



A. Increases.

B. Stays the same.

C. Decreases.

Lightbulb Brightness

Q.61 The three bulbs are identical and the two batteries are identical. Compare the brightnesses of the bulbs.

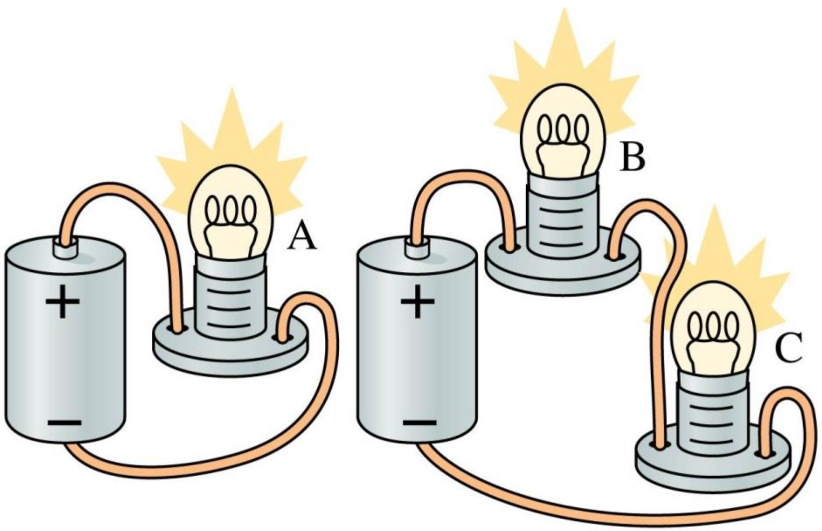
a) $A > B > C$.

b) $A > C > B$.

c) $A > B = C$.

d) $A < B = C$.

e) $A = B = C$.



Lightbulb Brightness

Q.62 The three bulbs are identical and the two batteries are identical. Compare the brightnesses of the bulbs.

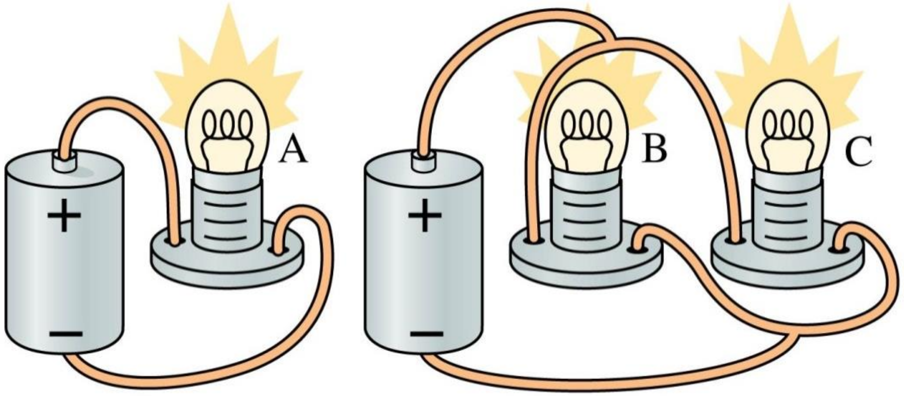
a) A > B > C.

b) A > C > B.

c) A > B = C.

d) A < B = C.

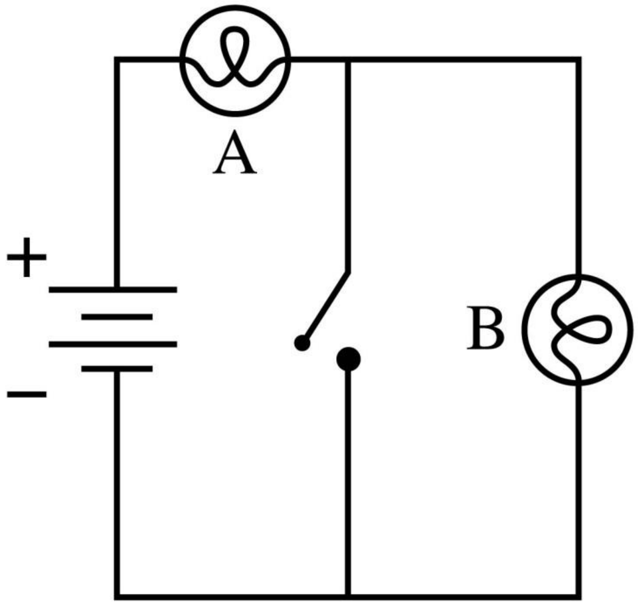
e) A = B = C.



Lightbulb Brightness

Q.63 The lightbulbs are identical. Initially both bulbs are glowing. What happens when the switch is closed?

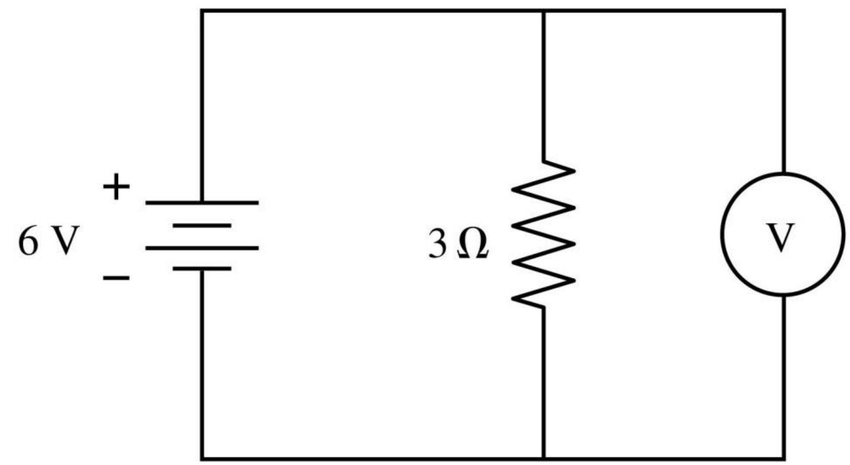
a) Nothing.
b) A stays the same; B gets dimmer.
c) A gets brighter; B stays the same.
d) Both get dimmer.
e) A gets brighter; B goes out.



Voltmeters

Q.64 What does the voltmeter read?

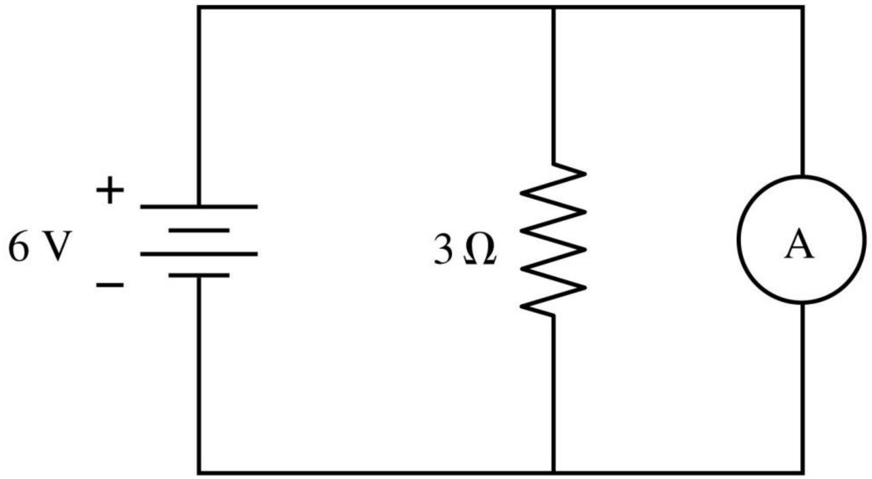
a) 6 V.
b) 3 V.
c) 2 V.
d) Some other value.
e) Nothing because this will fry the meter.



Ammeters

Q.65 What does the ammeter read?

a) 6 A.
b) 3 A.
c) 2 A.
d) Some other value.
e) Nothing because this will fry the meter.



PROBLEM-SOLVING STRATEGY 31.1 **Resistor circuits**

MODEL Assume that wires are ideal and, where appropriate, that batteries are ideal.

VISUALIZE Draw a circuit diagram. Label all known and unknown quantities.

PROBLEM-SOLVING STRATEGY 31.1

Resistor circuits

MP

SOLVE Base your mathematical analysis on Kirchhoff's laws and on the rules for series and parallel resistors.

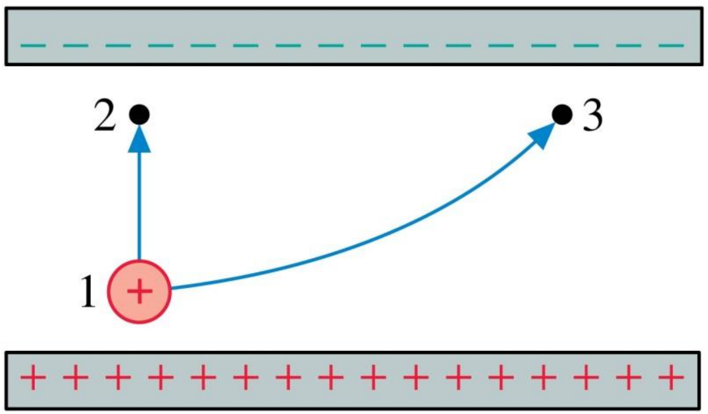
- Step by step, reduce the circuit to the smallest possible number of equivalent resistors.
- Write Kirchhoff's loop law for each independent loop in the circuit.
- Determine the current through and the potential difference across the equivalent resistors.
- Rebuild the circuit, using the facts that the current is the same through all resistors in series and the potential difference is the same for all parallel resistors.

ASSESS Use two important checks as you rebuild the circuit.

- Verify that the sum of the potential differences across series resistors matches ΔV for the equivalent resistor.
- Verify that the sum of the currents through parallel resistors matches I for the equivalent resistor.

Parallel-Plate Capacitor

Q.66 Two protons, one after the other, are launched from point 1 with the same speed. They follow the two trajectories shown. The protons' speeds at points 2 and 3 are related by



a) $v_2 > v_3$.
b) $v_2 = v_3$.
c) $v_2 < v_3$.
d) Not enough information to compare their speeds.

Batteries

Q.67 The charge escalator in a battery does 4.8×10^{-19} J of work for each positive ion that it moves from the negative to the positive terminal. What is the battery's emf?

a) 9 V.

b) 4.8 V.

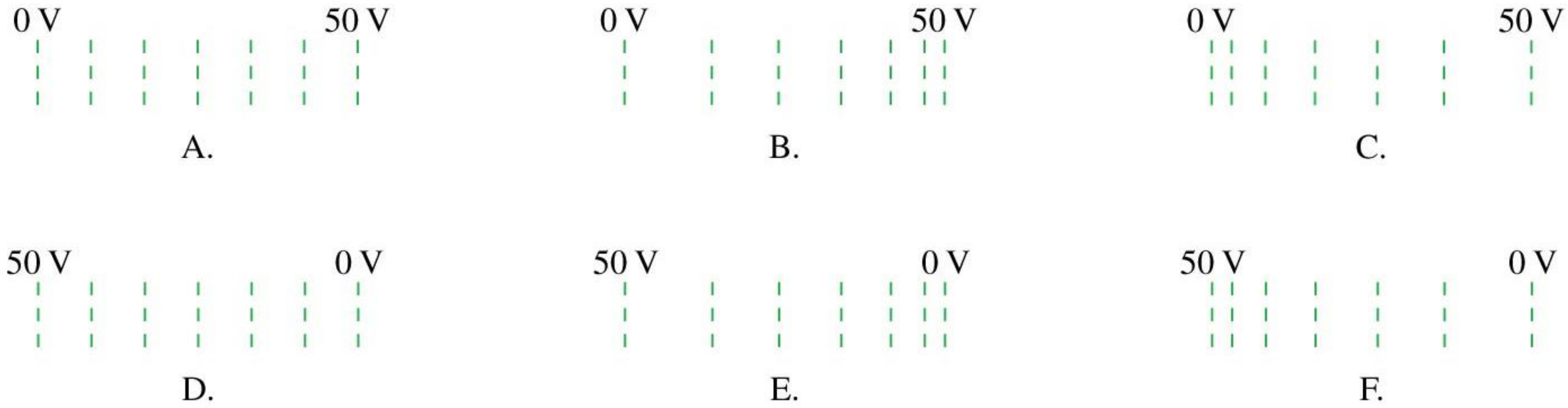
c) 3 V.

d) 4.8×10^{-19} V.

e) I have no idea.

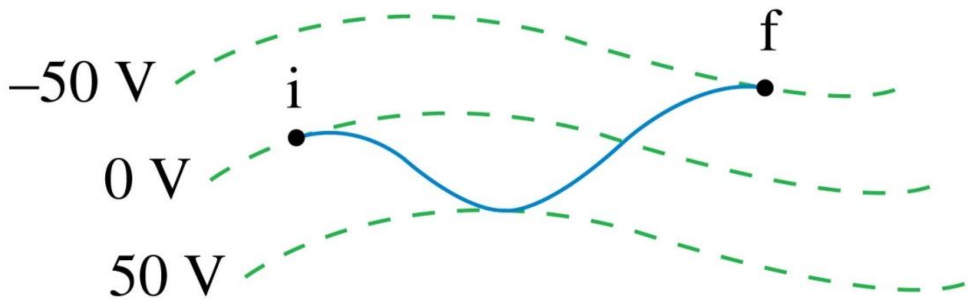
Electric Potential

Q.68 Which set of equipotential surfaces matches this electric field?



Kirchoff's Loop Rule

Q.69 A particle follows the trajectory shown from initial position i to final position f. The potential difference ΔV *is*



a) 100 V.

b) 50 V.

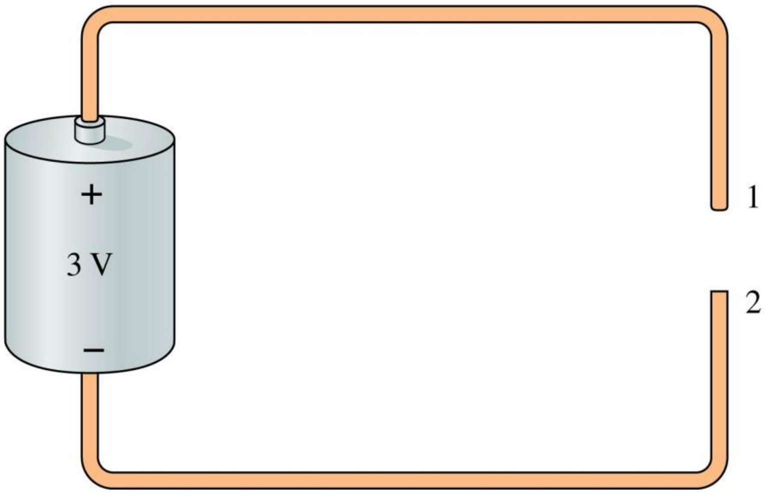
c) 0 V.

d) –50 V.

e) –100 V.

Potential Difference

Q.70 Metal wires are attached to the terminals of a 3 V battery. What is the potential difference between points 1 and 2?



a) 6 V.

b) 3 V.

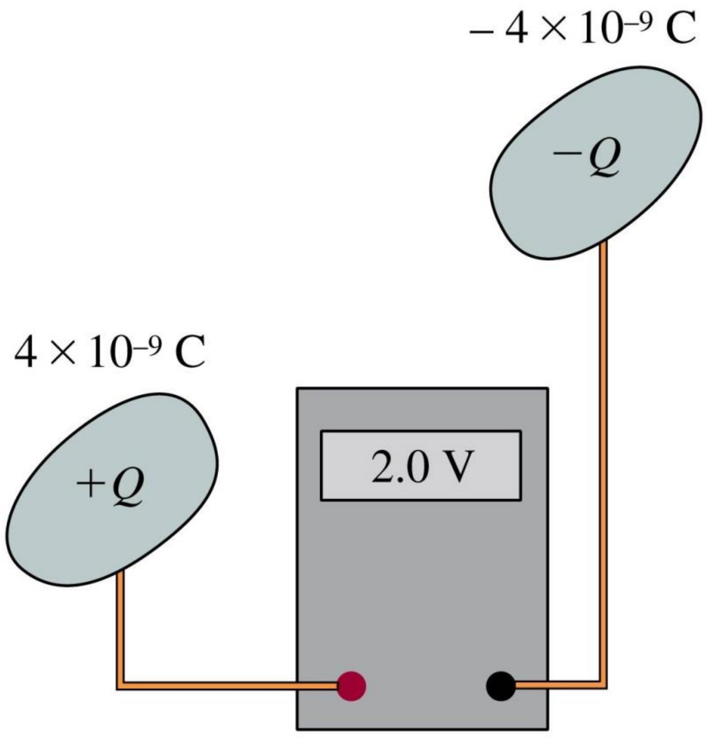
c) 0 V.

d) Undefined.

e) Not enough information to tell.

Capacitance

Q.71 What is the capacitance of these two electrodes?



a) 8 nF.

b) 4 nF.

c) 2 nF.

d) 1 nF.

e) Some other value.

Charging a Capacitor

Q.72

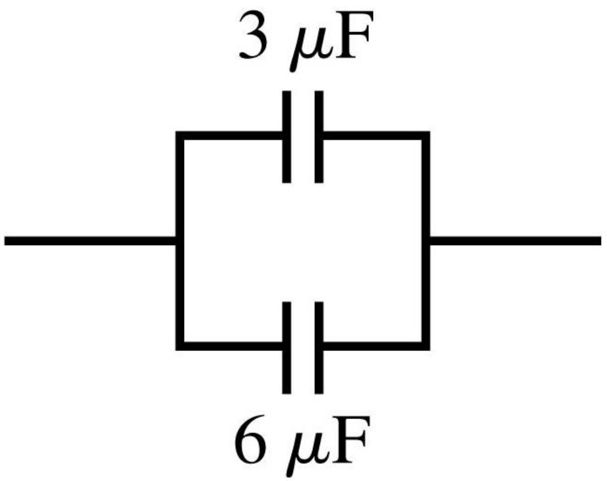
The spacing between the plates of 1.0 μF capacitor is 0.050 mm.

a. What is the surface area of the plates?

b. How much charge is on the plates if this capacitor is attached to a 15 V battery?

Capacitance

Q.73 The equivalent capacitance is



a) 9 μF.

b) 6 μF.

c) 3 μF.

d) 2 μF.

e) 1 μF.

Capacitance

Q.74 The equivalent capacitance is

a) 9 μF.

b) 6 μF.

c) 3 μF.

d) 2 μF.

e) 1 μF.