The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Science A Physics

Lectures 13-22:

Answers to 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.

Discovering Electricity

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a) Attract the plastic rod.

b) Repel the plastic rod.

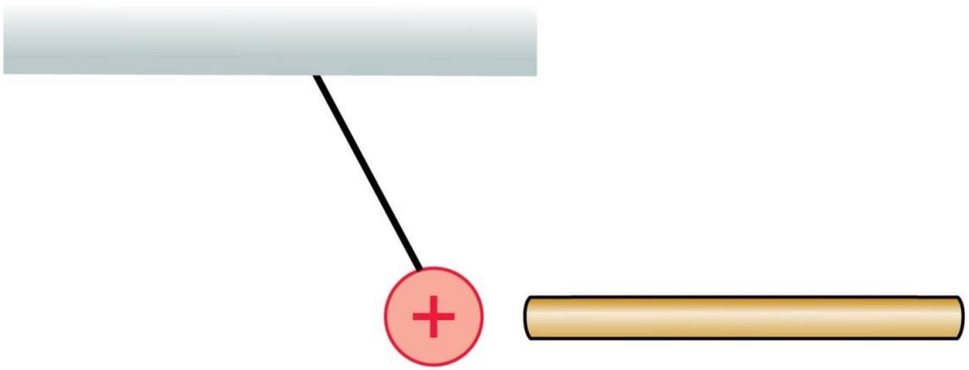
c) Not affect the plastic rod.

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

The object could have plastic charge, which would repel the plastic rod. Or it could be neutral and attract both charged rods.

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.

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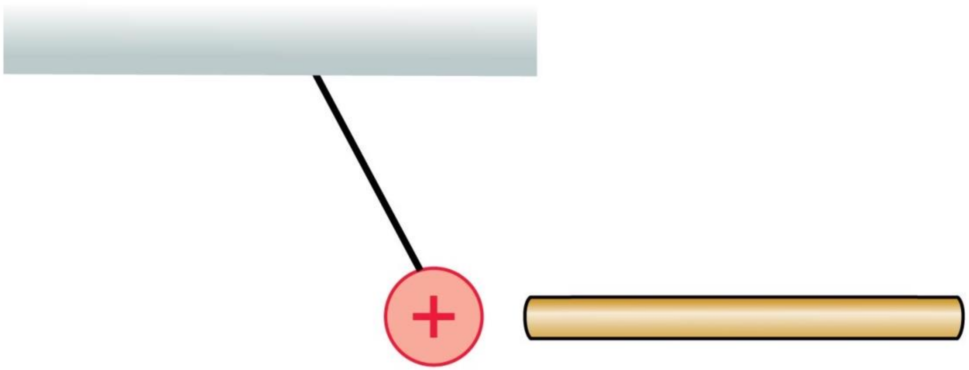


a) Positive.

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:

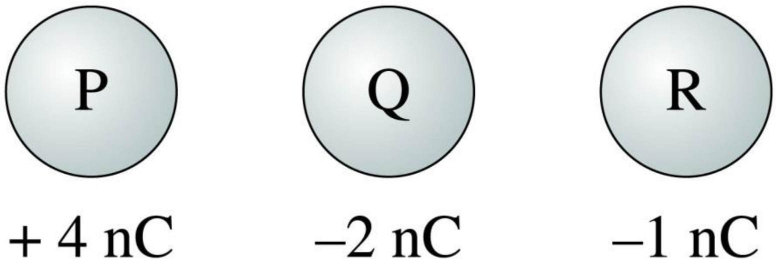
$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{K|q_1||q_2|}{r^2}$$

- 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.

Charge

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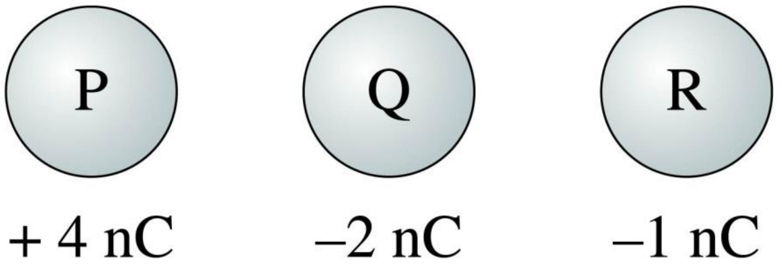


a) –1 nC or less.

b) –0.5 nC.

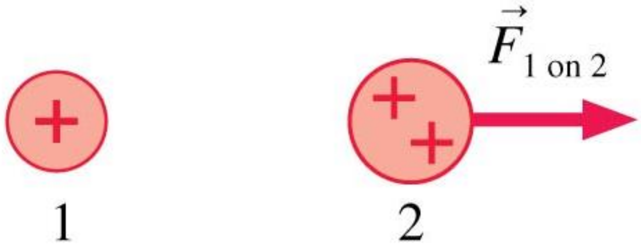
c) 0 nC.

d) +0.5 nC.

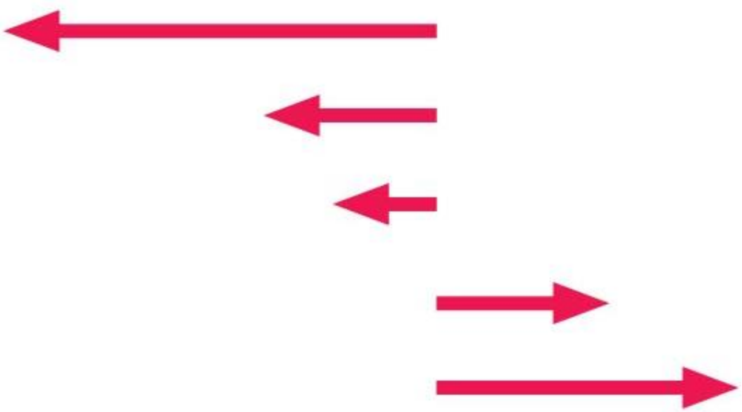
e) +1.0 nC or more.

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)



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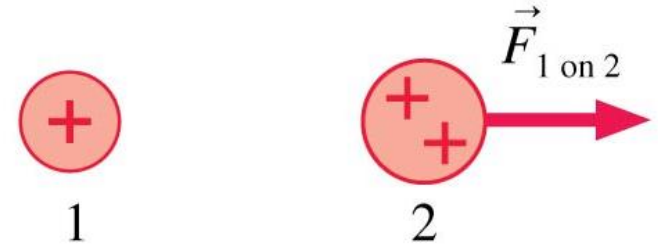
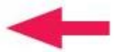


a) 

b) 

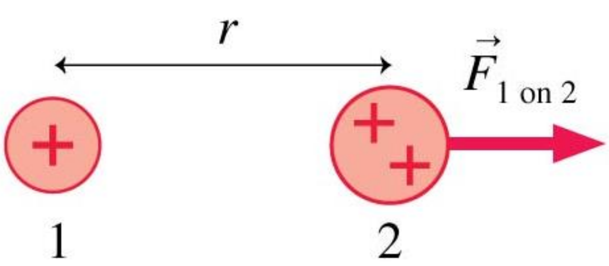
Newton's third law

c) 

d) 

e) 

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) 

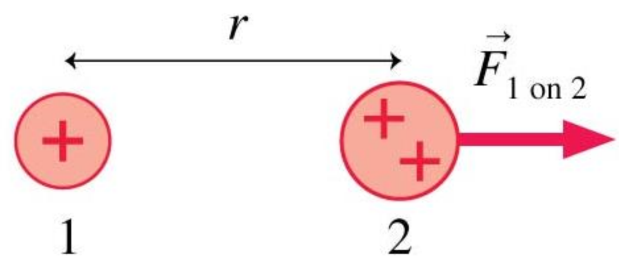
b) 

c) 

d) None of the above.

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) 

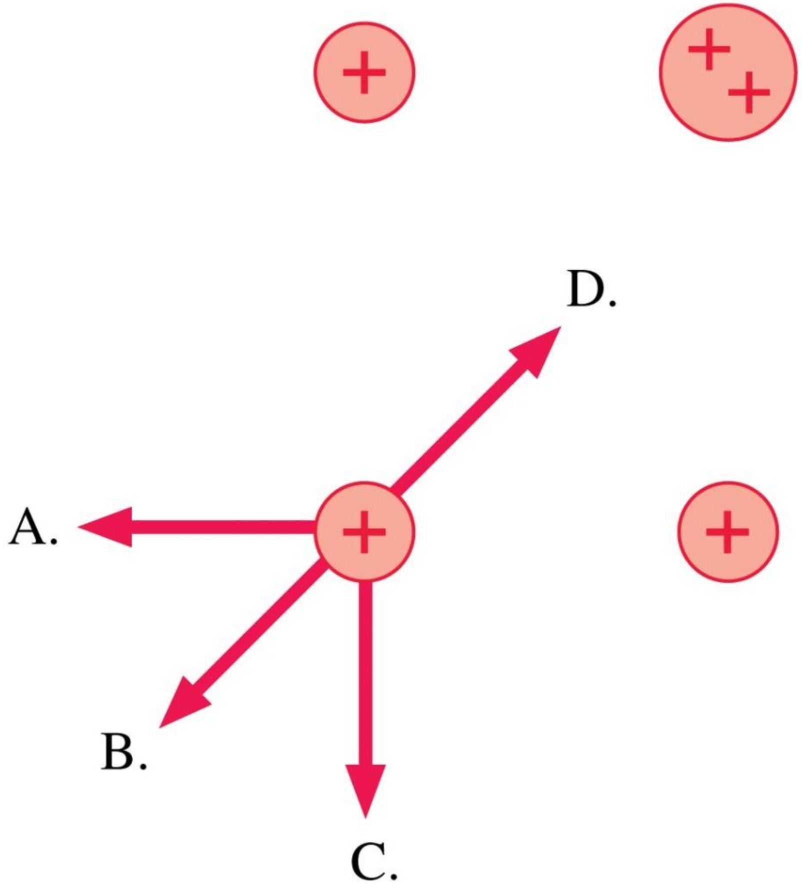
c) 

d) None of the above.

At half the distance, the force is **four** times as large: 

Electric Force

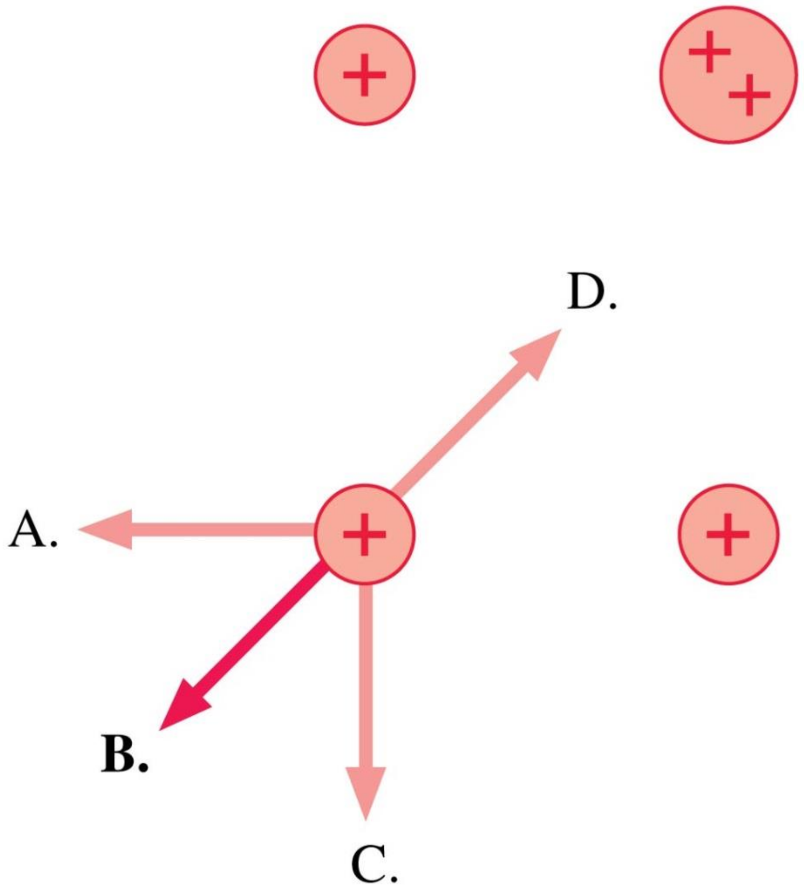
Q.6 Which is the direction of the net force on the charge at the lower left?



E. None of these.

Electric Force

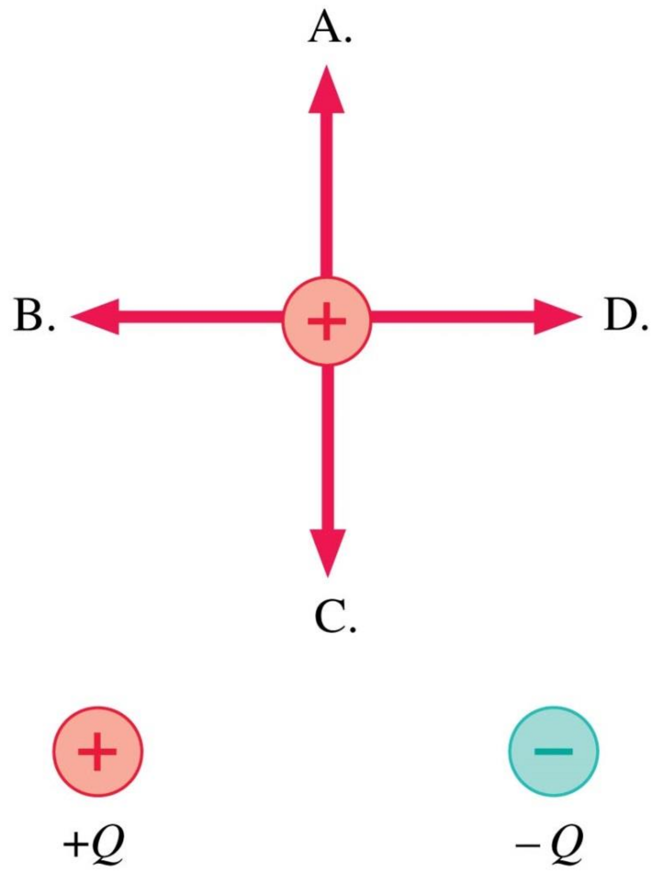
Q.6 Which is the direction of the net force on the charge at the lower left?



E. None of these.

Electric Force

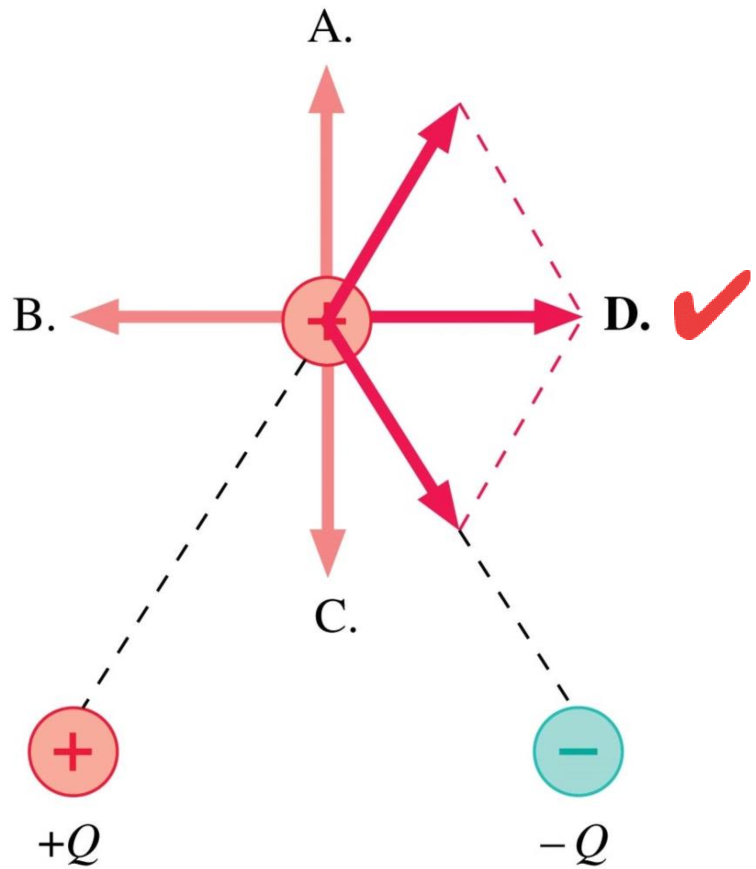
Q.7 Which is the direction of the net force on the charge at the top?



E. None of these.

Electric Force

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



E. None of these.

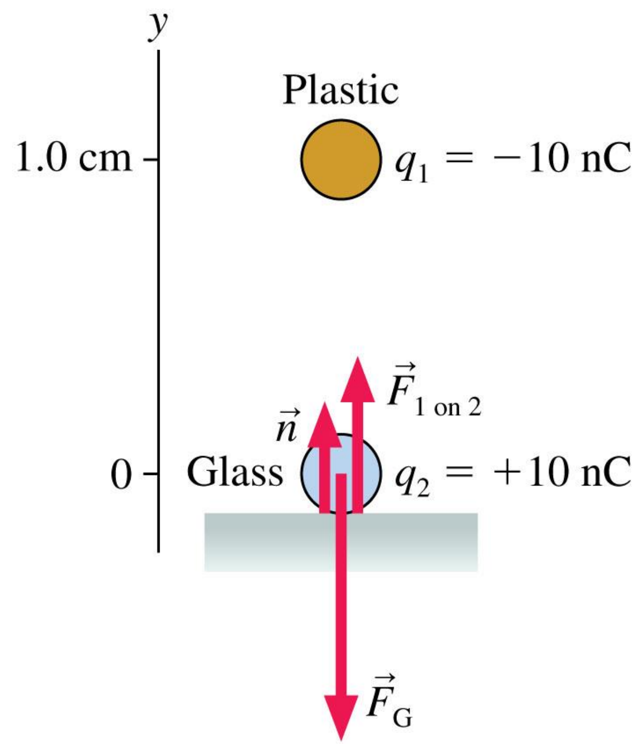
Lifting a Glass Bead

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?

MODEL:

Model the plastic sphere and glass bead as point charges.

Lifting a Glass Bead



VISUALIZE: The figure below establishes a *y*-axis, identifies the plastic sphere as q_1 and the glass bead as q_2, and shows a free-body diagram. Model the plastic sphere and glass bead as point charges.

Lifting a Glass Bead

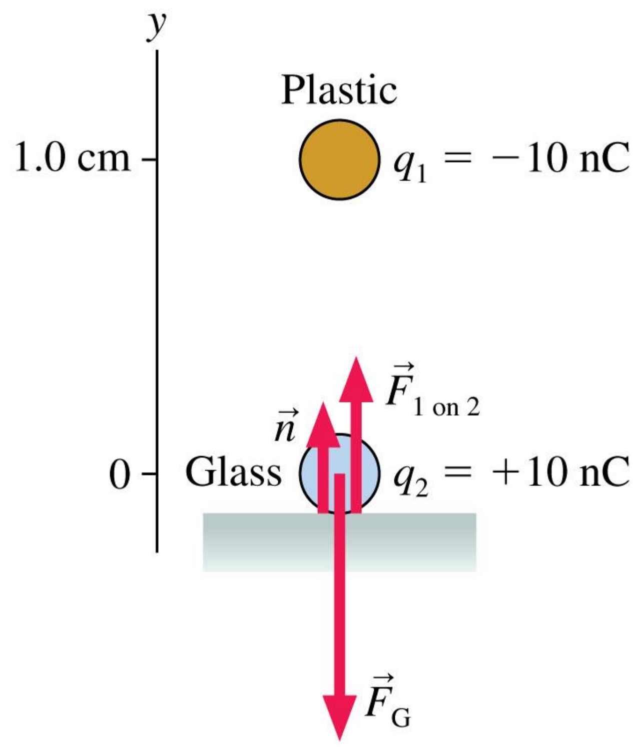
SOLVE: If $F_{1 \text{ on } 2}$ is less than the gravitational force $F_G = m_{\text{bead}}g$, then the bead will remain at rest on the table with $\vec{F}_{1 \text{ on } 2} + \vec{F}_G + \vec{n} = \vec{0}$. But if $F_{1 \text{ on } 2}$ is greater than $m_{\text{bead}}g$, the glass bead will accelerate upward from the table. Using the values provided, we have

$$F_{1 \text{ on } 2} = \frac{K|q_1||q_2|}{r^2} = 9.0 \times 10^{-3} \text{ N}$$

$$F_G = m_{\text{bead}}g = 1.5 \times 10^{-4} \text{ N}$$

$F_{1 \text{ on } 2}$ exceeds $m_{\text{bead}}g$ by a factor of 60, so the glass bead will leap upward.

Lifting a Glass Bead



ASSESS: The values used in this example are realistic for spheres ≅ 2 mm in diameter. In general, as in this example, electric forces are *significantly* larger than gravitational forces. Consequently, we can neglect gravity when working electric-force problems unless the particles are fairly massive.

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 Force

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

a) Up.

b) Down.

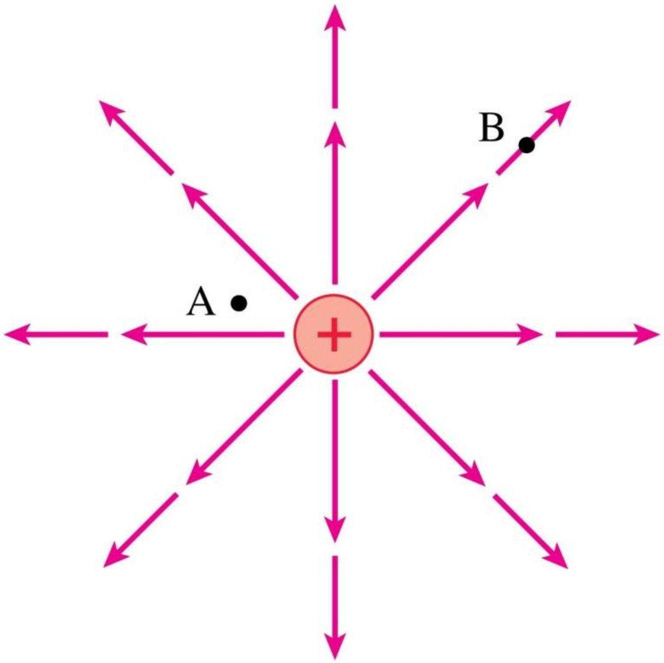
c) Left.

d) Right. $-Q$ is slightly closer than $+Q$.

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

Electric Field

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



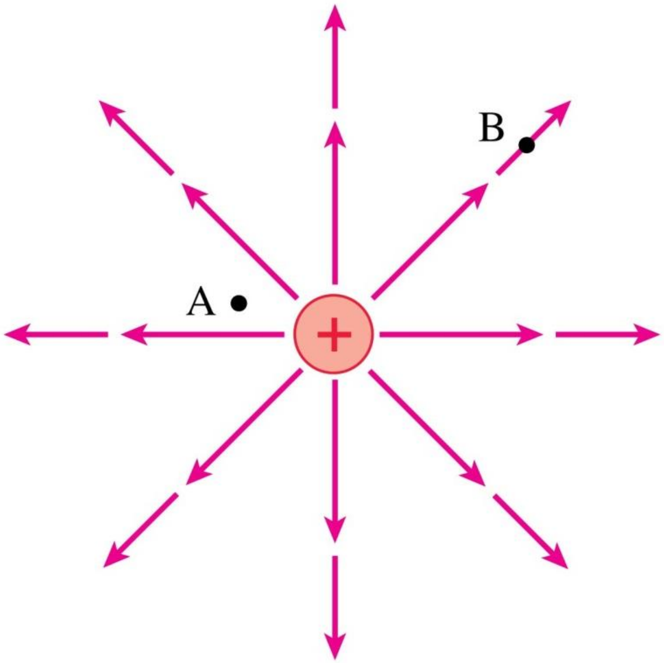
a) Point A.

b) Point B.

c) Not enough information to tell.

Electric Field

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



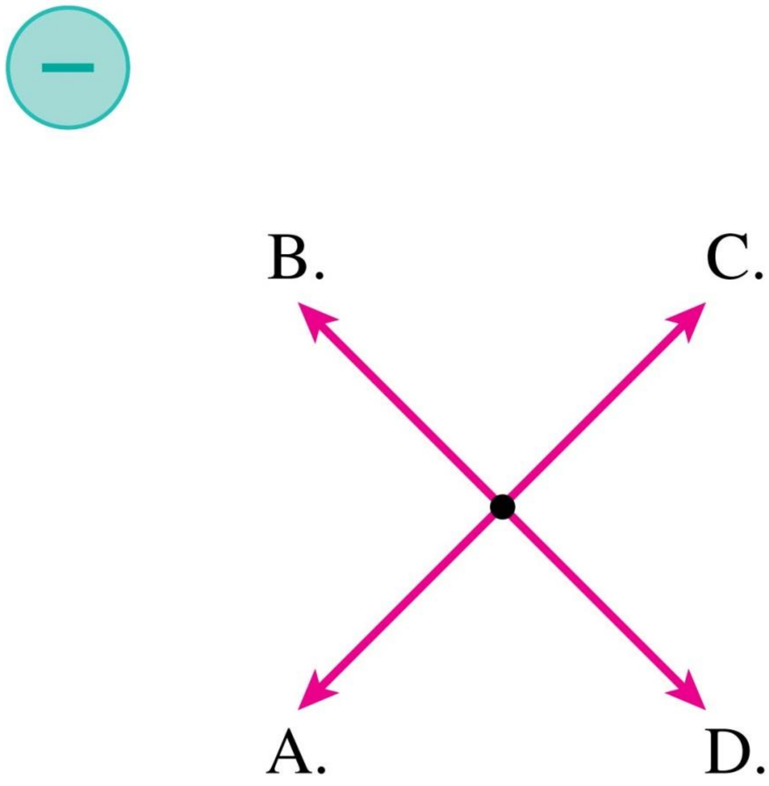
a) **Point A.**

b) Point B.

c) Not enough information to tell.

Electric Field

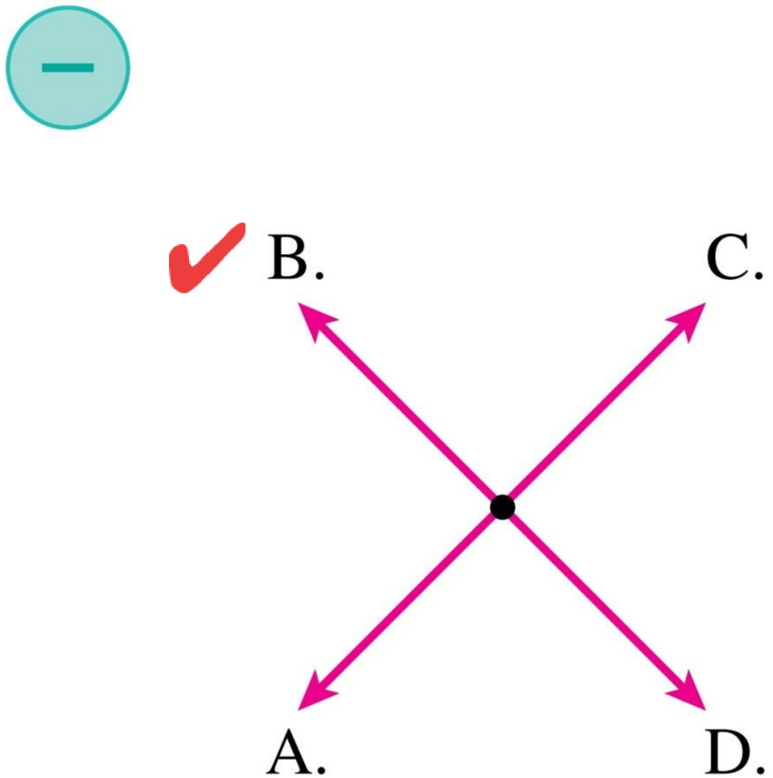
Q.11 Which is the electric field at the dot?



E. None of these.

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?

The Electric Field of a Proton

SOLVE: a. The proton's charge is $q = e$. Its electric field strength at the distance of the electron is

$$E = \frac{1}{4\pi\epsilon_0}\frac{e}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{1.6 \times 10^{-19}\ \mathrm{C}}{(5.3 \times 10^{-11}\mathrm{m})^2} = 5.1 \times 10^{11}\ \mathrm{N/C}$$

Notice how large this field is.

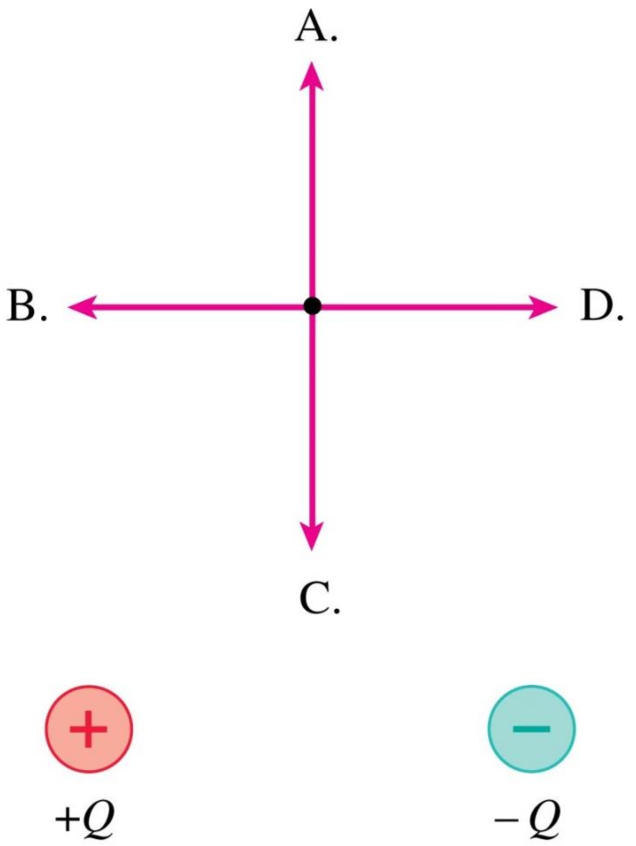
The Electric Field of a Proton

SOLVE: b. We could use Coulomb's law to find the force on the electron, but the whole point of knowing the electric field is that we can use it directly to find the force on a charge in the field. The magnitude of the force on the electron is

$$\begin{aligned} F_{\text{on elec}} &= |q_{\text{e}}|E_{\text{of proton}} \\ &= (1.60 \times 10^{-19}\ \text{C})(5.1 \times 10^{11}\ \text{N/C}) \\ &= 8.2 \times 10^{-8}\ \text{N} \end{aligned}$$

Electric Field

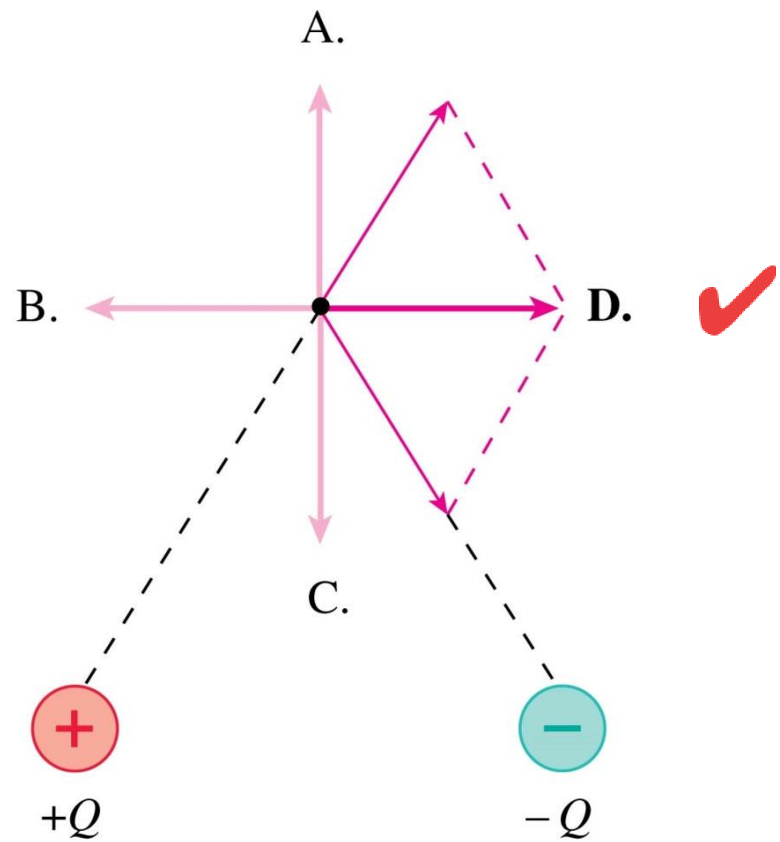
Q.13 What is the direction of the electric field at the dot?



E. None of these.

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**

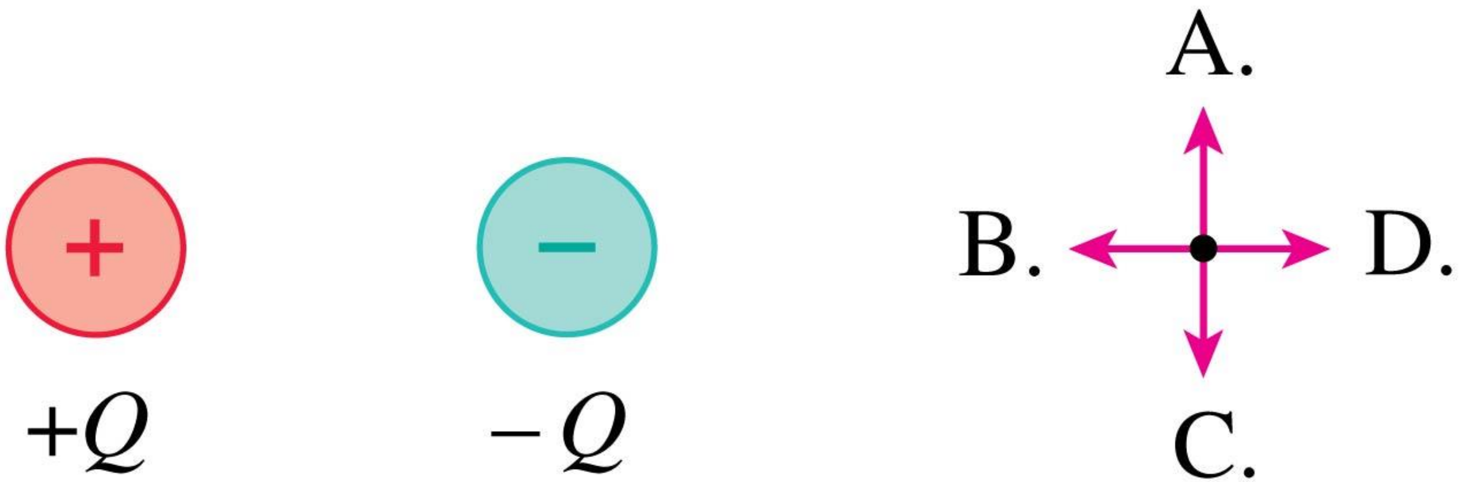
SOLVE The mathematical representation is $\vec{E}_{\text{net}} = \sum \vec{E}_i$.

- 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

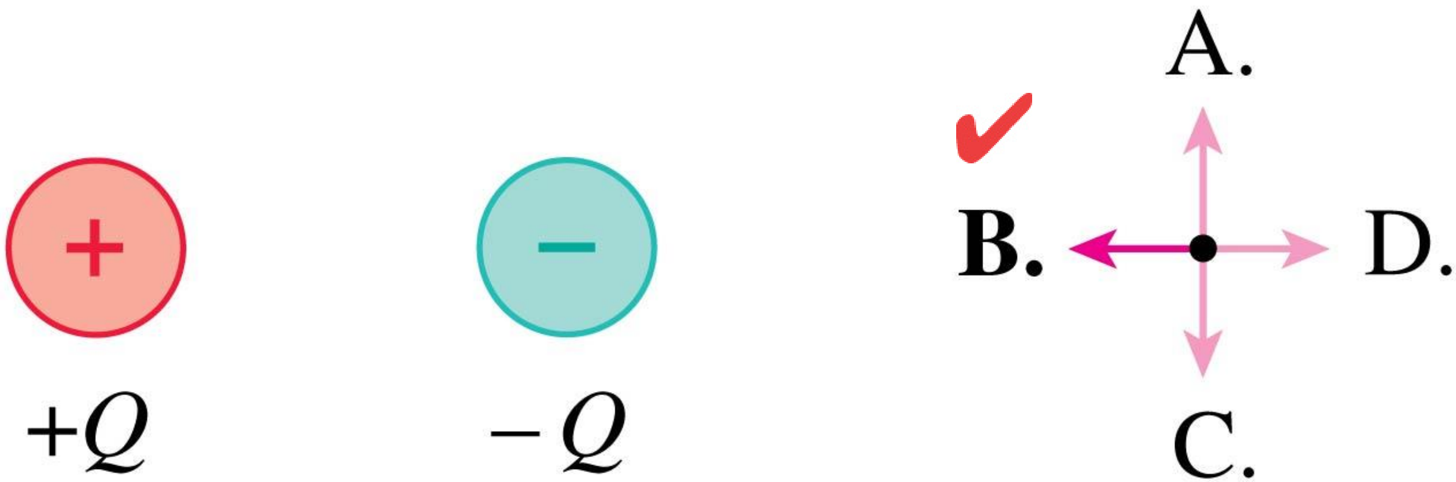
Q.14 What is the direction of the electric field at the dot?



E. The field is zero.

Electrical Field of Multiple Point Charges

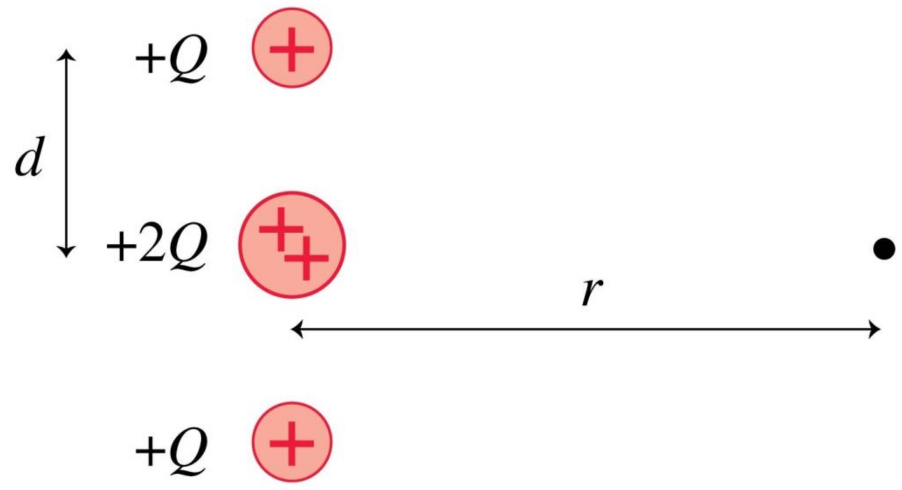
Q.14 What is the direction of the electric field at the dot?



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

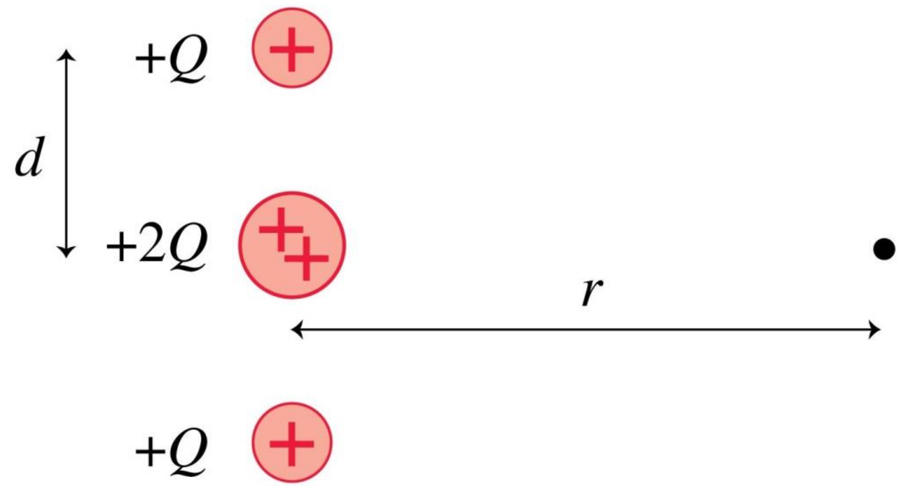
C. $\dfrac{4Q}{4\pi\epsilon_0 r^2}$

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

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

Electrical Field of Multiple Point Charges

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



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

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

C. $$\frac{4Q}{4\pi\epsilon_0 r^2}$$ Looks like a point charge $4Q$ at the origin.

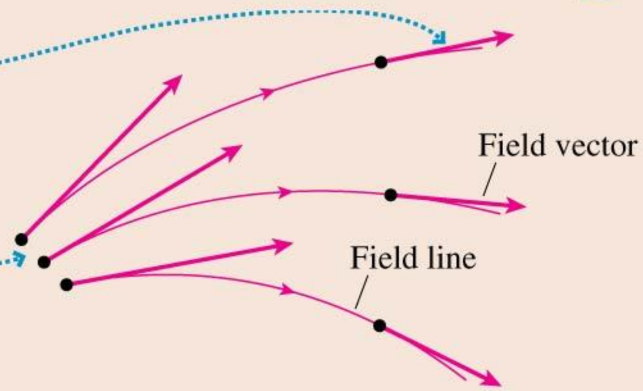
D. $$\frac{4Q}{4\pi\epsilon_0 (r^2 + d^2)}$$

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

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.

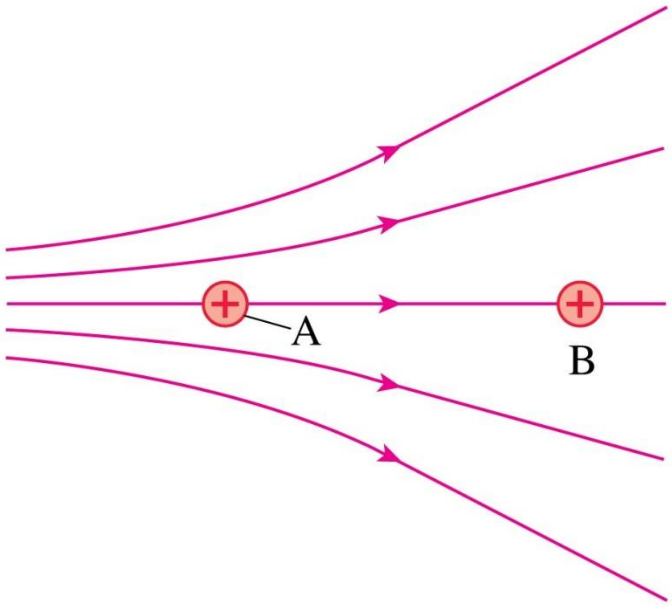


❸ Electric field lines never cross.

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.

Electrical Field

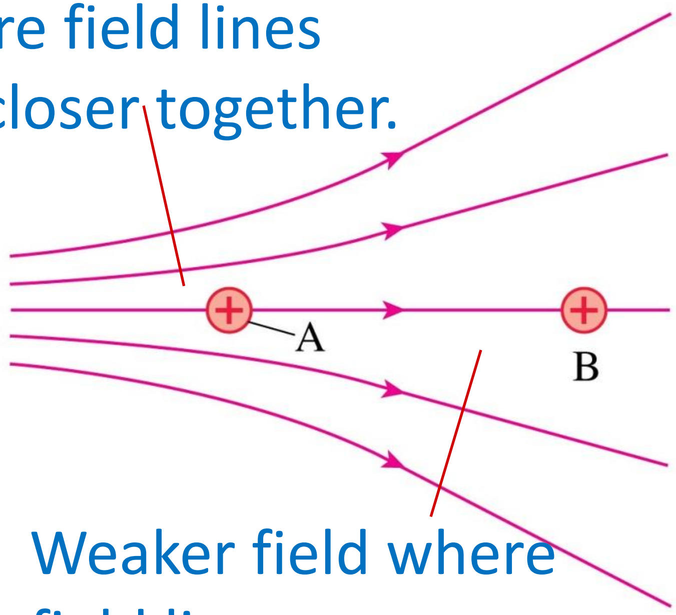
Q.16 Two protons, A and B, are in an electric field. Which proton has the larger acceleration?

a) **Proton A.**

b) Proton B.

c) Both have the same acceleration.

Stronger field where field lines are closer together.



Weaker field where field lines are farther apart.

The Parallel Plate Capacitor

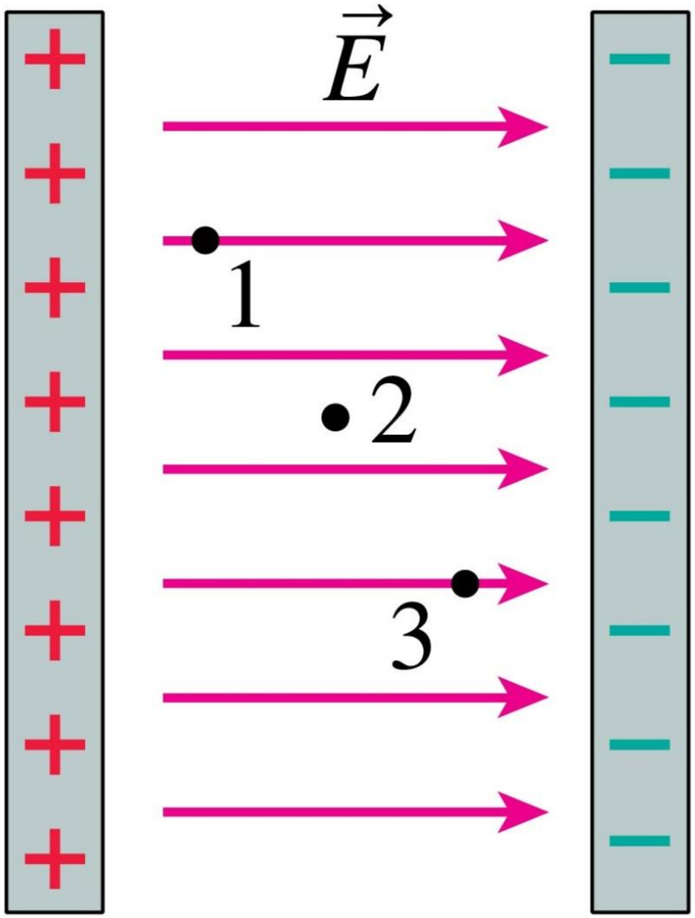
Q.17 Three points inside a parallel-plate capacitor are marked. Which is true?

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 Parallel Plate Capacitor

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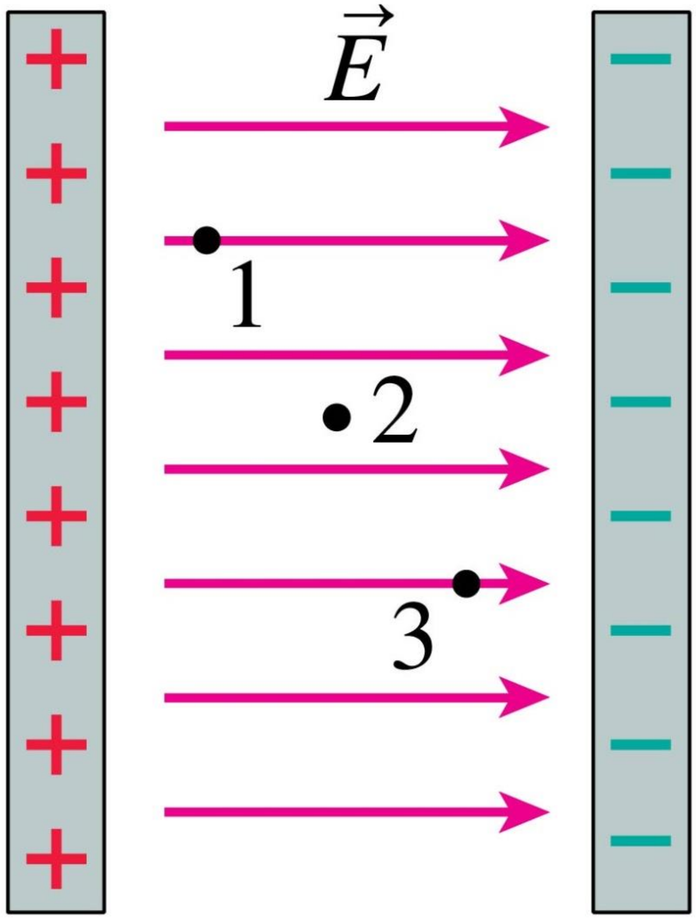
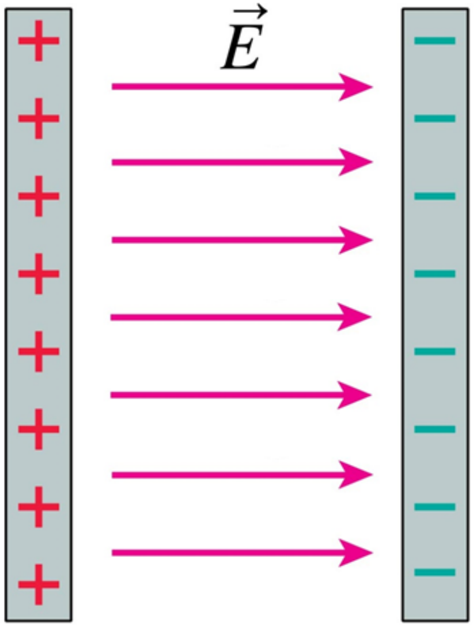


The Electric Field Inside a Capacitor



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?

MODEL The electrodes can be modeled as a parallel-plate capacitor.

The Electric Field Inside a Capacitor

SOLVE:

The electric field strength inside the capacitor is $E = Q/\epsilon_0 A$. Thus, the charge to produce a field of strength E is

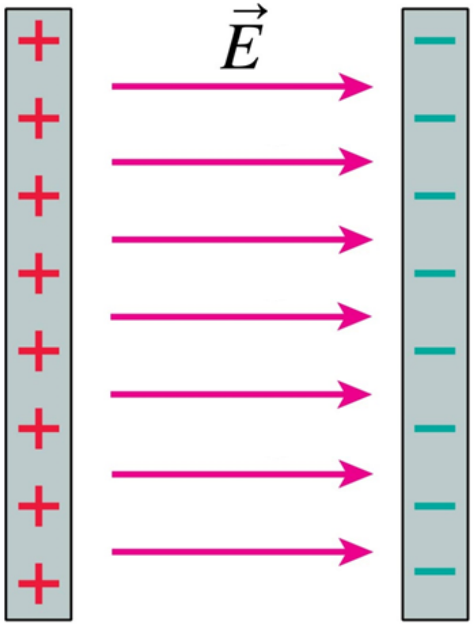
Q = $(8.85\times10^{-12}\ \text{C}^2/\text{N m}^2)(2.0\times10^{-4}\ \text{m}^2)(2.0\times10^{6}\ \text{N/C})$
$= 3.5\times10^{-9}\ \text{C} = 3.5\ \text{nC}$

The positive plate must be charged to +3.5 nC and the negative plate to -3.5 nC. In general, the plates are charged by using a battery to move electrons from one plate to the other. The number of electrons in 3.5 nC is

$$N = \frac{Q}{e} = \frac{3.5\times10^{-9}\ \text{C}}{1.6\times10^{-19}\ \text{C/electron}} = 2.2\times10^{10}\ \text{electrons}$$

Thus, 2.2×10^{10} electrons are moved from one electrode to the other. Note that the capacitor as a whole has no net charge.

The Electric Field Inside a Capacitor

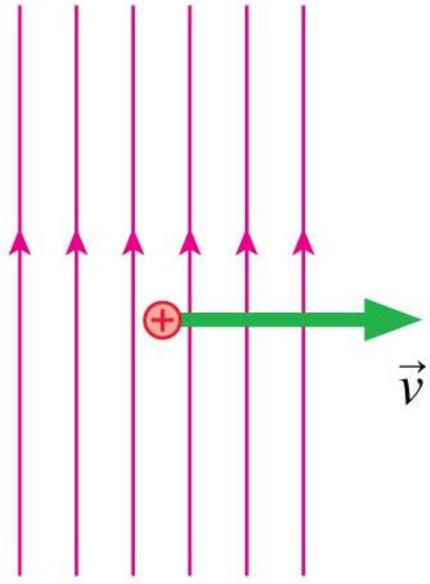


ASSESS:

The plate spacing does not enter the result. As long as the spacing is much smaller than the plate dimensions, as is true in this example, the field is independent of the spacing.

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



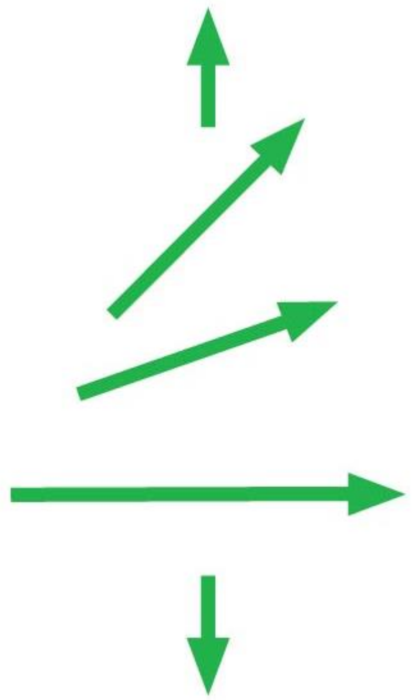
A.

B.

C.

D.

E.



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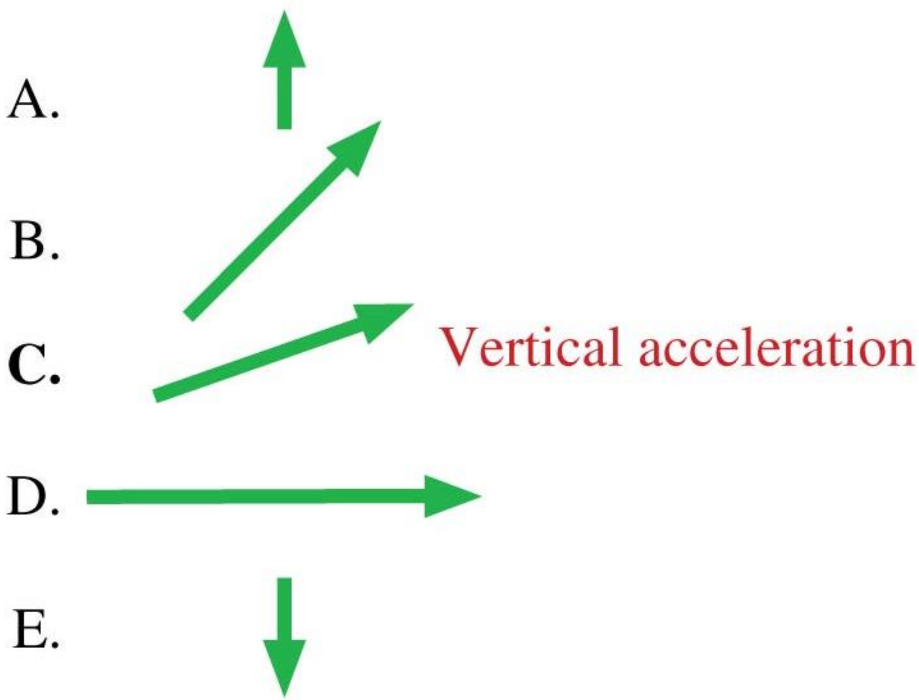
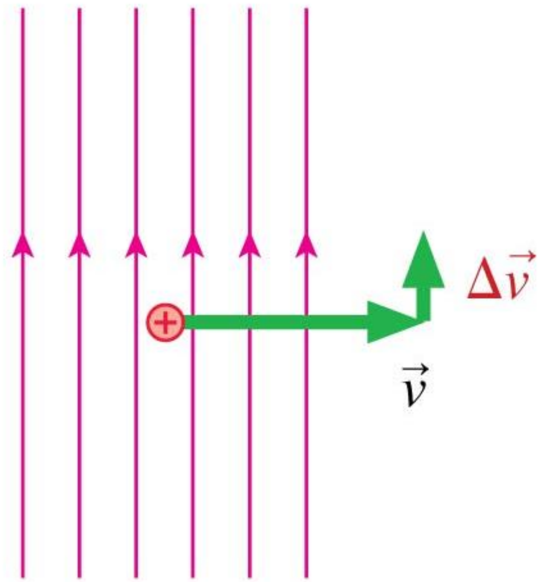
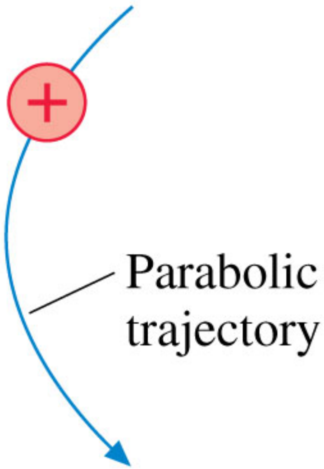
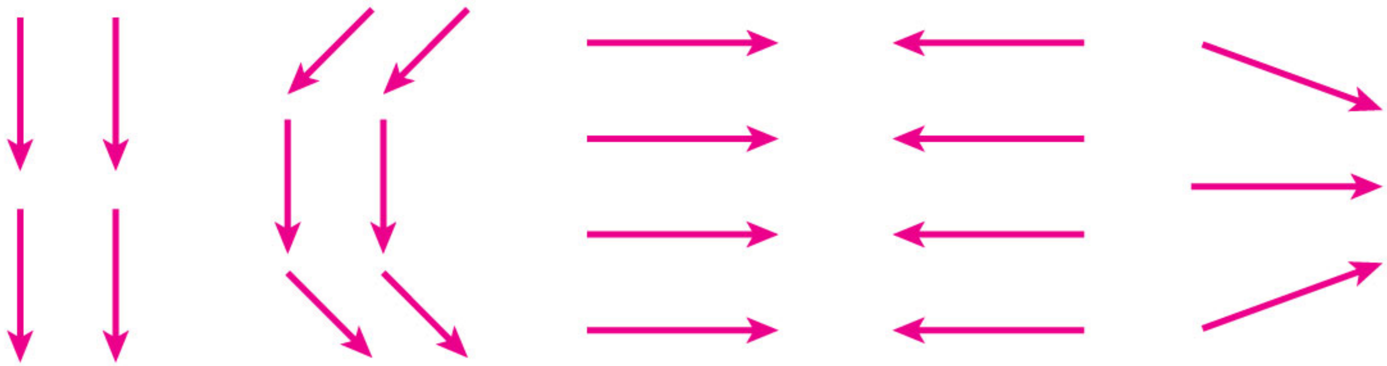




Motion of a Charged Particle in an Electric Field

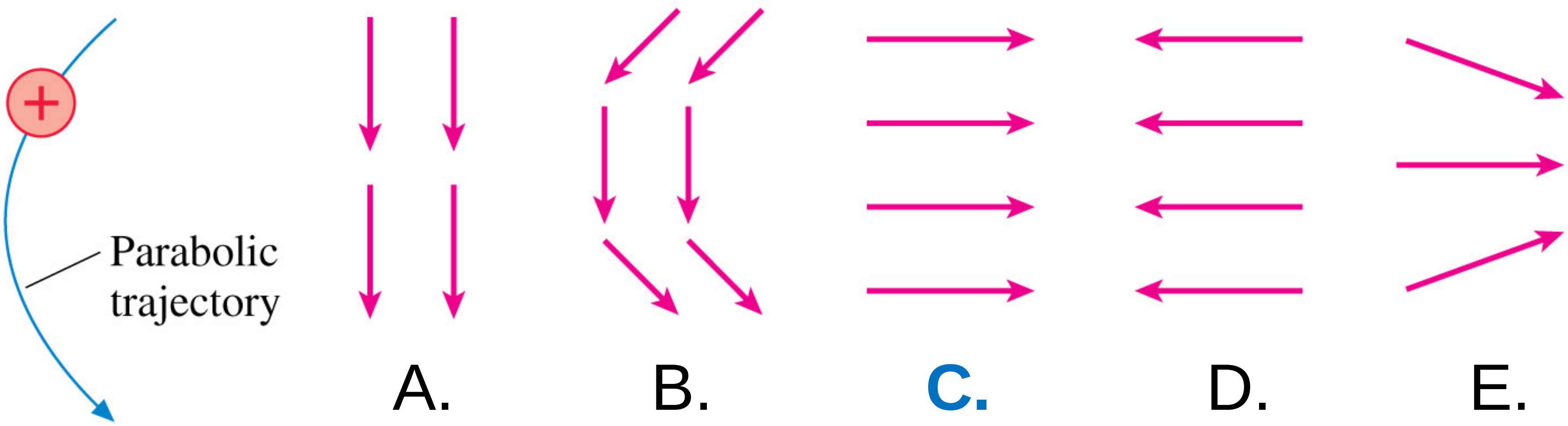




A. B. C. D. E.

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

Motion of a Charged Particle in an Electric Field



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

Electric Flux

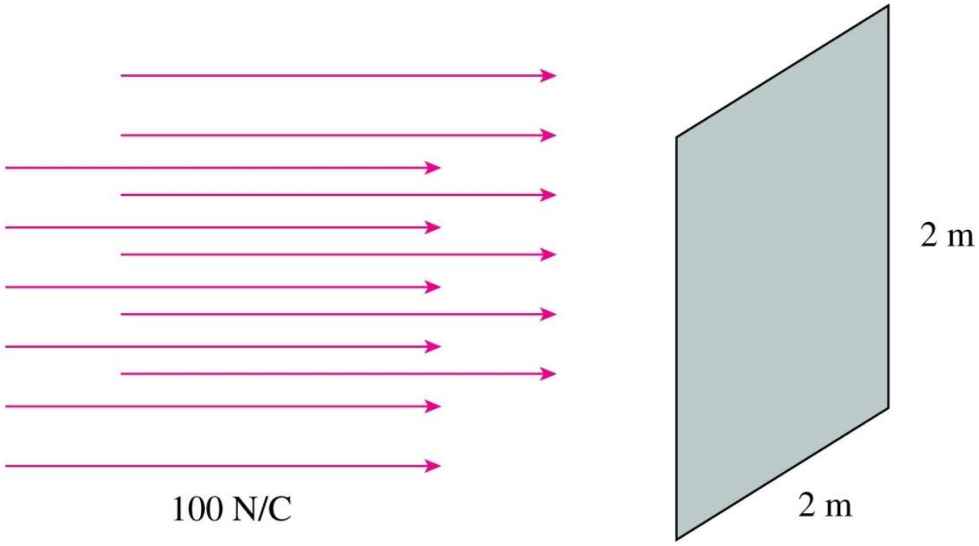
Q.21 The electric flux through the shaded surface is

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.21 The electric flux through the shaded surface is

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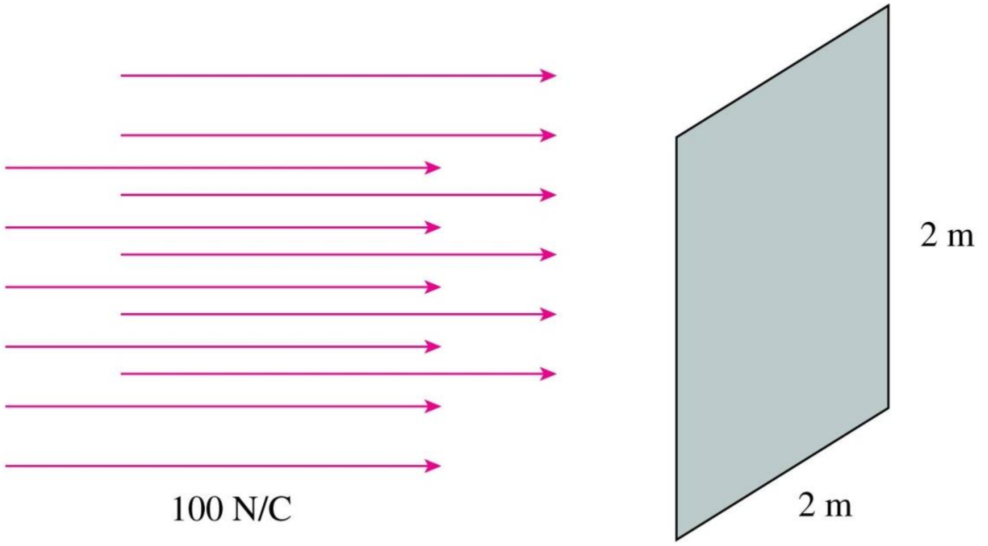


Electric Flux

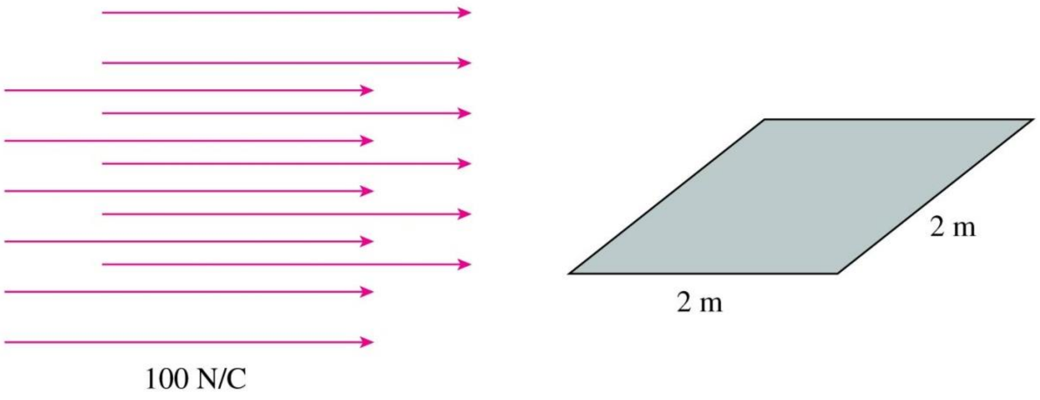
Q.22 The electric flux through the shaded surface is

a) 0.

b) 200 N m/C.

c) 400 N m^2/C.

d) Some other value.



Electric Flux

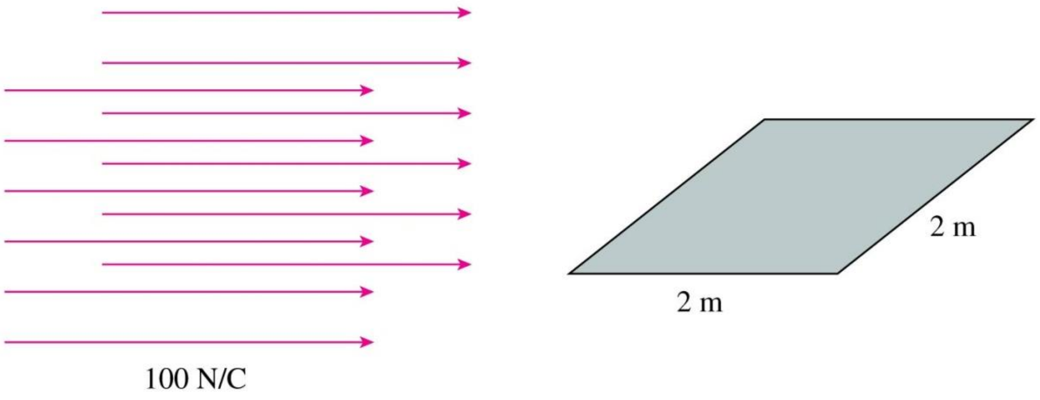
Q.22 The electric flux through the shaded surface is

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

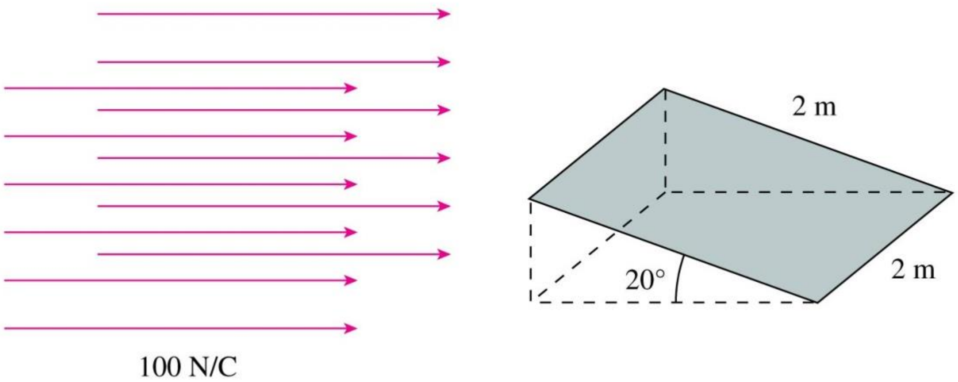
a) 0.

b) 400cos20° N m^2/C.

c) 400cos70° N m^2/C.

d) 400 N m^2/C.

e) Some other value.



Electric Flux

Q.23 The electric flux through the shaded surface is

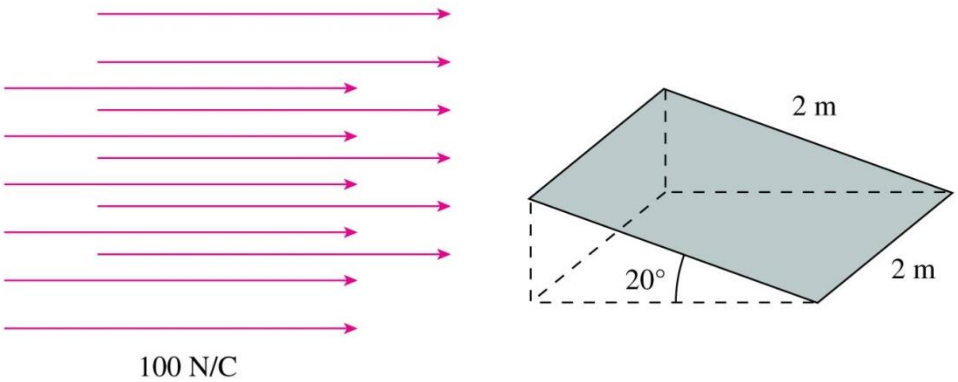
a) 0.

b) 400cos20° N m²/C.

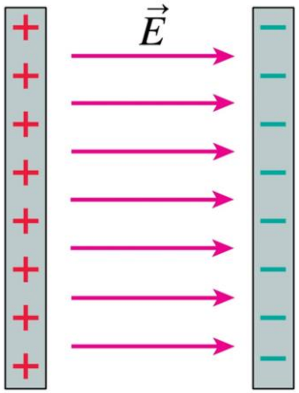
c) 400cos70° N m²/C.

d) 400 N m²/C.

e) Some other value.



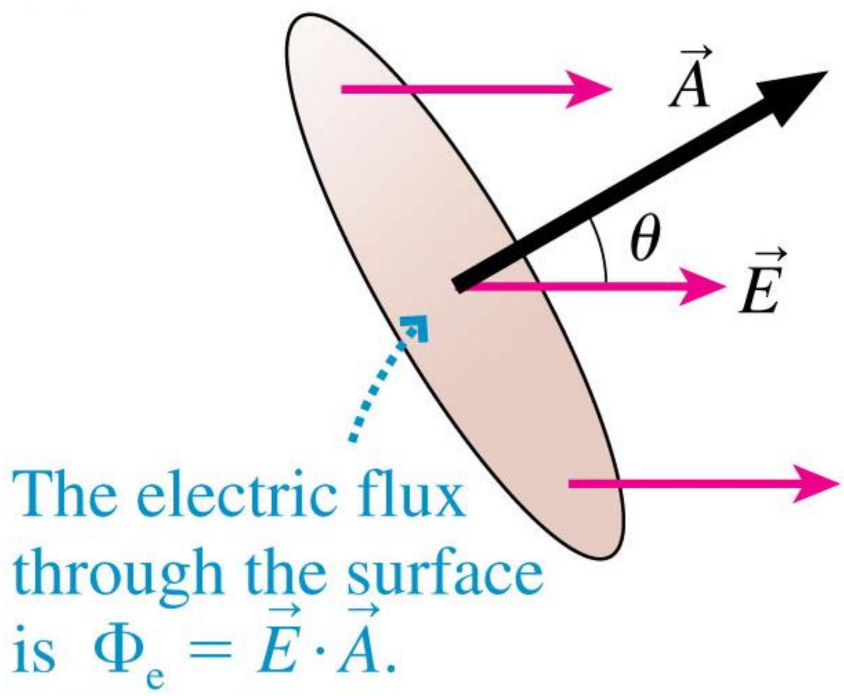
The Electric Flux Inside a Parallel-Plate Capacitor



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?

MODEL Assume the surface is located near the centre of the capacitor where the electric field is uniform. The electric flux doesn't depend on the shape of the surface.

The Electric Flux Inside a Parallel-Plate Capacitor



VISUALIZE: The surface is square, rather than circular, but otherwise the situation looks like the figure above.

The Electric Flux Inside a Parallel-Plate Capacitor

SOLVE The electric field inside a parallel-plate capacitor is

$$E = \frac{Q}{\epsilon_0 A_{\text{plates}}} = \frac{5.0 \times 10^{-9}\ \text{C}}{(8.85 \times 10^{-12} \text{C}^2/\text{N m}^2)(1.0 \times 10^{-2}\ \text{m}^2)}$$
$$= 5.65 \times 10^4\ \text{N/C}$$

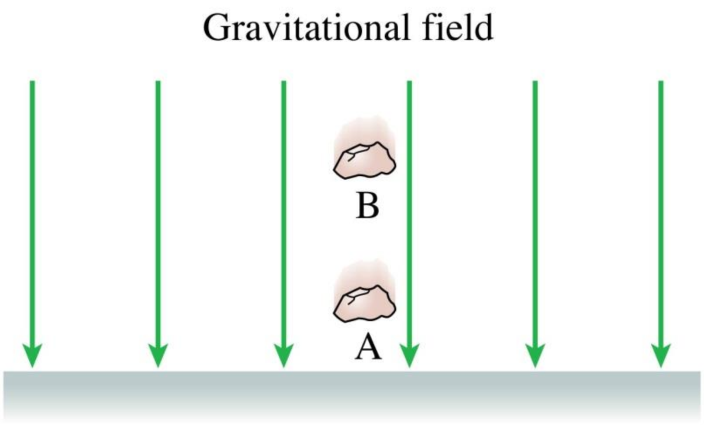
A 1.0 cm × 1.0 cm surface has A = $1.0 \times 10^{-4}\ \text{m}^2$. The electric flux through this surface is

$$\Phi_\text{e} = \vec{E}\vec{A} = EA\cos\theta$$
$$= (5.65 \times 10^4 \text{N/C})(1.0 \times 10^{-4} \text{m}^2)\cos 45°$$
$$= 4.0 \times 10^{-5}\ \text{N m}^2/\text{C}$$

ASSESS: The units of electric flux are the product of electric field and area units: N m^2/C.

Gravitational Potential

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



a) Rock A.

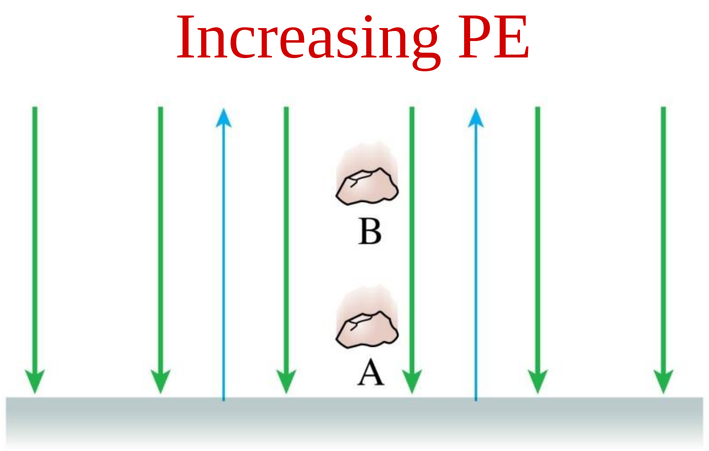
b) Rock B.

c) They have the same potential energy.

d) Both have zero potential energy.

Gravitational Potential

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



a) Rock A.

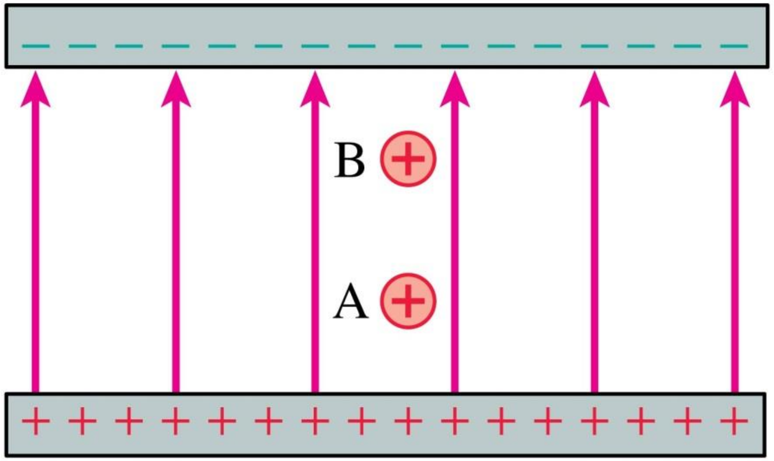
b) Rock B.

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.

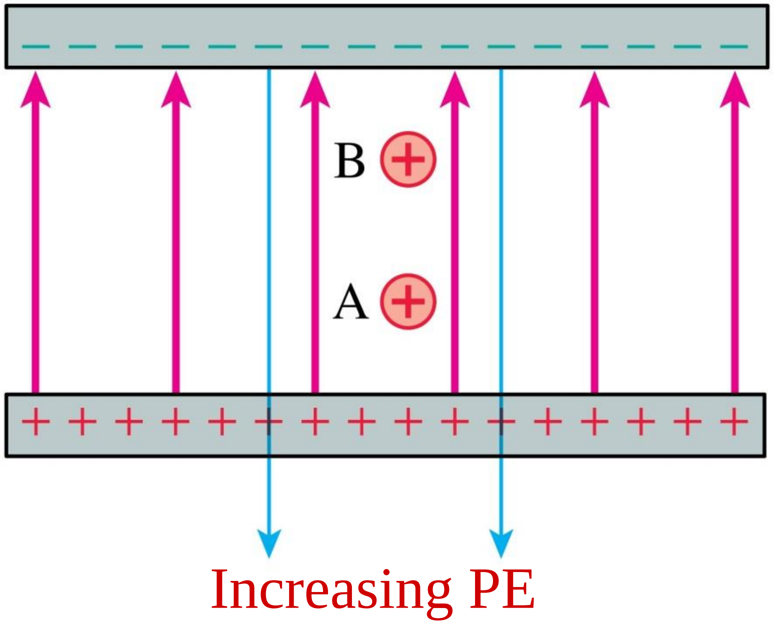
b) Charge B.

c) They have the same potential energy.

d) Both have zero potential energy.

Electric Potential Energy

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



a) **Charge A.**

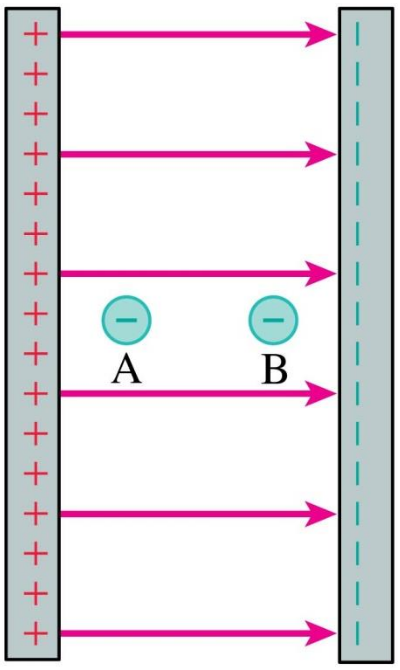
b) Charge B.

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.

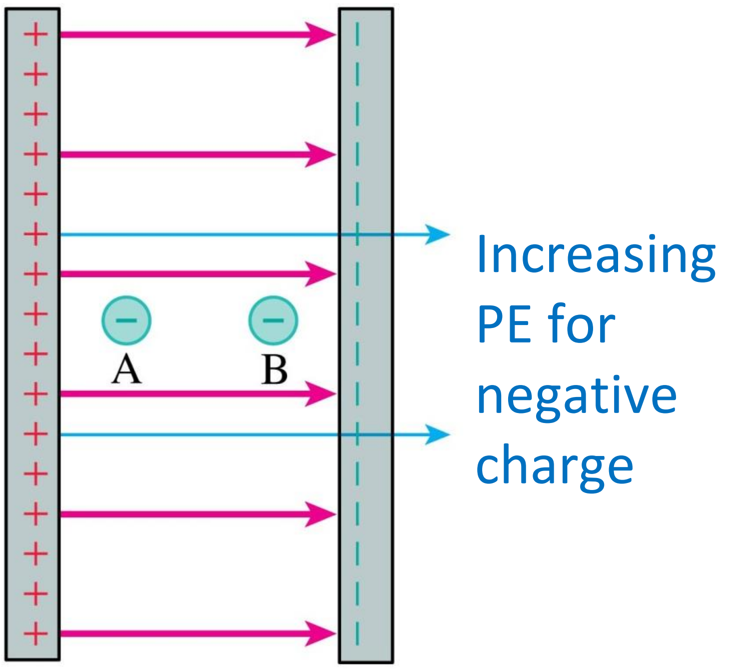
b) Charge B.

c) They have the same potential energy.

d) Both have zero potential energy.

Electric Potential Energy

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



a) Charge A.

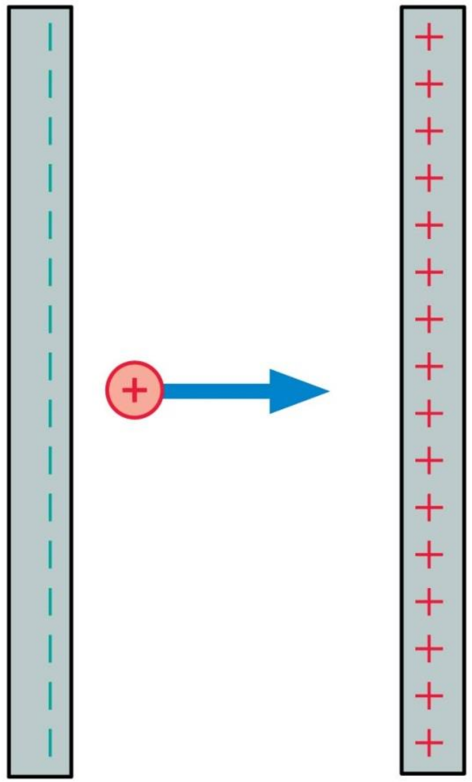
b) Charge B.

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



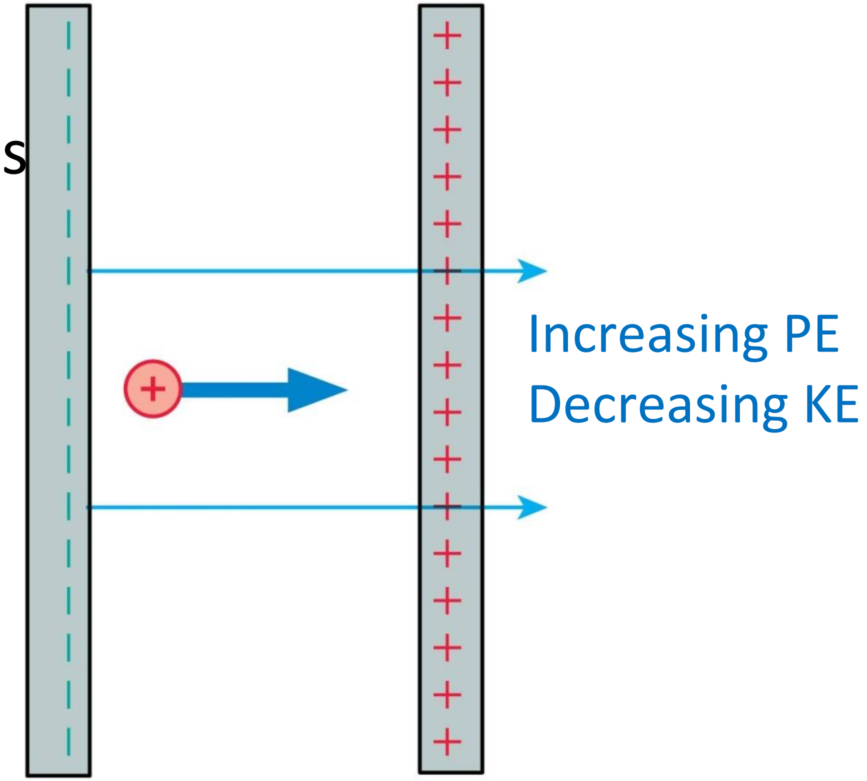
a) Increases.

b) Remains constant.

c) Decreases.

Electric Potential Energy

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



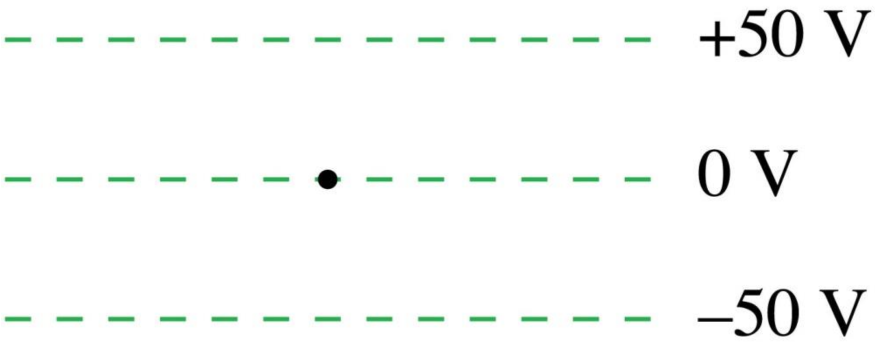
a) Increases.

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.

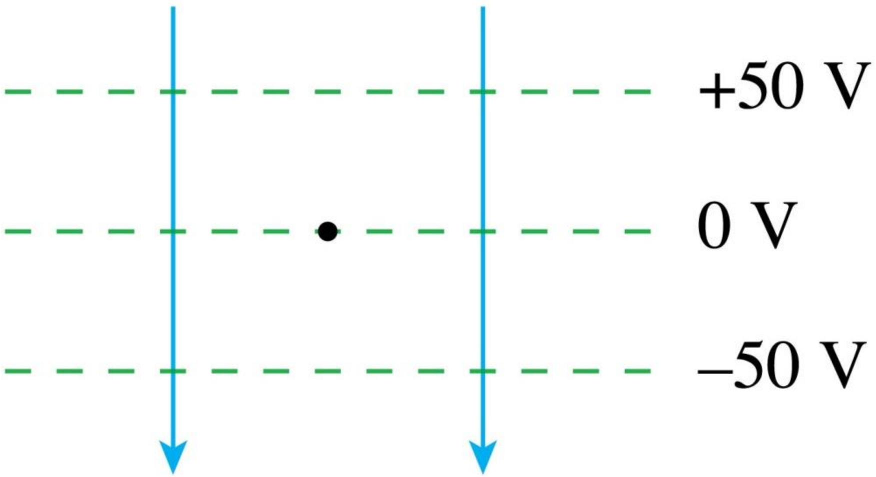
c) Moves upward with an increasing speed.

d) Moves downward with a steady speed.

e) Moves downward with an increasing speed.

Electric Potential

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



Decreasing PE
Increasing KE

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.

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

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.

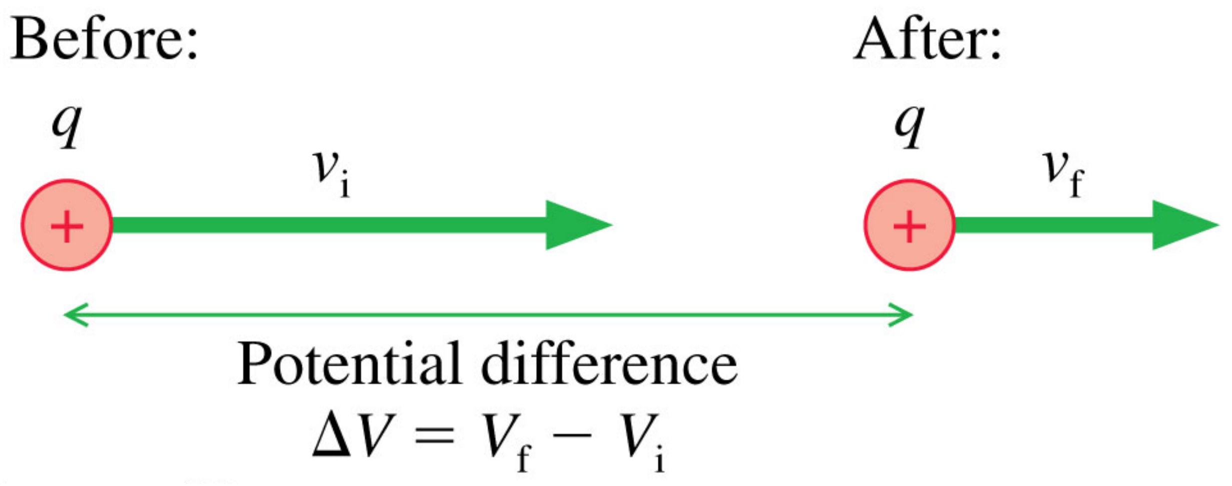
Exercise 22

Moving through a Potential Difference

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?

MODEL: Energy is conserved. The electric potential determines the potential energy.

Moving through a Potential Difference



VISUALISE: The figure above is a before-and-after pictorial representation of a charged particle moving through a potential difference. A positive charge *slows down* as it moves into a region of higher potential ($K \rightarrow U$). A negative charge *speeds up* ($U \rightarrow K$).

Moving through a Potential Difference

SOLVE:

The potential energy of charge q is $U=qV$. Conservation of energy, now expressed in terms of the electric potential V, is $K_f + qV_f = K_i + qV_i$, or

$$K_f = K_i - q\Delta V$$

Where $\Delta V = V_f - V_i$ is the potential difference through which the particle moves. In terms of the speeds, energy conservation is

$$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 - q\Delta V$$

We can solve this for the final speed:

$$v_f = \sqrt{v_i^2 - \frac{2q}{m}\Delta V}$$

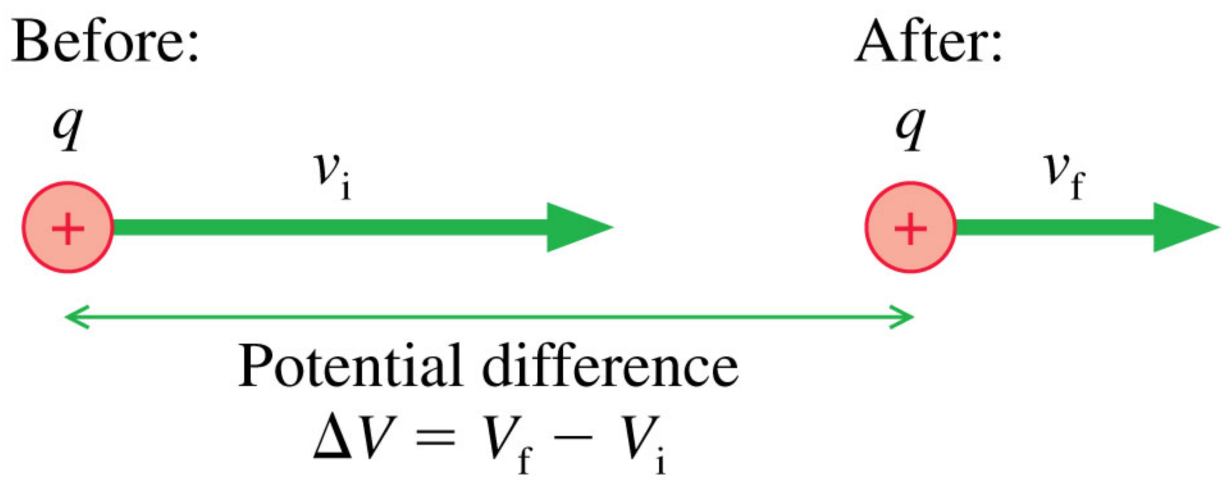
Moving through a Potential Difference

For a proton, with $q = e$, the final speed is

$$(v_\mathrm{f})_\mathrm{p} = \sqrt{(2.0 \times 10^5\ \mathrm{m/s})^2 - \frac{2(1.60 \times 10^{-19}\ \mathrm{C})(100\ \mathrm{V})}{1.67 \times 10^{-27}\ \mathrm{kg}}}$$
$$= 1.4 \times 10^5\ \mathrm{m/s}$$

An electron, though, with $q = -e$ and a difference mass, speeds up to $(v_\mathrm{f})_\mathrm{e} = 5.9 \times 10^6\ \mathrm{m/s}$.

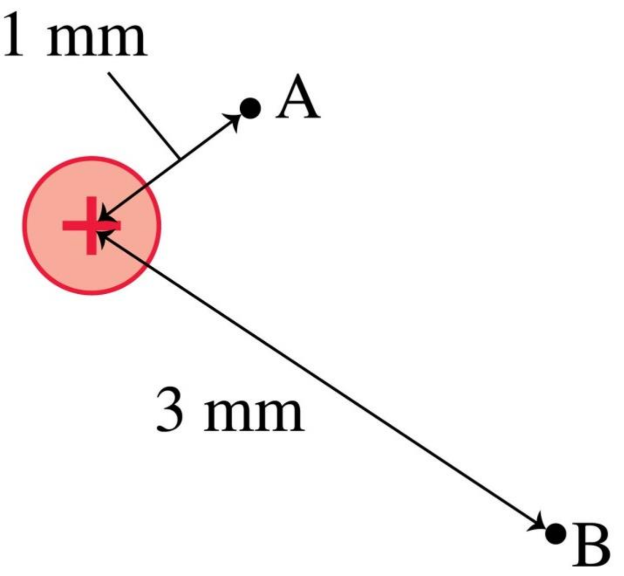
Moving through a Potential Difference



ASSESS: The electric potential *already existed* in space due to other charges that are not explicitly seen in the problem. The electron and proton have nothing to do with creating the potential. Instead, they *respond* to the potential by having potential energy $U=qV$.

Electric Potential

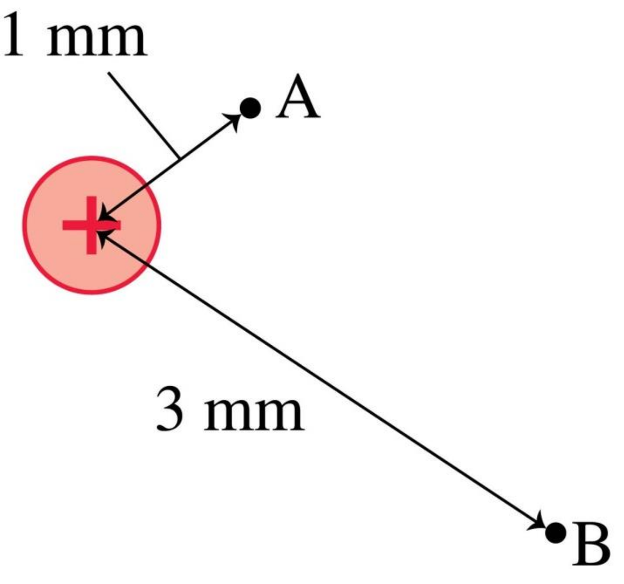
32. What is the ratio V_B/V_A of the electric potentials at the two points?



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

Electric Potential

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



a) 9.
b) 3.
c) 1/3. Potential of a point charge decreases inversely with distance.
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?

Calculating the Potential of a Point Charge

SOLVE: The potential at *r* = 1.0 cm is

$$V_{1\text{ cm}} = \frac{1}{4\pi\epsilon_0}\frac{q}{r} = \left(9.0 \times 10^9\ \text{N}\frac{\text{m}^2}{\text{C}^2}\right)\frac{1.0 \times 10^{-9}\ \text{C}}{0.010\ \text{m}} = 900\ \text{V}$$

We can similarly calculate $V_{3\text{ cm}} = 300\ \text{V}$.

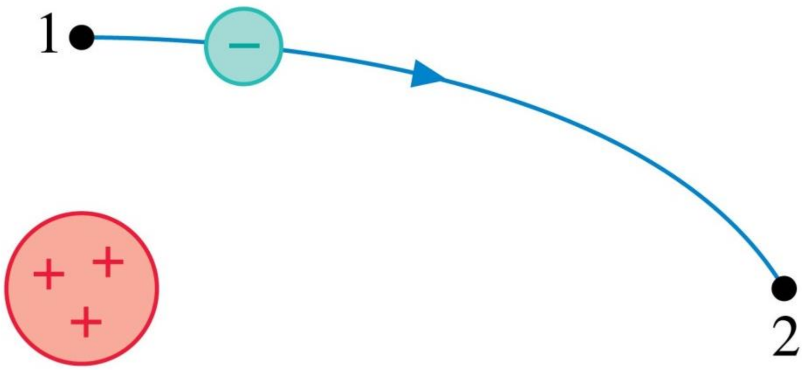
Thus, the potential difference between these two points is $\Delta V = V_{1\text{ cm}} - V_{3\text{ cm}} = 600\ \text{V}$.

Calculating the Potential of a Point Charge

ASSESS: 1 nC is typical of the electrostatic charge produced by rubbing, and you can see that such a charge creates a fairly large potential nearby. Why are we not shocked and injured when working with the "high voltages" of such charges? The sensation of being shocked is a result of current, not potential. Some high-potential sources simply do not have the ability to generate much current. We will look at current in later lectures.

Electric Potential

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



a) $v_2 > v_1$.

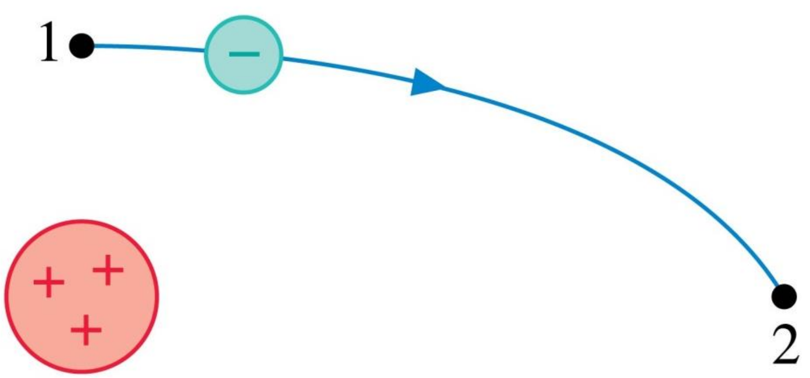
b) $v_2 = v_1$.

c) $v_2 < v_1$.

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

Electric Potential

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



a) $v_2 > v_1$.

b) $v_2 = v_1$.

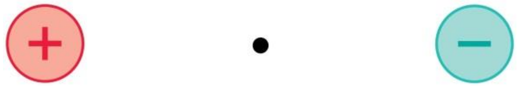
c) $v_2 < v_1$.

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

Increasing PE (becoming less negative), so decreasing KE.

Electric Potential

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



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

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

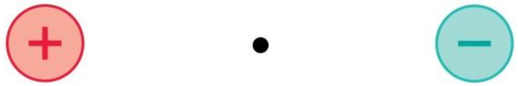
c) $\vec{E} = \vec{0}$; $V < 0$.

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

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

Electric Potential

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



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

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

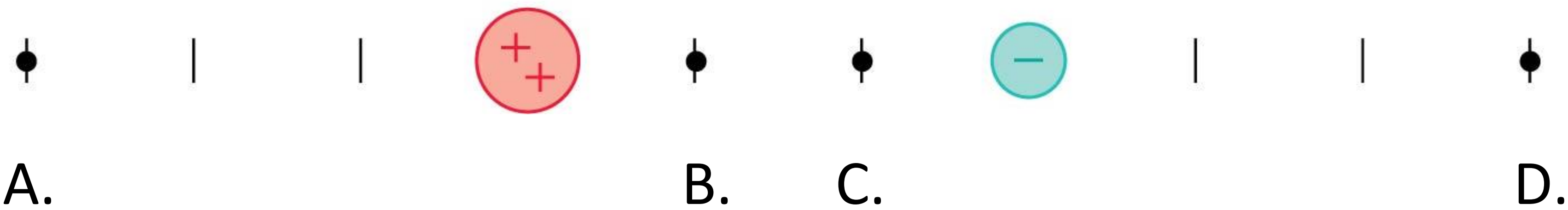
c) $\vec{E} = \vec{0}$; $V < 0$.

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

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

Electric Potential

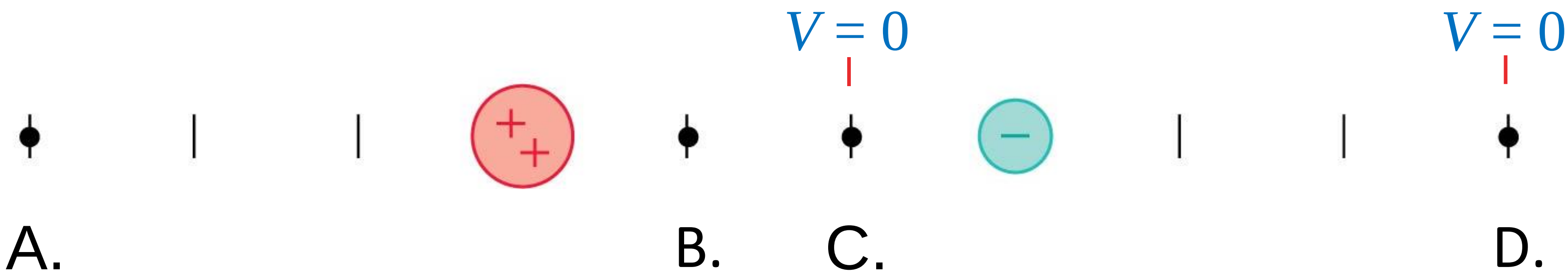
Q.36 At which point or points is the electric potential zero?



E. More than one of these.

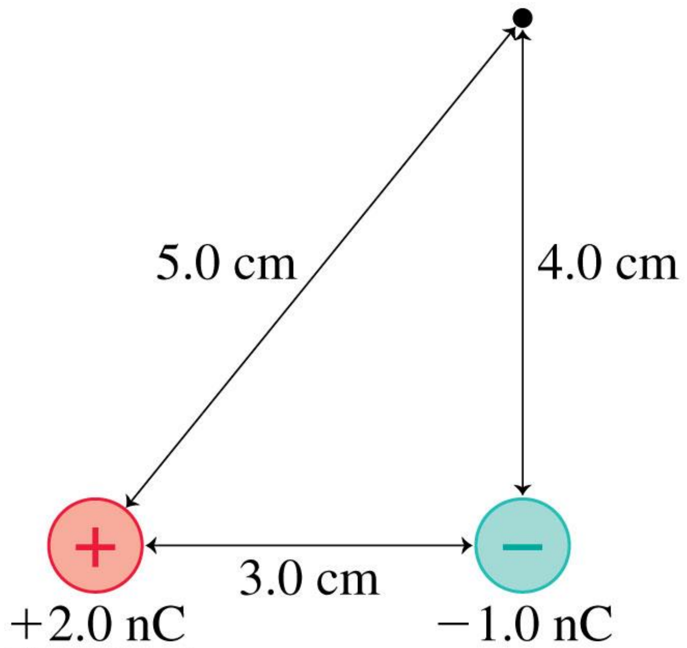
Electric Potential

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



E. More than one of these.

The Potential of Two Charges

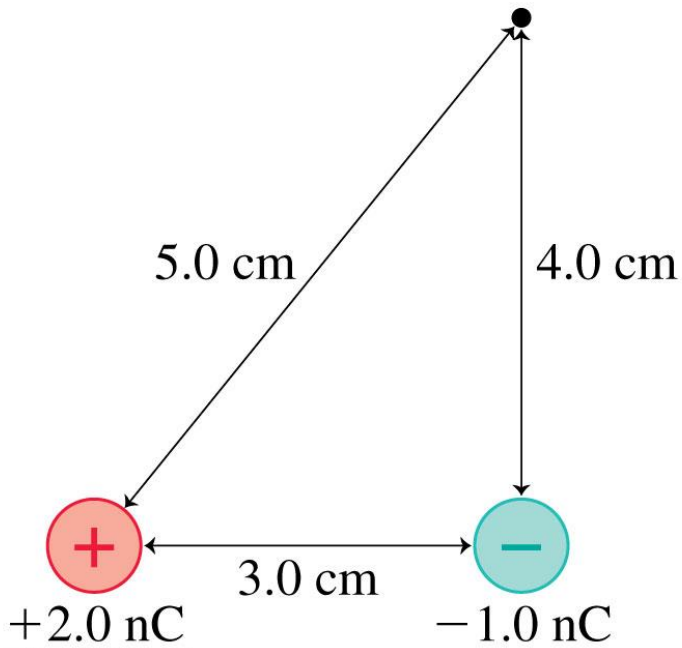


Q.37 What is the electric potential at the point indicated in the figure?

MODEL:

The potential is the sum of the potentials due to each charge.

The Potential of Two Charges



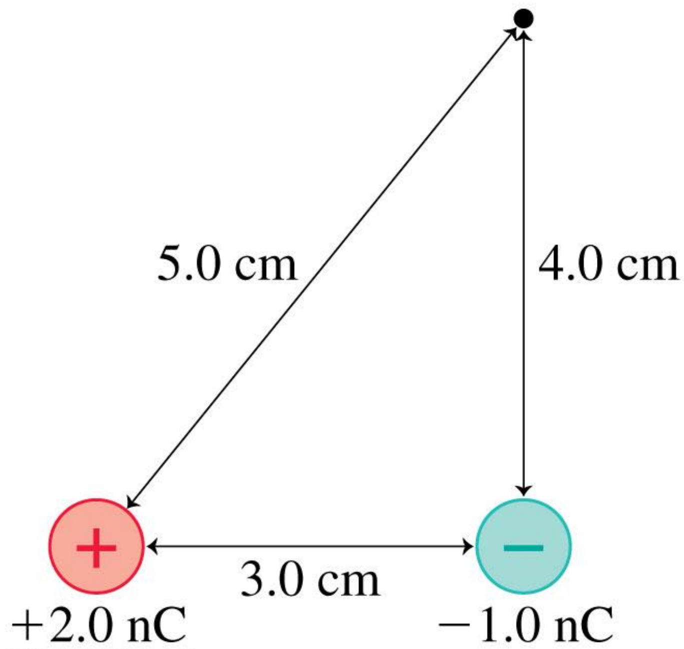
SOLVE: The potential at the indicated point is

$$V = \frac{1}{4\pi\epsilon_0}\frac{q_1}{r_1} + \frac{1}{4\pi\epsilon_0}\frac{q_2}{r_2}$$

$$= \left(9.0 \times 10^9\ \mathrm{N}\frac{\mathrm{m}^2}{\mathrm{C}^2}\right)\left(\frac{2.0 \times 10^{-9}\ \mathrm{C}}{0.050\ \mathrm{m}} + \frac{-1.0 \times 10^{-9}\ \mathrm{C}}{0.040\ \mathrm{m}}\right)$$

$$= 135\ \mathrm{V}$$

The Potential of Two Charges



ASSESS: The potential is a scalar, so we found the net potential by adding two numbers. We don't need any angles or components to calculate the potential.

Batteries

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.

Batteries

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.

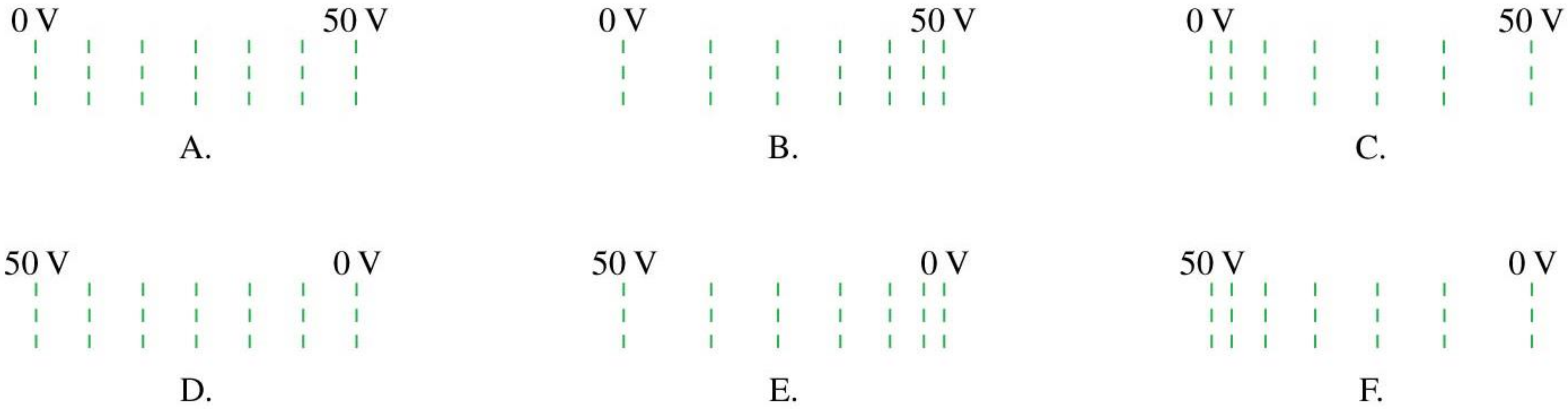
$$\mathcal{E} = \frac{W}{q} \text{ and } q = e = 1.6 \times 10^{-19}\text{ C for an ion.}$$

d) 4.8×10^{-19} V.

e) I have no idea.

Electric Potential

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



Electric Potential

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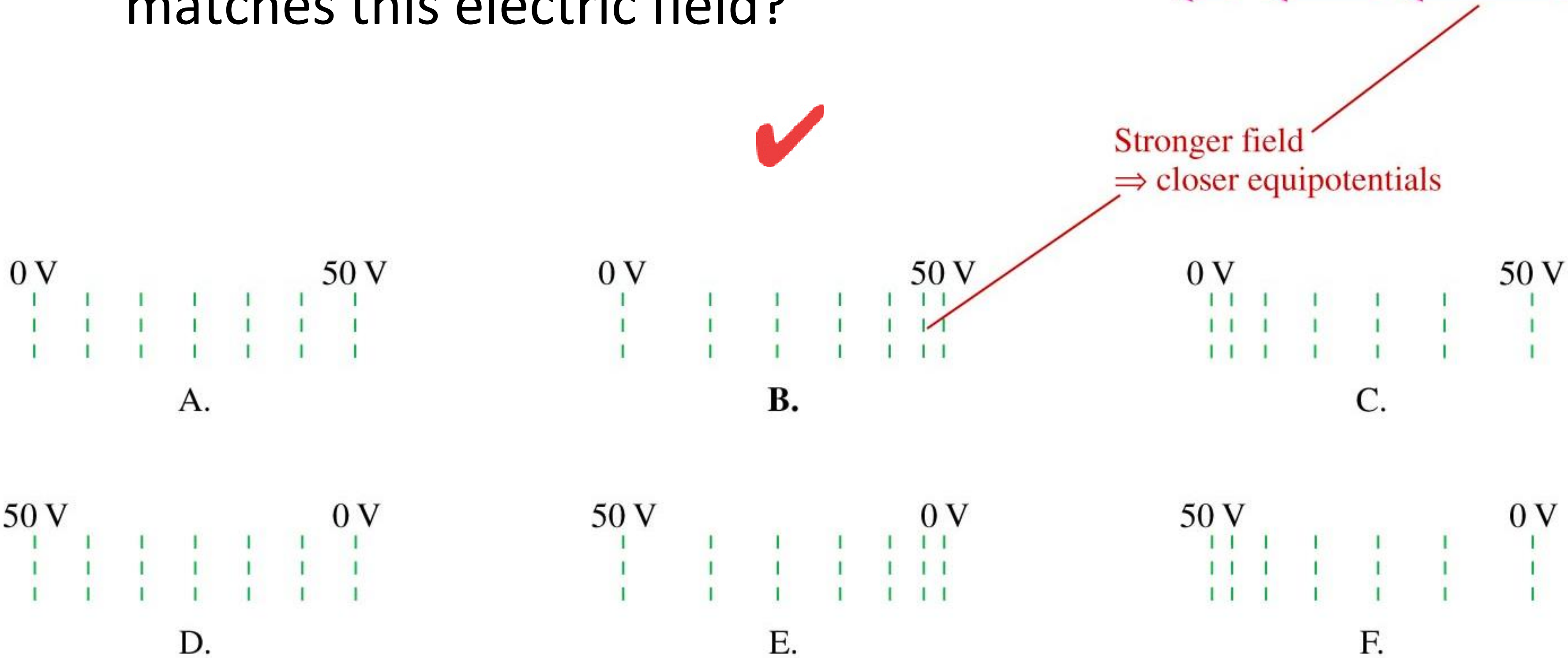
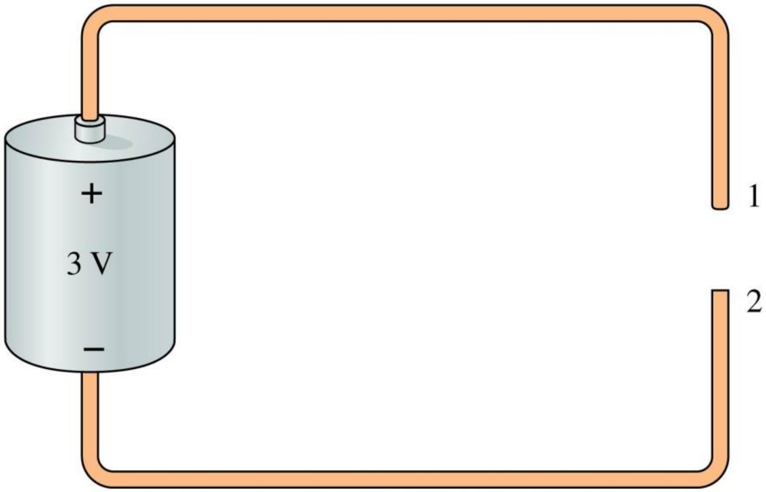


Potential Difference

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.

Potential Difference

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.

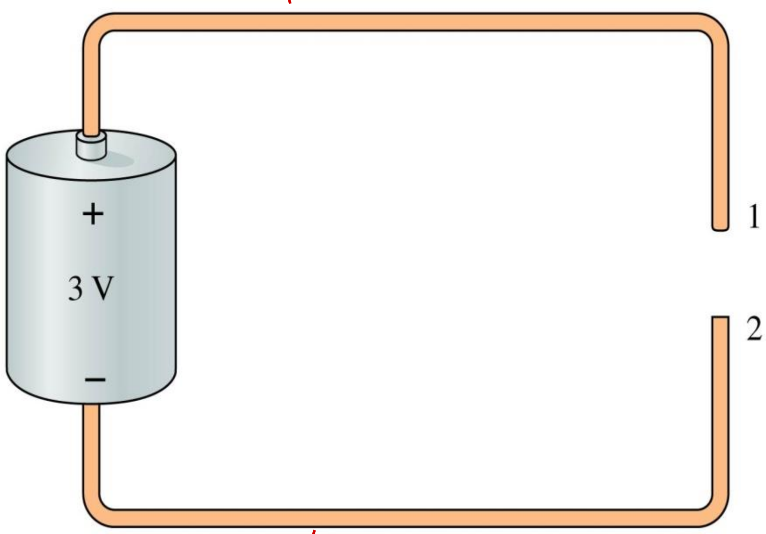
b) 3 V.

c) 0 V.

d) Undefined.

e) Not enough information to tell.

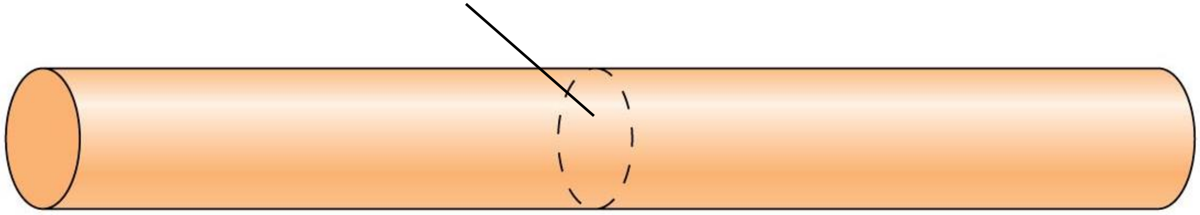
Every point on this conductor is at the same potential as the positive terminal of the battery.



Every point on this conductor is at the same potential as the negative terminal of the battery.

Current

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.

Current

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.

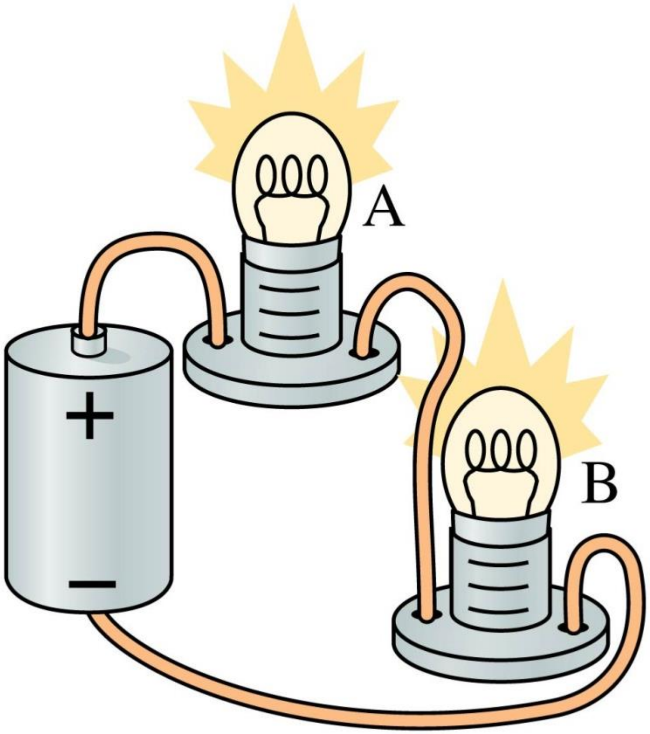
c) 60 A.

d) 2 A.

e) Some other value.

Conservation of Current

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



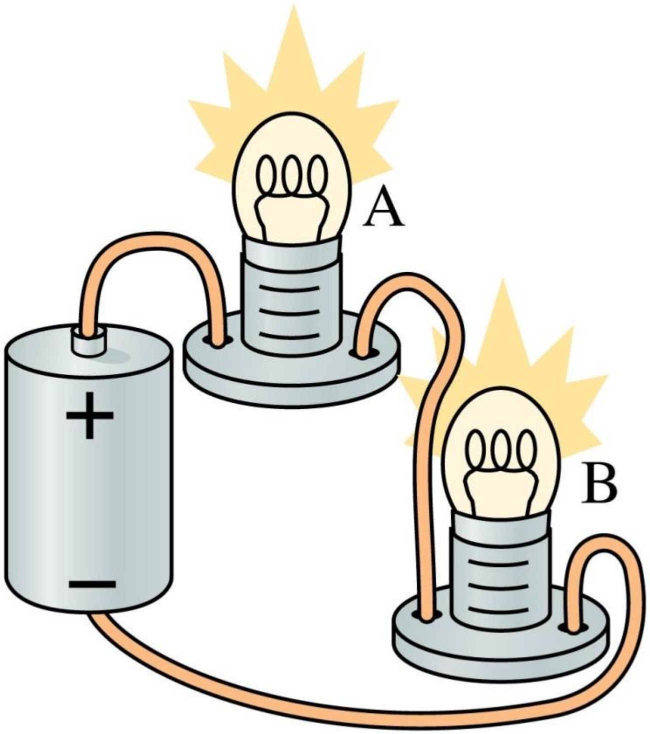
a) Bulb A.

b) Bulb B.

c) The bulbs are equally bright.

Conservation of Current

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



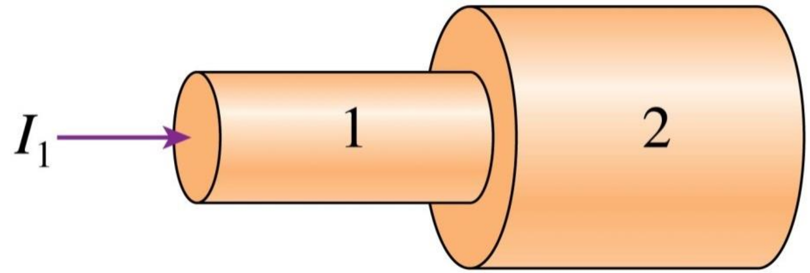
a) Bulb A.

b) Bulb B.

c) The bulbs are equally bright.

Conservation of Current

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) $I_1 > I_2$.

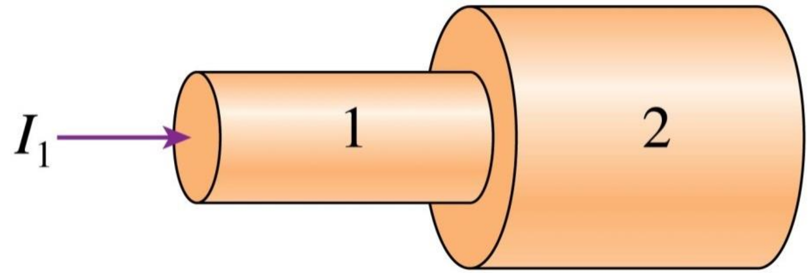
b) $I_1 = I_2$.

c) $I_1 < I_2$.

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

Conservation of Current

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) $I_1 > I_2$.

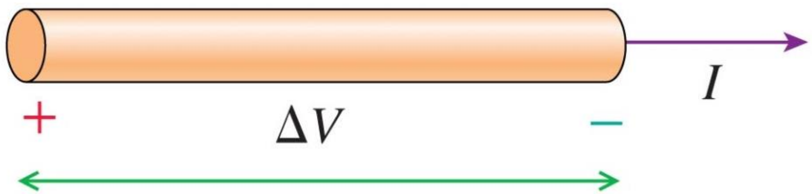
b) $I_1 = I_2$. Conservation of current

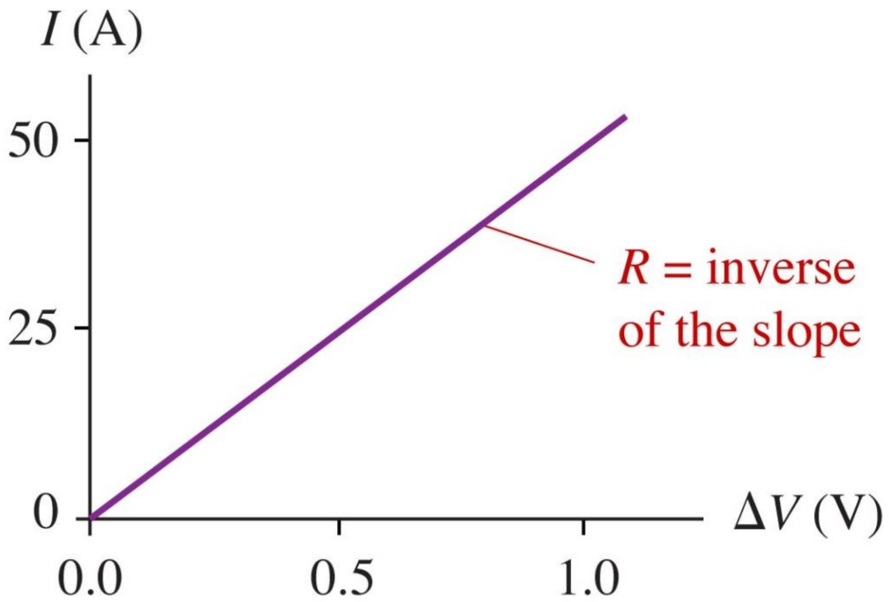
c) $I_1 < I_2$.

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.

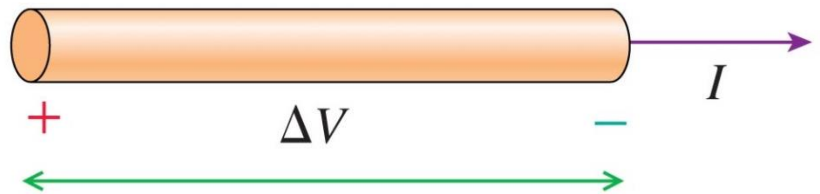
C. 50 Ω.

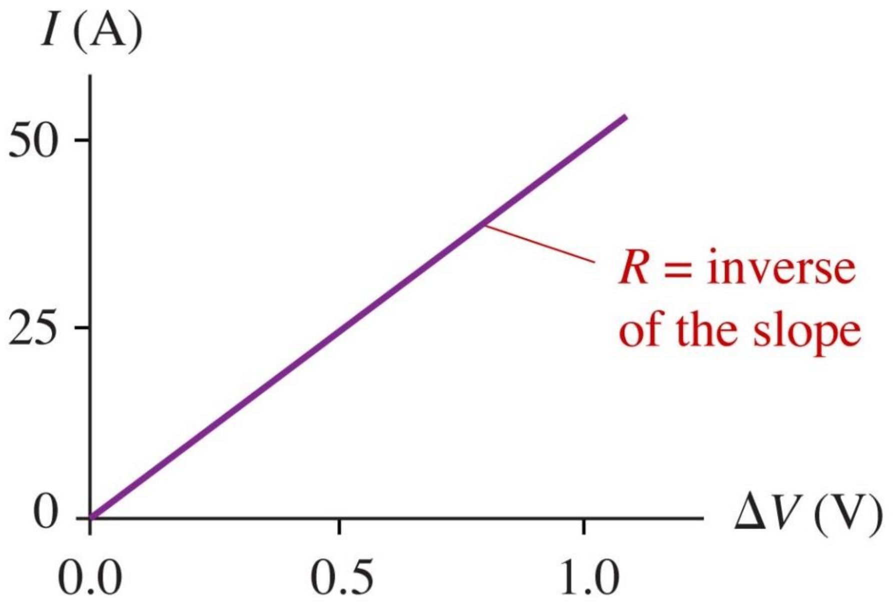
D. 100 Ω.

E. Some other value.

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. $0.01\ \Omega$.

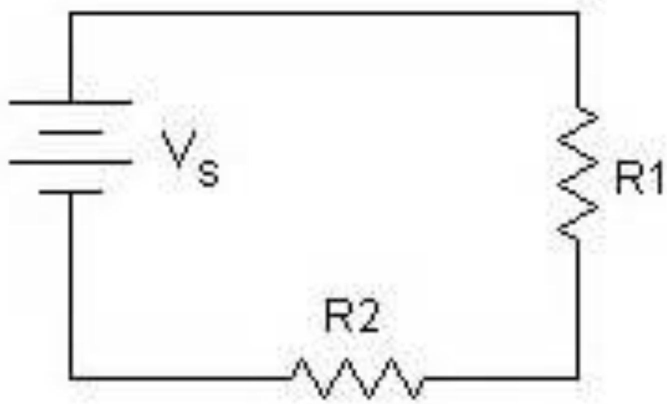
B. $0.02\ \Omega$.

C. $50\ \Omega$.

D. $100\ \Omega$.

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?

MODEL: Assume the resistor is connected to the battery with ideal wires.

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?

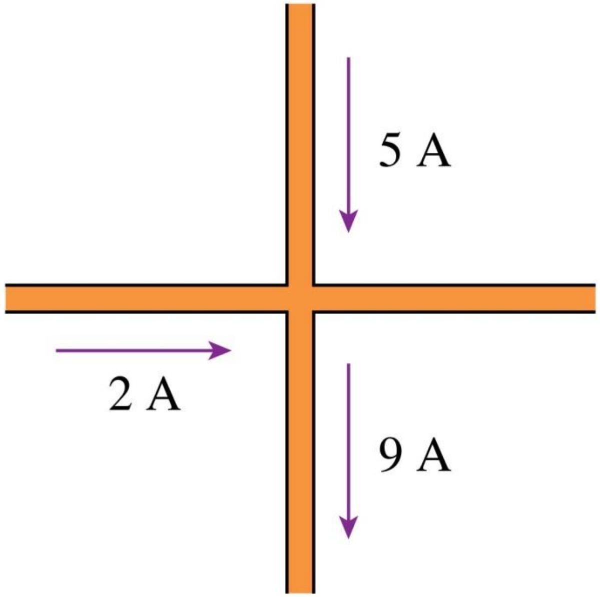
MODEL: Assume the resistor is connected to the battery with ideal wires.

SOLVE: Connecting the resistor to the battery with ideal wires makes $\Delta V_{\text{resist}} = \Delta V_{\text{bat}} = 9.0\ \text{V}$. From Ohm's law, the resistance giving a 15 mA current is

$$R = \frac{\Delta V_{\text{resist}}}{I} = \frac{9.0\ \text{V}}{0.015\ \text{A}} = 600\ \Omega$$

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.

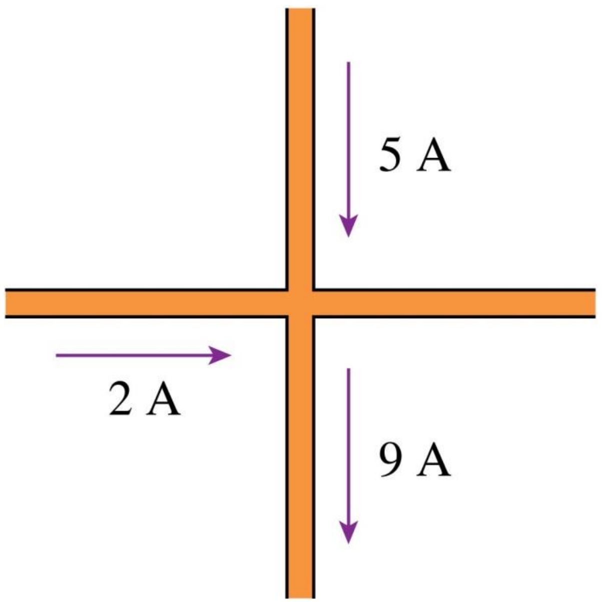
c) 2 A to the right.

d) 2 A to the left.

e) Not enough information to tell.

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.

Conservation of current

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.

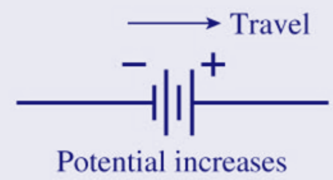
TACTICS BOX 31.1 Using Kirchhoff's loop law

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

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

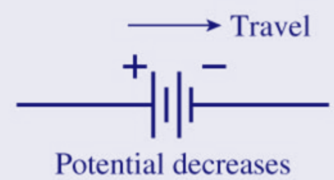
- For an ideal battery in the negative-to-positive direction:

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

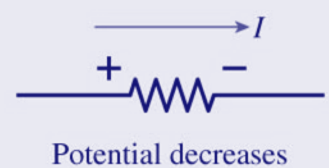


- For an ideal battery in the positive-to-negative direction:

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



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

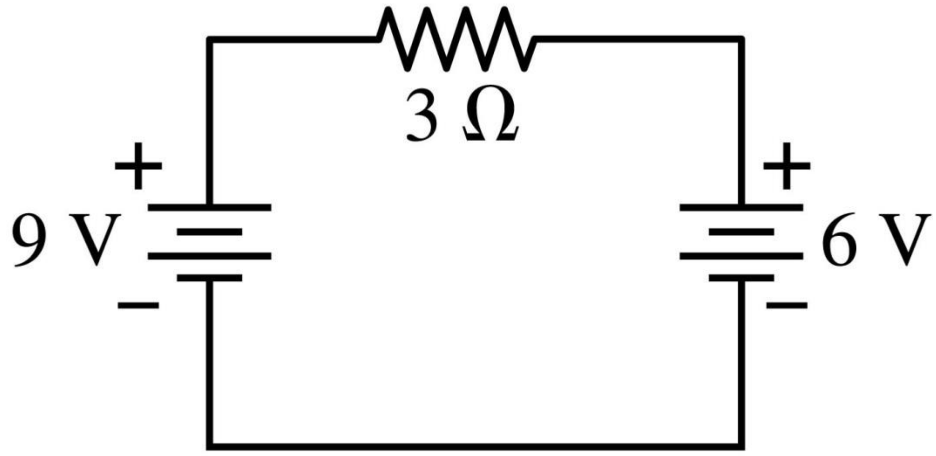


❹ **Apply the loop law:** $\sum(\Delta V)_i = 0$

Exercises 4–7

Using Kirchoff's Loop Law

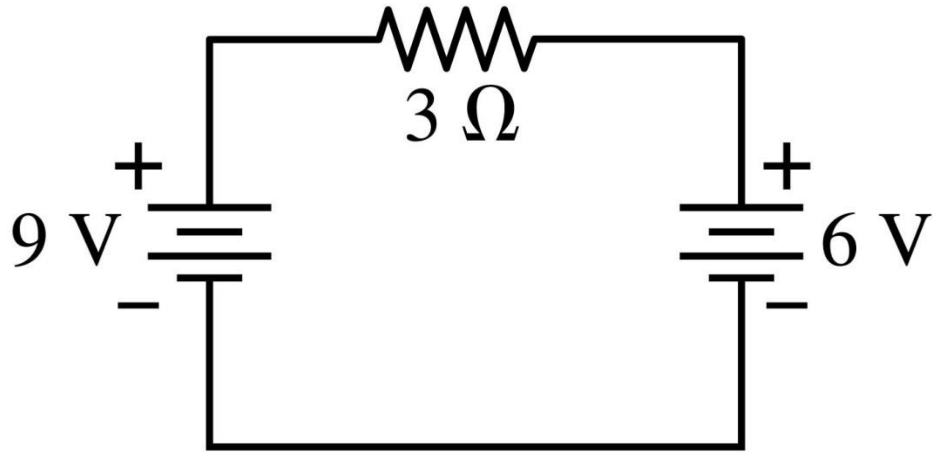
Q.47 The current through the 3 Ω resistor is



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

Using Kirchoff's Loop Law

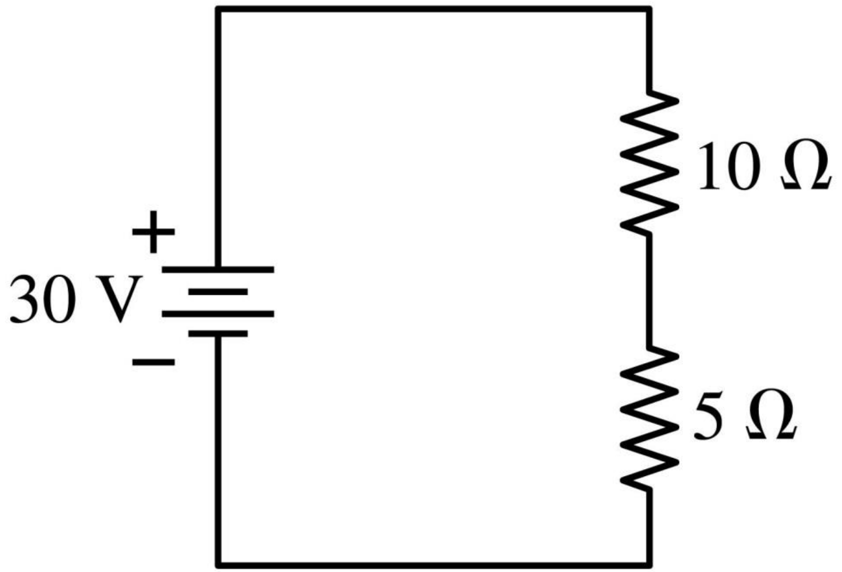
Q.47 The current through the 3 Ω resistor is



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.

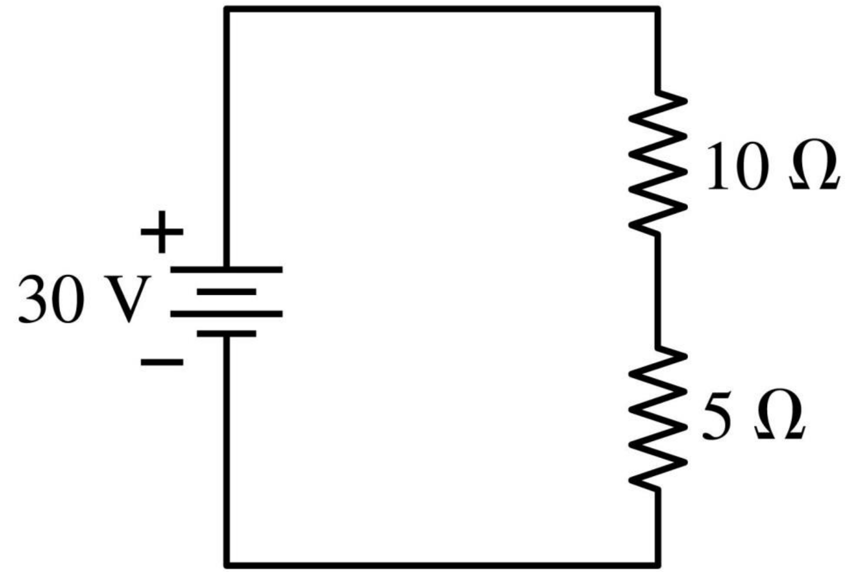
c) 15 V.

d) 10 V.

e) 5 V.

Resistors in Series

Q.48 The potential difference across the 10 resistor is



a) 30 V.

b) 20 V.

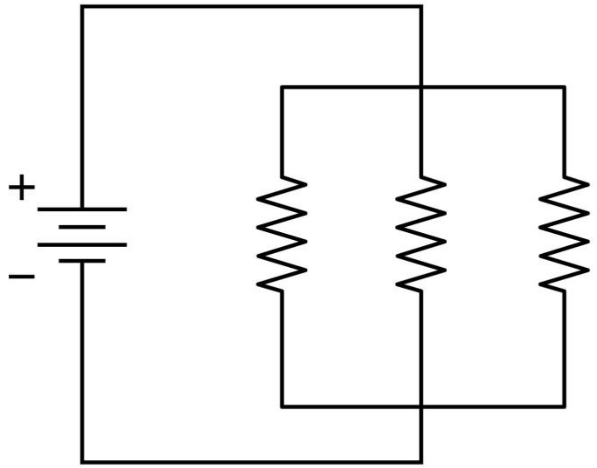
c) 15 V.

d) 10 V.

e) 5 V.

Resistors in Parallel

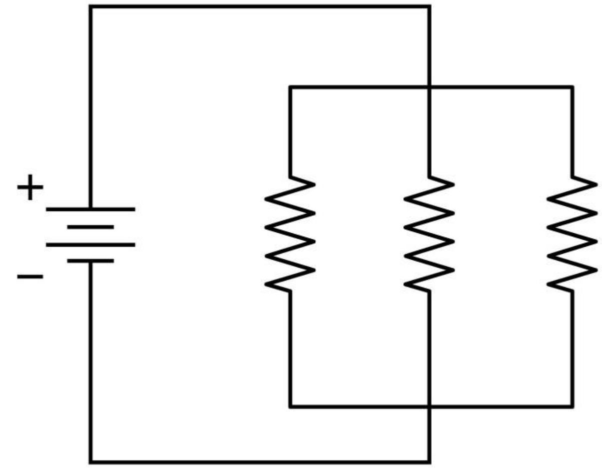
Q.49 What things about the resistors in this circuit are the same for all three?



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

Resistors in Parallel

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



a) Current *I*.

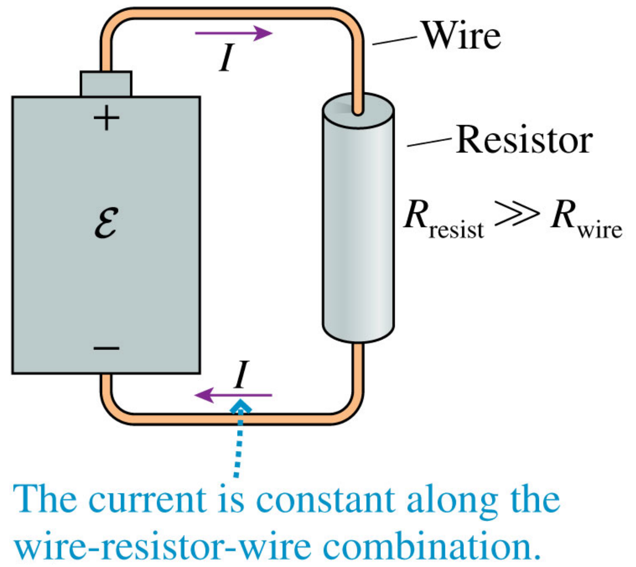
b) Potential difference ΔV.

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?

Delivering Power

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

SOLVE: This is our basic battery-and-resistor circuit, which we analyzed earlier, in this case

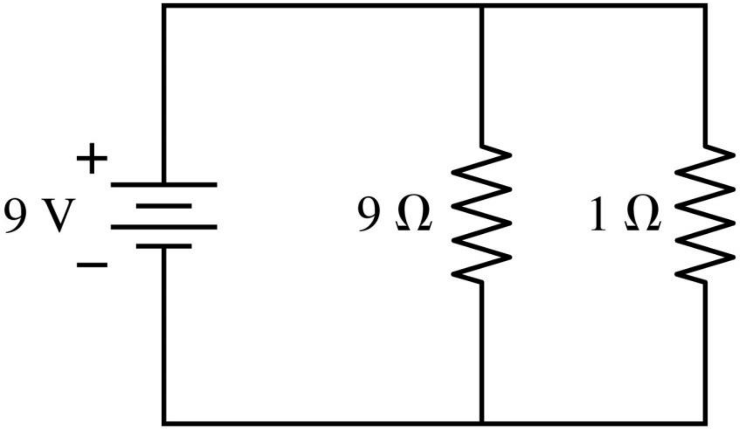
$$I = \frac{\varepsilon}{R} = \frac{120\ \mathrm{V}}{90\ \Omega} = 1.33\ \mathrm{A}$$

Thus the power delivered by the battery is

$$P_{bat} = I\varepsilon = (1.33\ \mathrm{A})(120\ \mathrm{V}) = 160\ \mathrm{W}$$

Power Dissipation

Q.51 Which resistor dissipates more power?



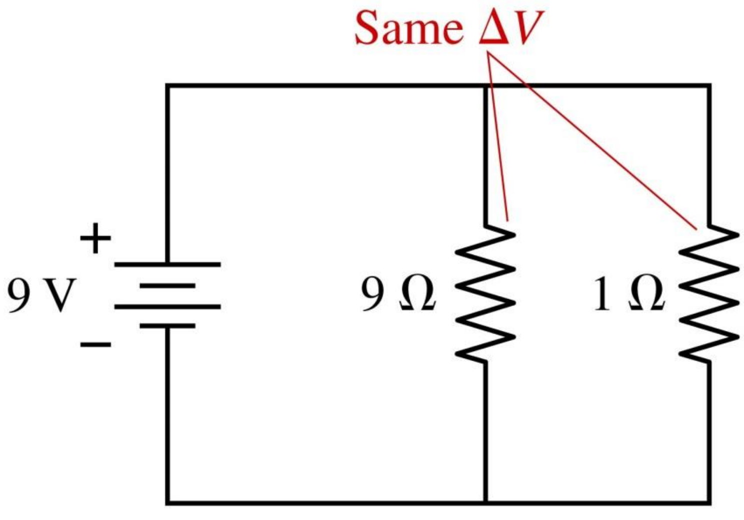
a) The 9 Ω resistor.

b) The 1 Ω resistor.

c) They dissipate the same power.

Power Dissipation

Q.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.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.

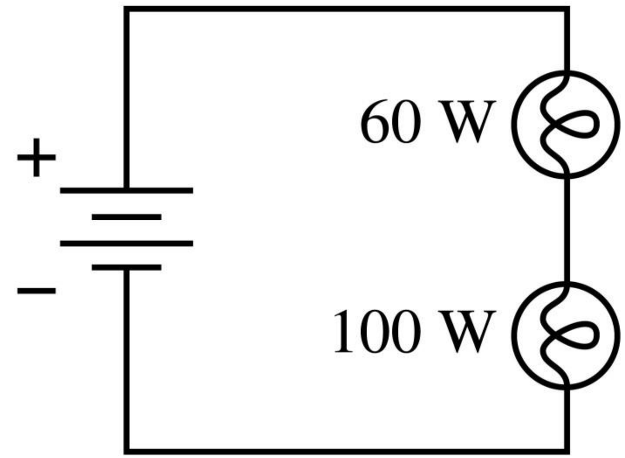
d) There's not enough information to tell.

$$P = \frac{(\Delta V)^2}{R} \text{ with both used at } \Delta V = 120 \text{ V}$$

Power Dissipation

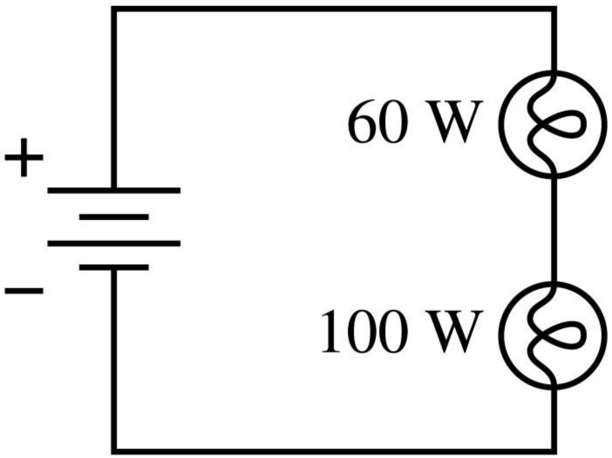
Q.53 Which bulb is brighter?

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



Power Dissipation

Q.53 Which bulb is brighter?



a) The 60 W bulb.

b) The 100 W bulb.

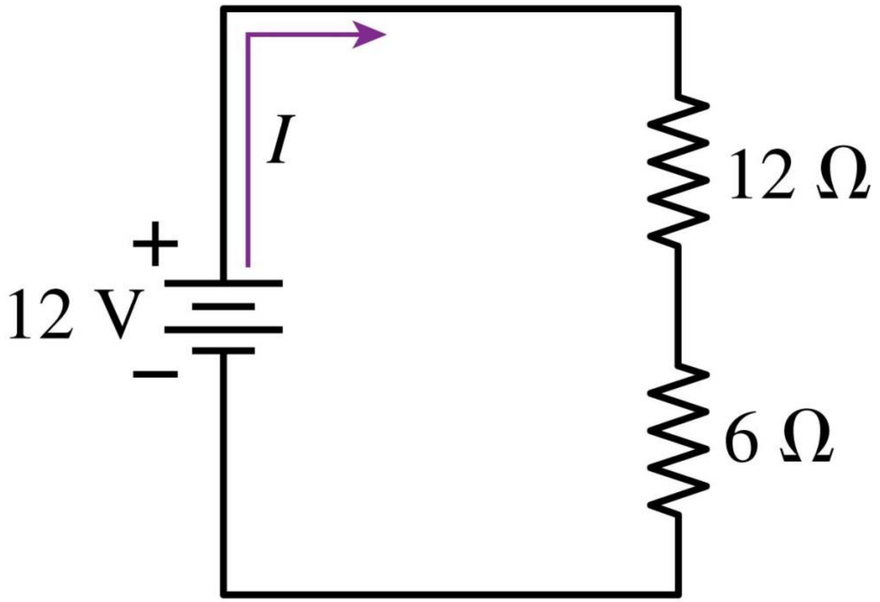
c) Their brightnesses are the same.

d) There's not enough information to tell.

$P = I^2R$ and both have the same current.

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.

Series Resistors

Q.54 The battery current *I* is

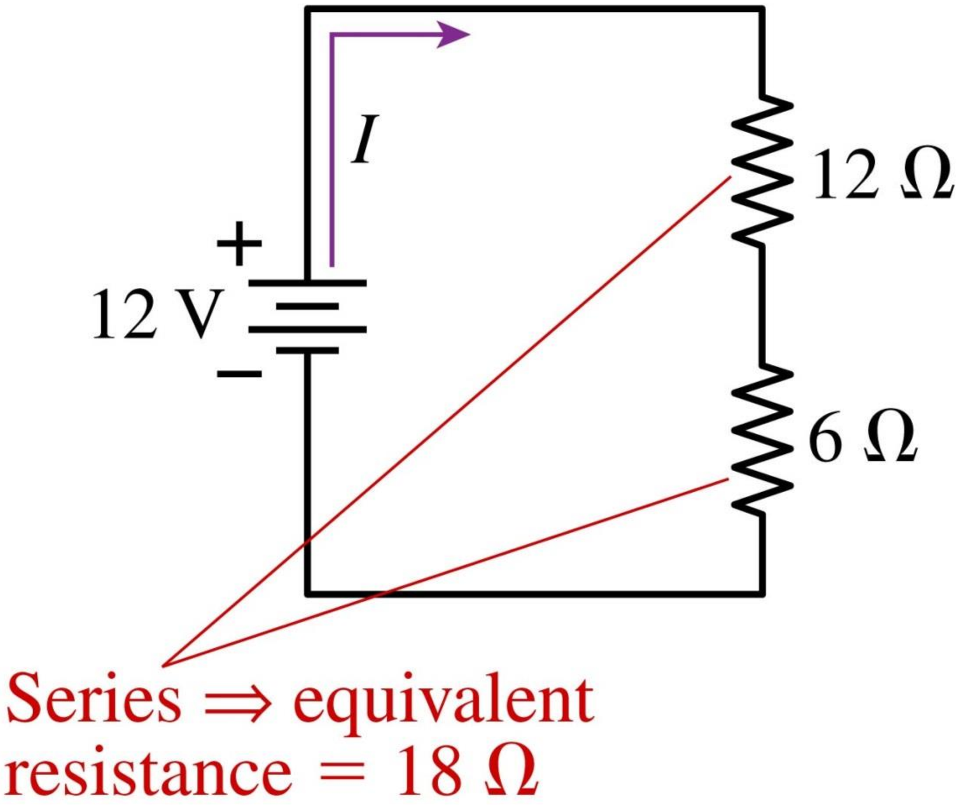
a) 3 A.

b) 2 A.

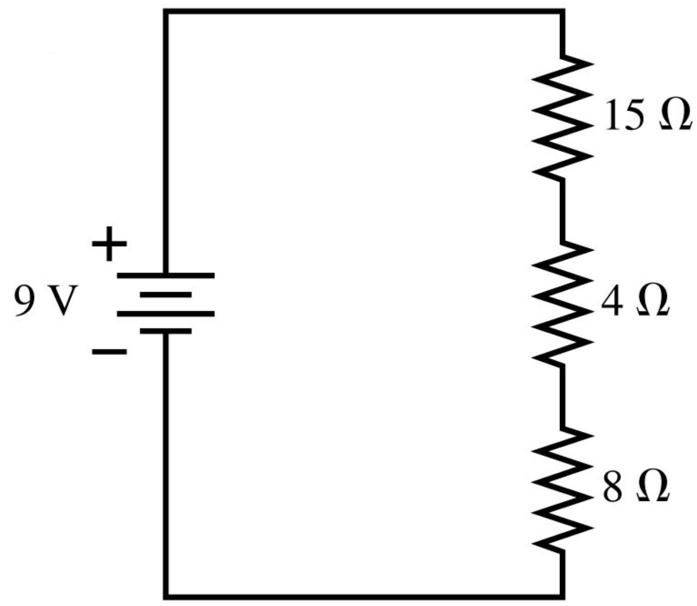
c) 1 A.

d) 2/3 A.

e) 1/2 A.



A Series Resistor Circuit

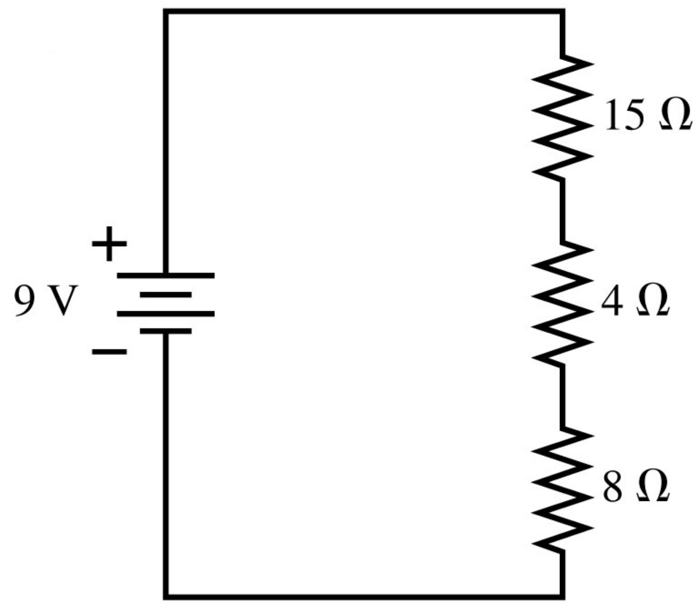


Q.55

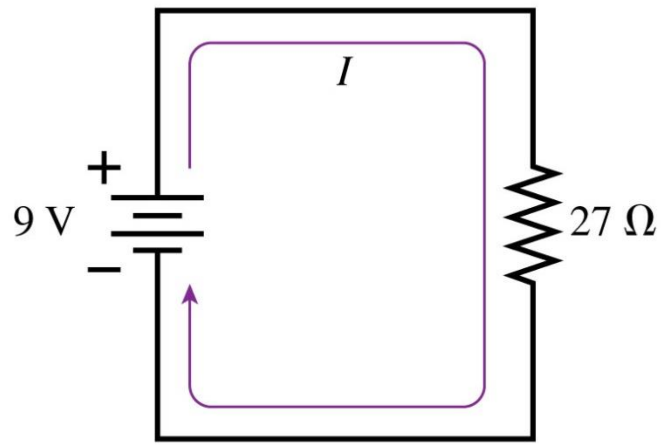
a. What is the current in the circuit below?

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

A Series Resistor Circuit



MODEL: The three resistors are end-to-end, with no junctions between them, and thus are in series. Assume ideal connecting wires and an ideal battery.

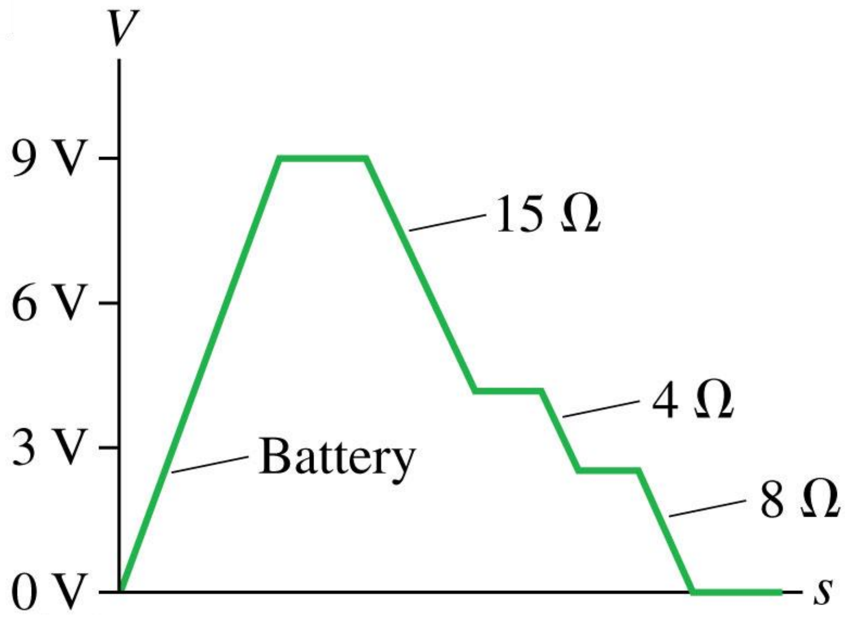


SOLVE: a. The battery "acts" the same – it provide the same current at the same potential difference – if we replace the three series resistors by their equivalent resistance

$$R_{\mathrm{eq}} = 15\ \Omega + 4\ \Omega + 8\ \Omega = 27\ \Omega$$

This is shown as an equivalent circuit below. Now we have a circuit with a single battery and a single resistor, for which we know the current to be

$$I = \frac{\varepsilon}{R_{\mathrm{eq}}} = \frac{9\ \mathrm{V}}{27\ \Omega} = 0.333\ \mathrm{A}$$



SOLVE b. I = 0.333 A is the current in each of the three resistors in the original circuit. Thus the potential differences across the resistors are $\Delta V_{\text{res 1}} = -IR_1 = -5.0\text{ V}$, $\Delta V_{\text{res 2}} = -IR_2 = -1.3\text{ V}$, and $\Delta V_{\text{res 3}} = -IR_3 = -2.7\text{ V}$ for the 15 Ω, the 4 Ω, and the 8 Ω resistors, respectively.

The figure above shows that the potential increases by 9 V due to the battery's emf, then decreases by 9 V in three steps.

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?

MODEL Assume ideal connecting wires, but not an ideal battery.

Lighting Up a Flashlight

SOLVE:

$$I = \frac{\varepsilon}{R + r} = \frac{3\ \text{V}}{6\ \Omega + 1\ \Omega} = 0.43\ \text{A}$$

This is 15% less than the 0.5 A an ideal battery would supply. The potential difference across the resistor is $\Delta V_\text{R} = IR = 2.6\ \text{V}$. Thus the power dissipation is

$$P_\text{R} = I\Delta V_\text{R} = 1.1\ \text{W}$$

The battery's terminal voltage is

$$\Delta V_\text{bat} = \frac{R}{R + r}\varepsilon = \frac{6\ \Omega}{6\ \Omega + 1\ \Omega} 3\ \text{V} = 2.6\ \text{V}$$

ASSESS: $1\ \Omega$ is a typical internal resistance for a flashlight battery. The internal resistance causes the battery's terminal voltage to be 0.4 V less than its emf in this circuit.

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?

SOLVE: The short-circuit current is

$$I_{\text{short}} = \frac{\varepsilon}{r} = \frac{12\ \text{V}}{0.020\ \Omega} = 600\ \text{A}$$

Power is generated by chemical reactions in the battery and dissipated by the load resistance. But with a short-circuit battery, the “shorted” battery has to dissipate power

$P = I^2 r = 7200$ W internally.

A Short-Circuited Battery

$P = I^2r = 7200$ W internally.

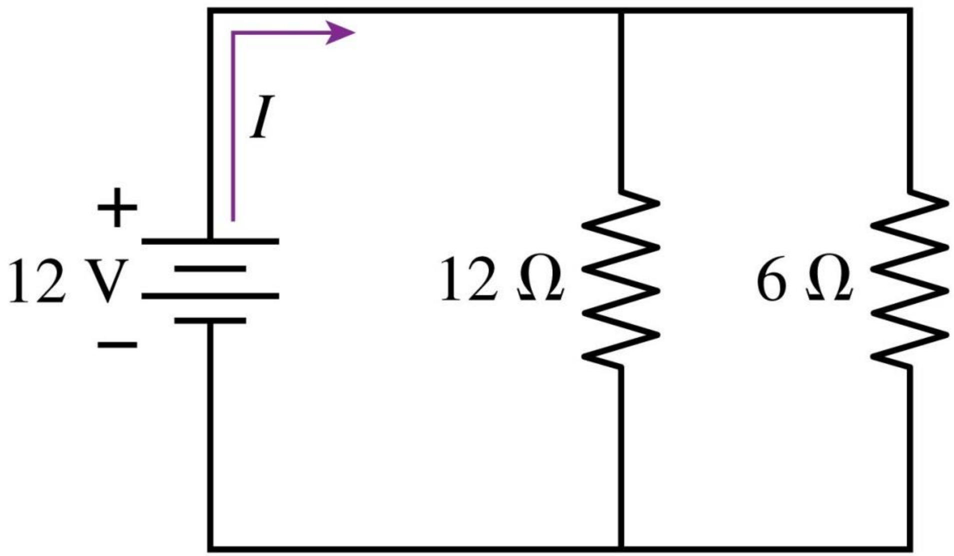
ASSESS: This value is realistic. Car batteries are designed to drive the starter motor, which has a very small resistance and can draw a current of a few hundred amps. That is why the battery cables are so thick. A shorted car battery can produce an **enormous** amount of current.

The normal response of a shorted car battery is to explode; it simply cannot dissipate this much power. Shorting a flashlight battery can make it rather hot, but your life is not in danger. Although the voltage of a car battery is relatively small, a car battery can be dangerous and should be treated with great respect.

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.



Parallel Resistors

Q.58 The battery current *I* is

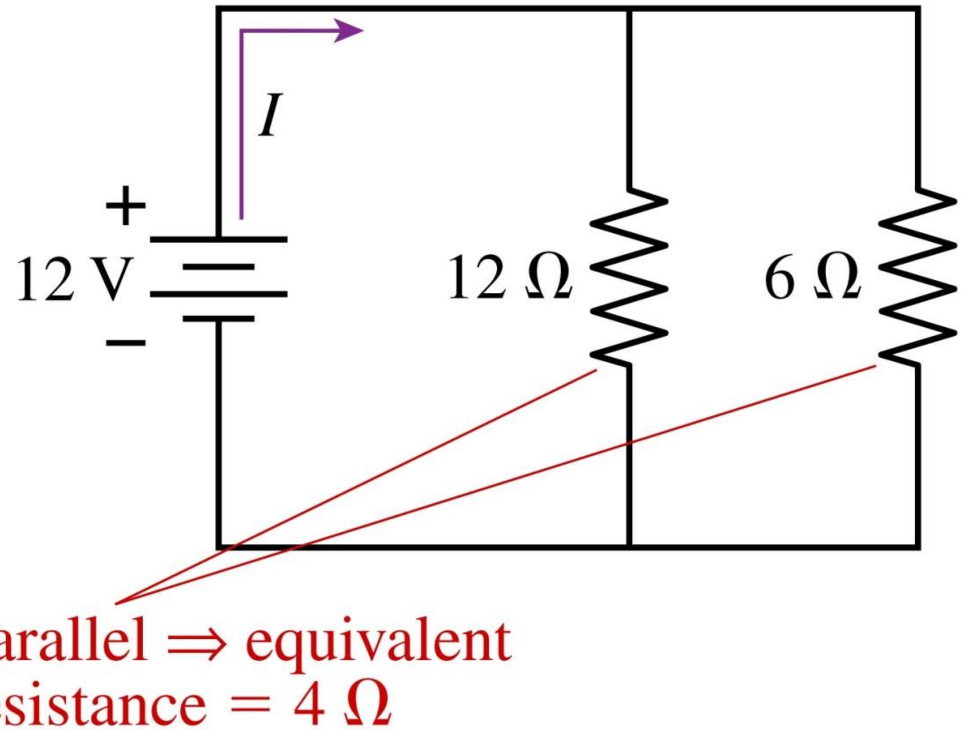
a) 3 A.

b) 2 A.

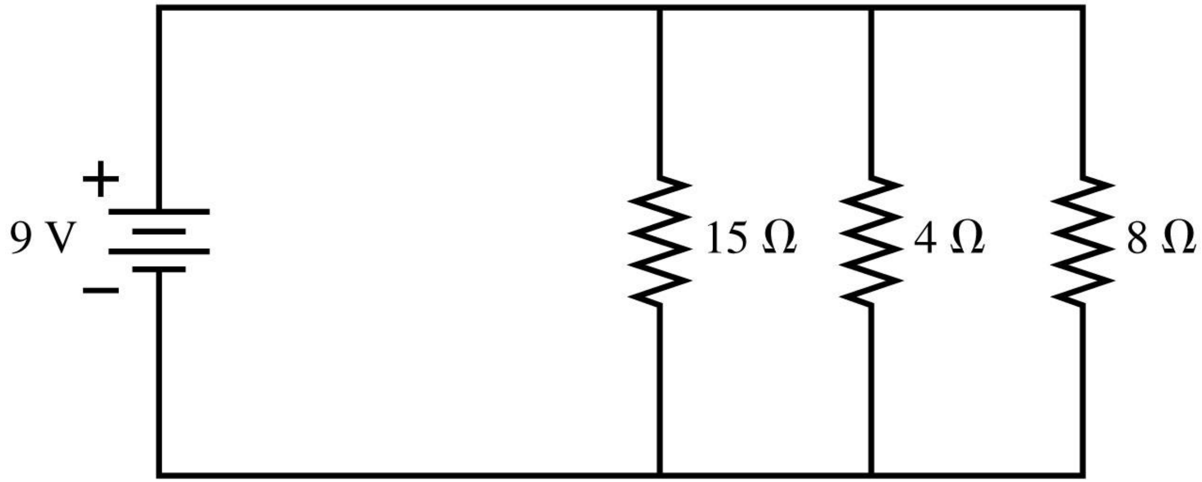
c) 1 A.

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.

MODEL: The resistors are in parallel. Assume an ideal battery and ideal connecting wires.

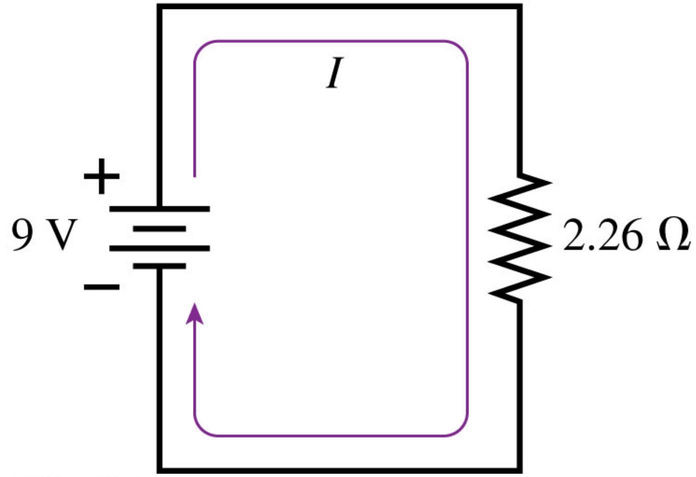
A Parallel Resistor Circuit

SOLVE: The three resistors can be replaced by a single equivalent resistor

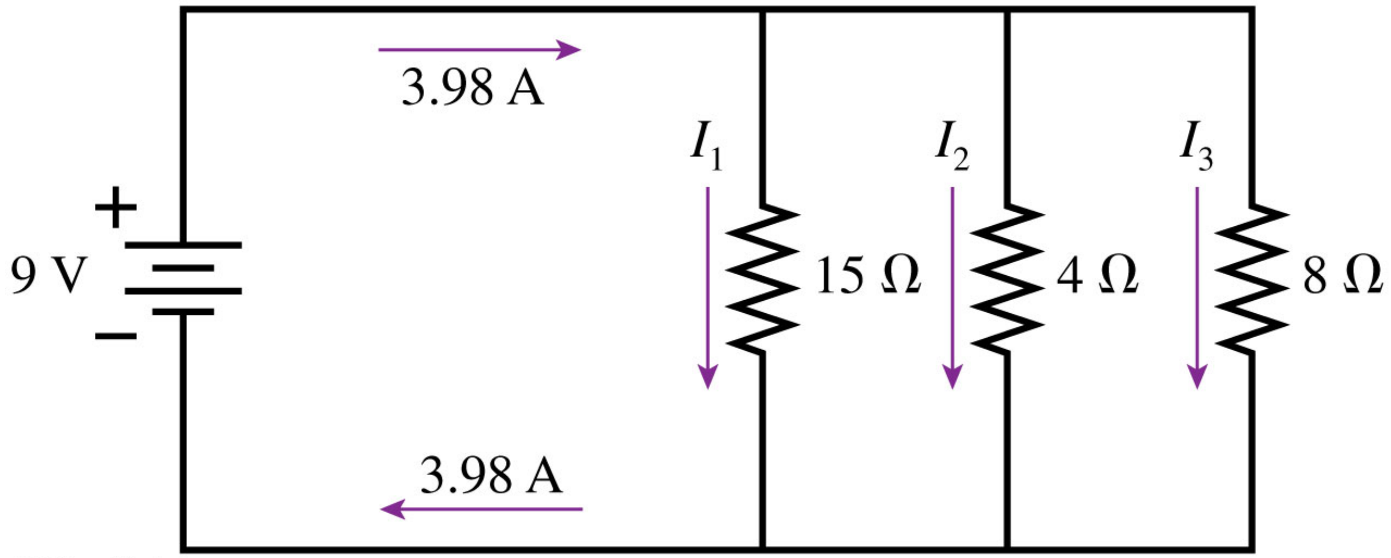
$$R_{\text{eq}} = \left(\frac{1}{15\,\Omega} + \frac{1}{4\,\Omega} + \frac{1}{8\,\Omega}\right)^{-1} = (0.4417\,\Omega^{-1})^{-1} = 2.26\,\Omega$$

The equivalent circuit is shown below, from which we find the current to be

$$I = \frac{\varepsilon}{R_{\text{eq}}} = \frac{9\text{ V}}{2.26\Omega} = 3.98\text{ A}$$



A Parallel Resistor Circuit



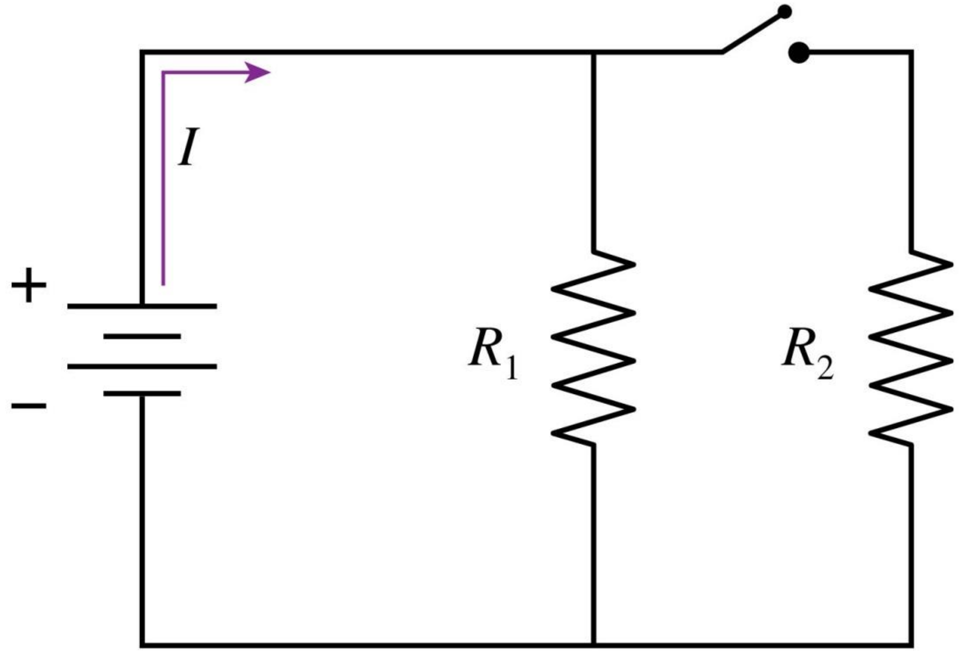
Thus. the currents, are

$$I_1 = \frac{9\text{ V}}{15\ \Omega} = 0.60\text{ A} \quad I_2 = \frac{9\text{ V}}{4\ \Omega} = 2.25\text{ A} \quad I_3 = \frac{9\text{ V}}{8\ \Omega} = 1.13\text{ A}$$

Assess: The sum of the three currents is 3.98 A, as required by Kirchhoff's junction law.

Parallel Resistors

Q.60 When the switch closes, the battery current



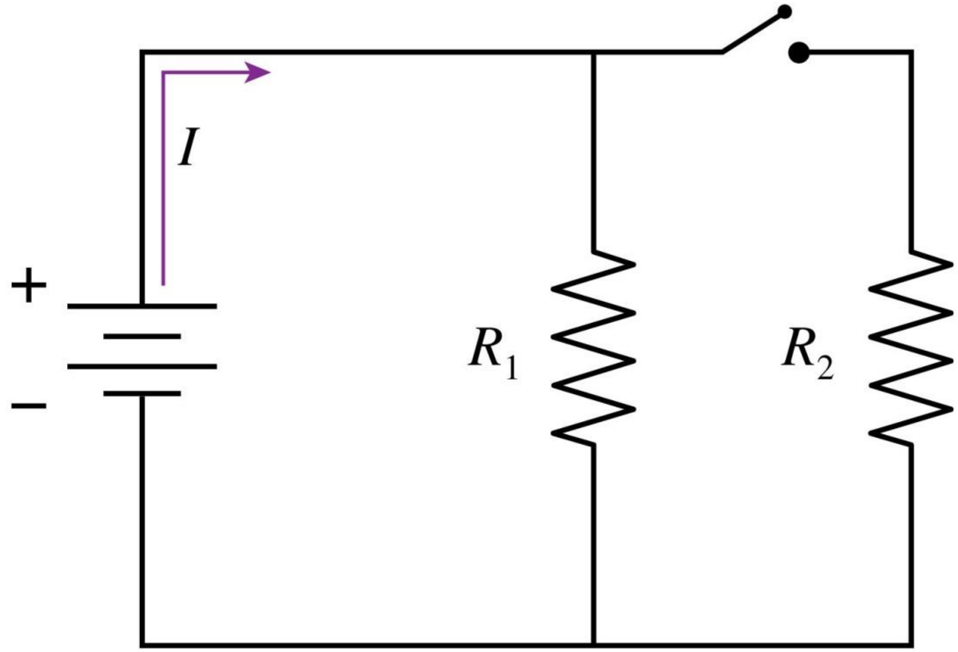
A. Increases.

B. Stays the same.

C. Decreases.

Parallel Resistors

Q.60 When the switch closes, the battery current



A. Increases.

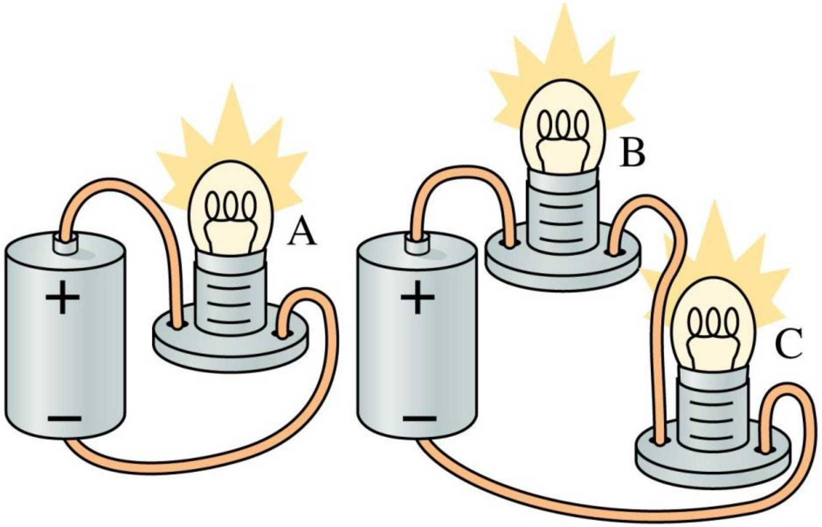
B. Stays the same.

C. Decreases.

Equivalent resistance decreases.
Potential difference is unchanged.

Lightbulb Brightness

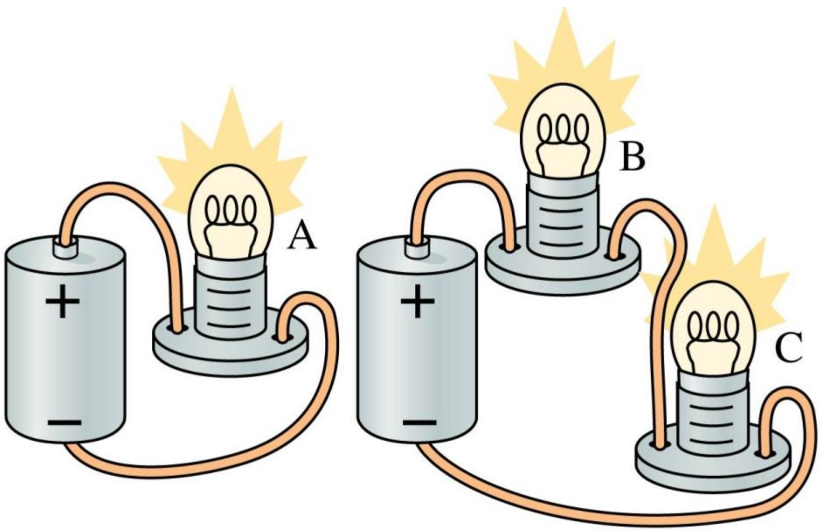
Q.61 The three bulbs are identical and the two batteries are identical. Compare the brightnesses of the bulbs.



a) $A > B > C$.
b) $A > C > B$.
c) $A > B = C$.
d) $A < B = C$.
e) $A = B = C$.

Lightbulb Brightness

Q.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) $A > B = C$.
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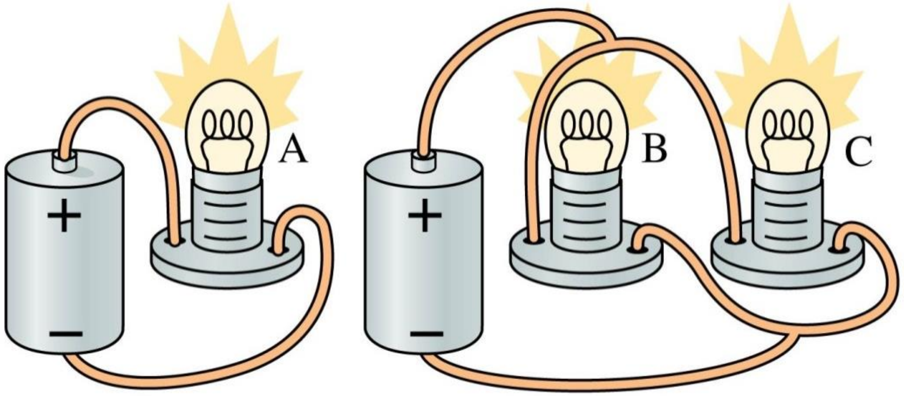
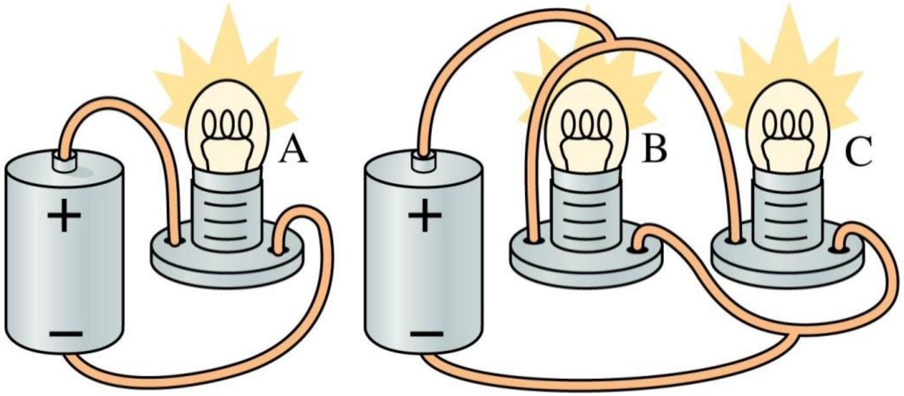


Lightbulb Brightness

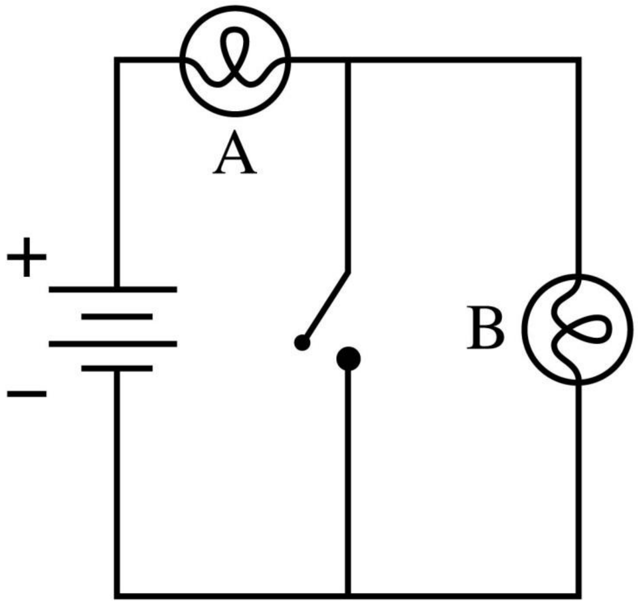
Q.62 The three bulbs are identical and the two batteries are identical. Compare the brightnesses of the bulbs.

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.

Lightbulb Brightness

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

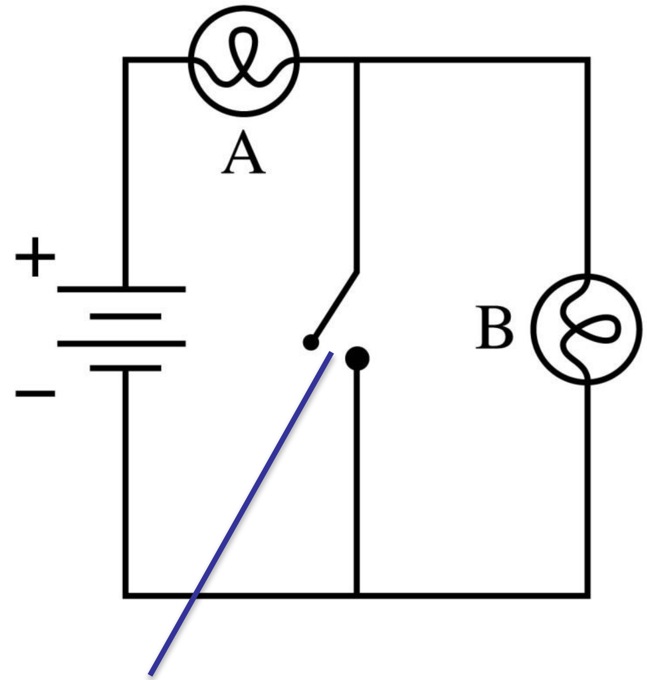
a) Nothing.

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.

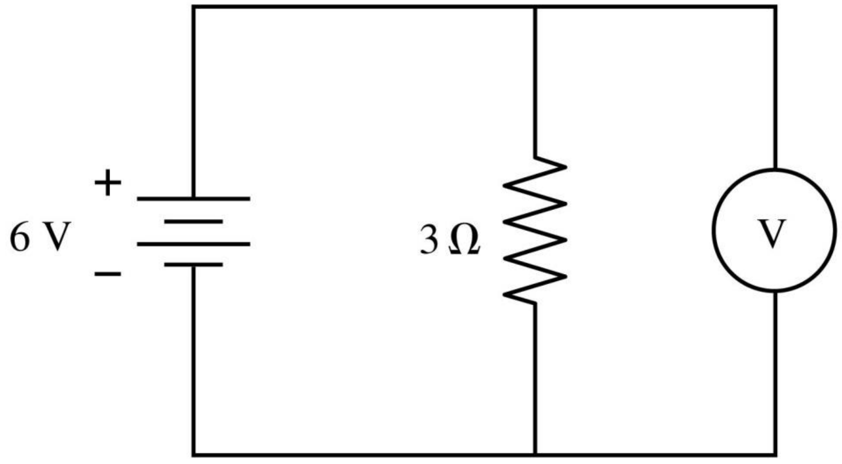


Short circuit.
Zero resistance path.

Voltmeters

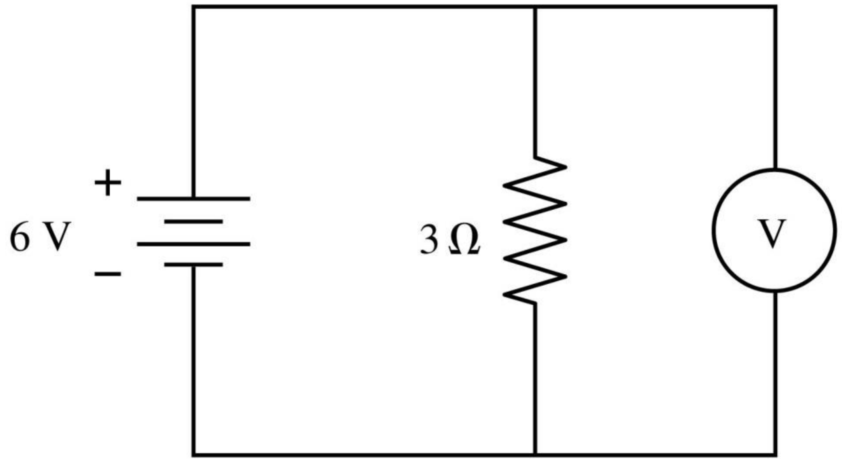
Q.64 What does the voltmeter read?

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



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?

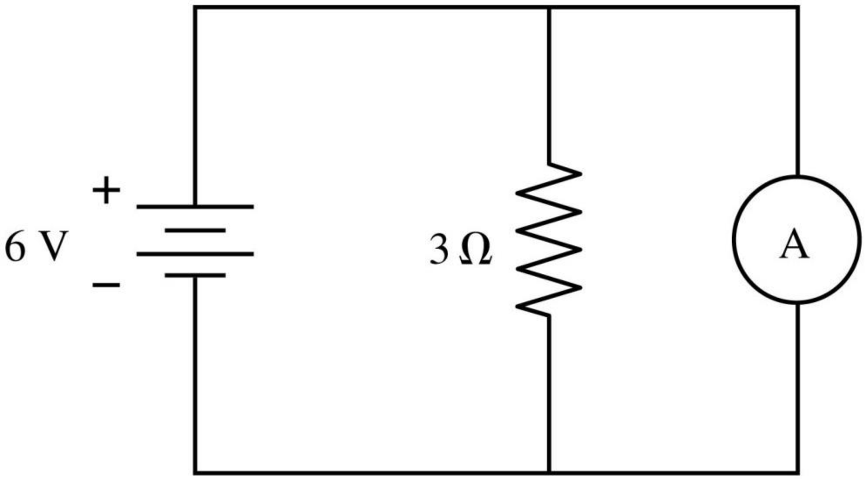
a) 6 A.

b) 3 A.

c) 2 A.

d) Some other value.

e) Nothing because this will fry the meter.



Ammeters

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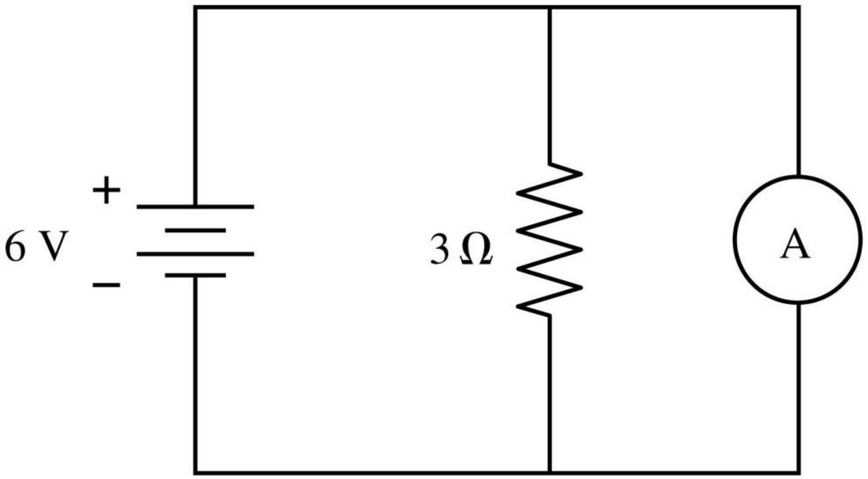


PROBLEM-SOLVING STRATEGY 31.1 **Resistor circuits**

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

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

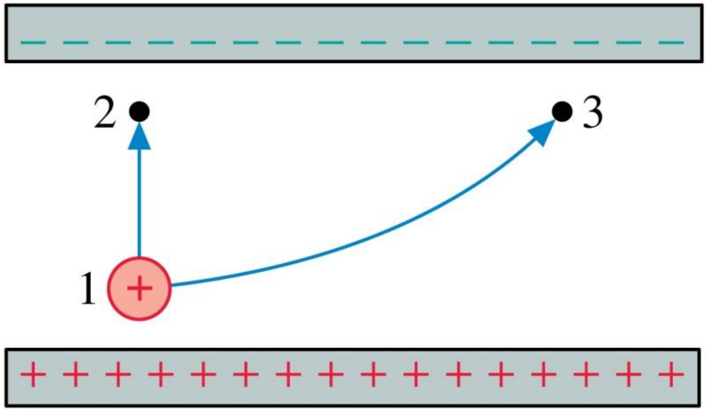
- Step by step, reduce the circuit to the smallest possible number of equivalent resistors.
- Write Kirchhoff's loop law for each independent loop in the circuit.
- Determine the current through and the potential difference across the equivalent resistors.
- Rebuild the circuit, using the facts that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

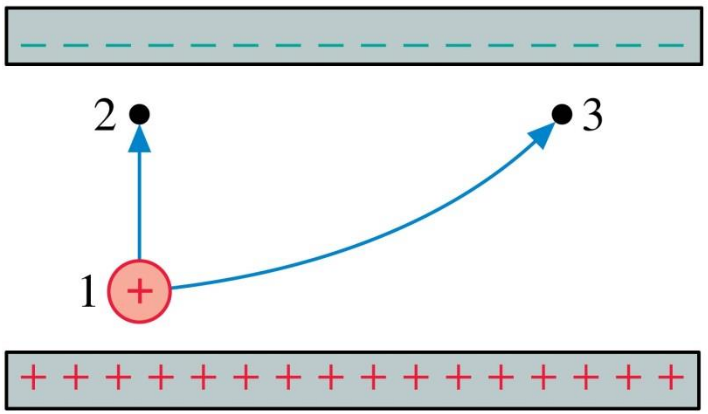
66. Two protons, one after the other, are launched from point 1 with the same speed. They follow the two trajectories shown. The protons' speeds at points 2 and 3 are related by



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

Parallel-Plate Capacitor

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) $\boldsymbol{v_2 = v_3}$. Energy conservation

c) $v_2 < v_3$.

d) Not enough information to compare their speeds.

Batteries

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.

Batteries

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.

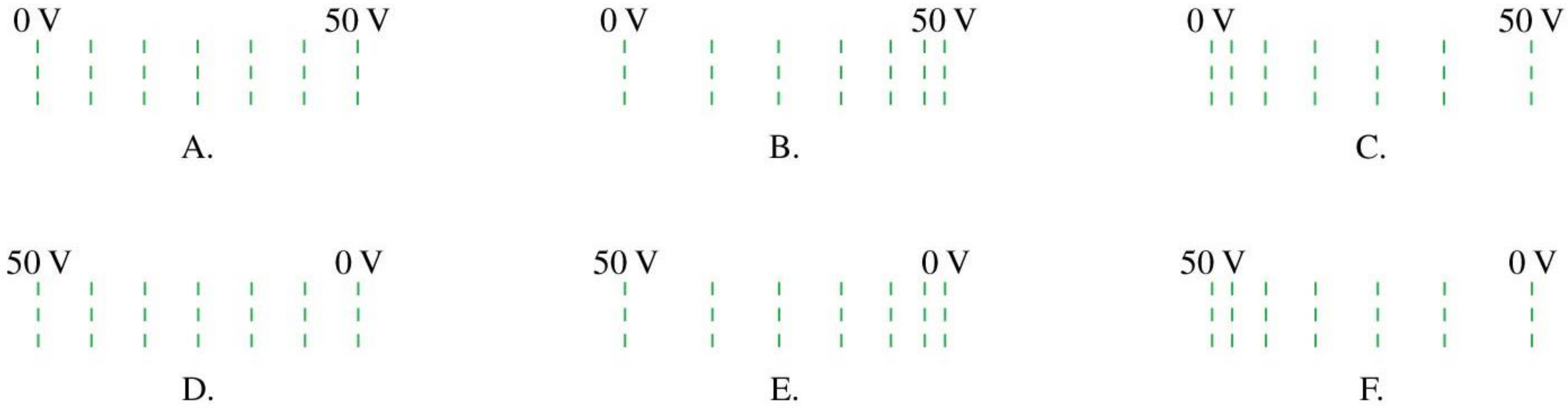
$$\mathcal{E} = \frac{W}{q} \text{ and } q = e = 1.6 \times 10^{-19} \text{ C for an ion.}$$

d) 4.8×10^{-19} V.

e) I have no idea.

Electric Potential

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



Electric Potential

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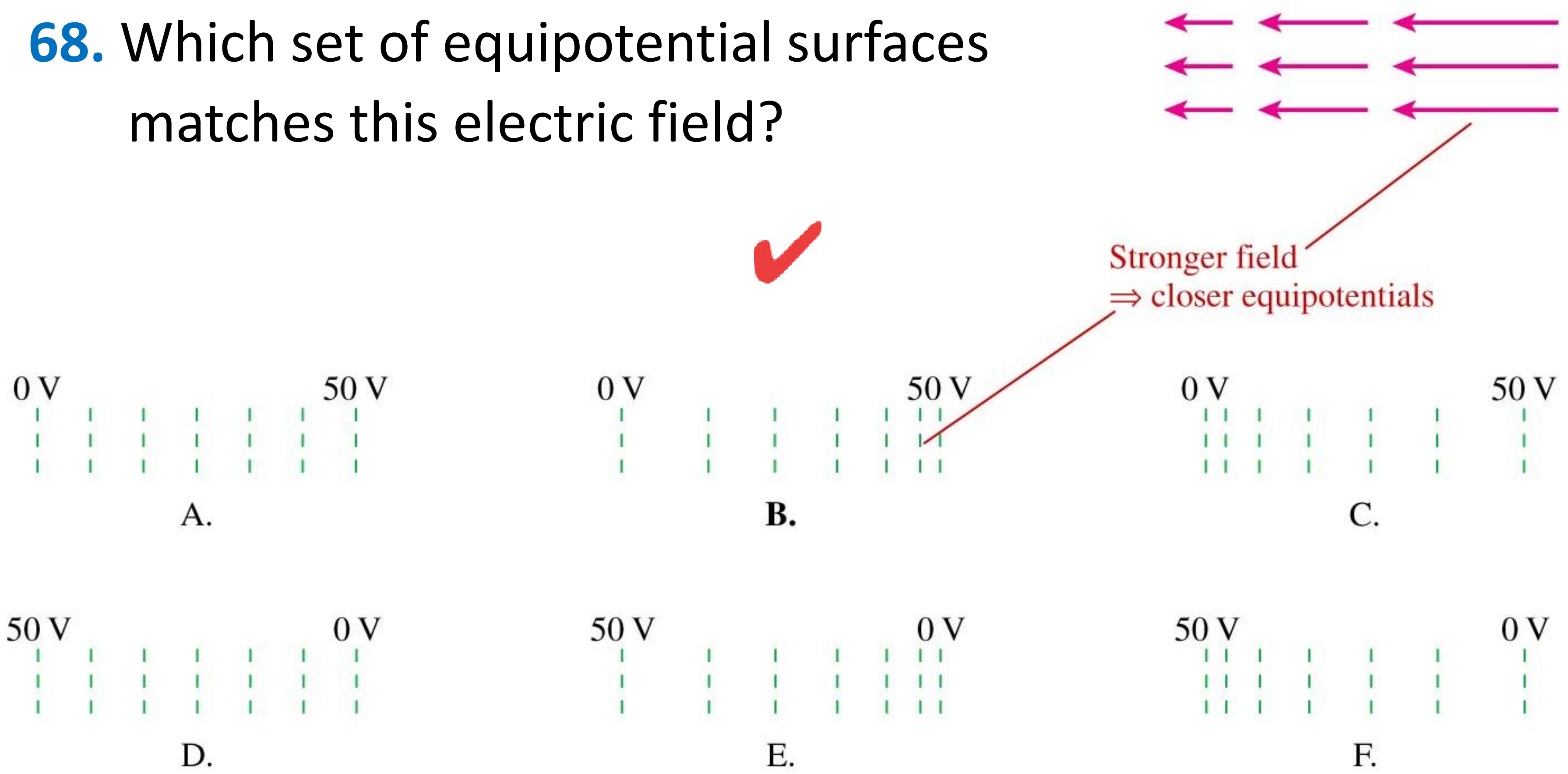
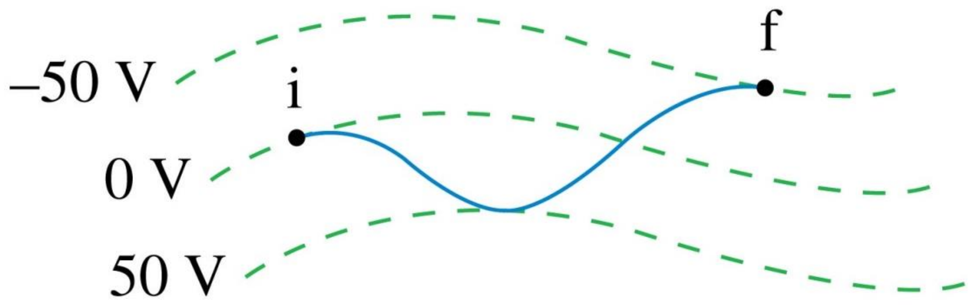


Kirchoff’s Loop Rule

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.

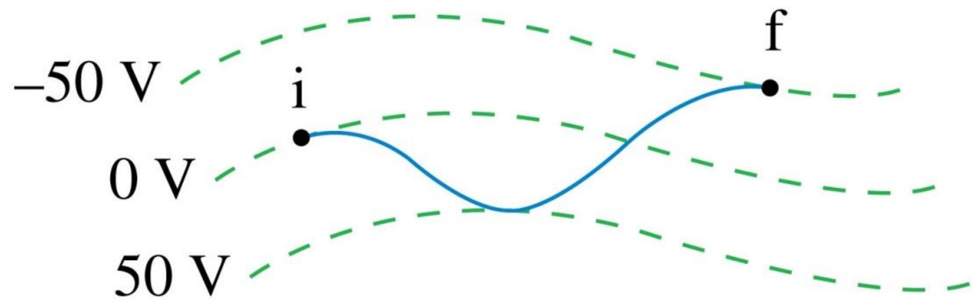
c) 0 V.

d) –50 V.

e) –100 V.

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.

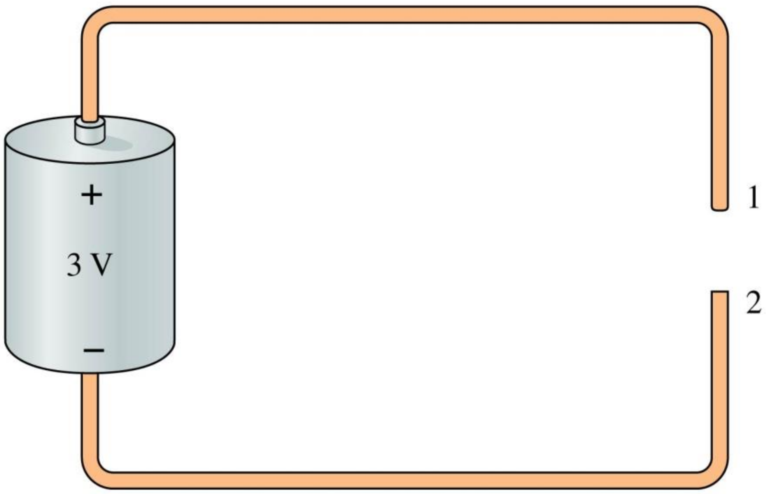
d) –50 V.

e) –100 V.

$\Delta V = V_{final} - V_{initial}$, independent of the path

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.

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.

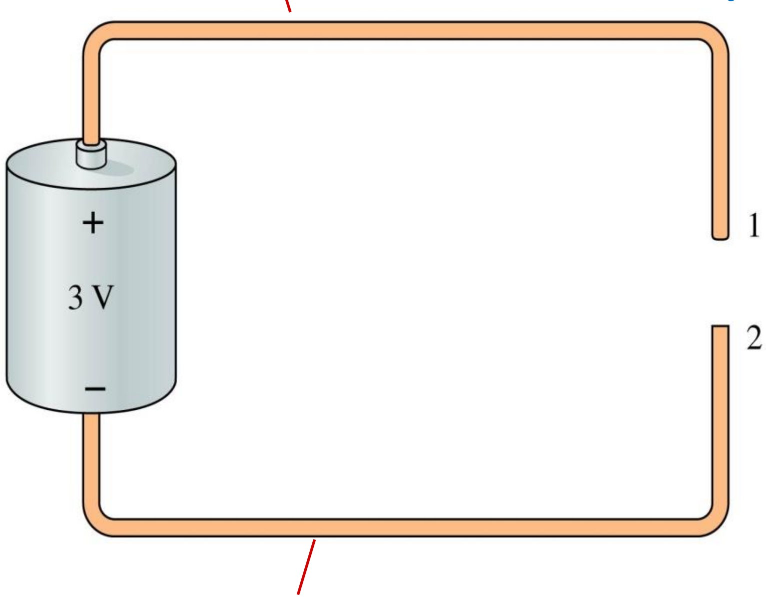
b) 3 V.

c) 0 V.

d) Undefined.

e) Not enough information to tell.

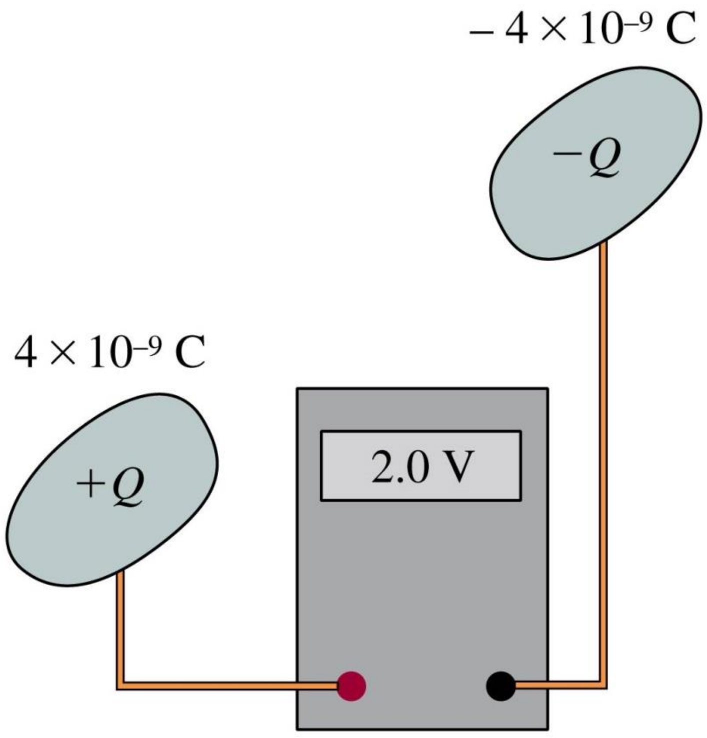
Every point on this conductor is at the same potential as the positive terminal of the battery.



Every point on this conductor is at the same potential as the negative terminal of the battery.

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.

Capacitance

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

a) 8 nF.

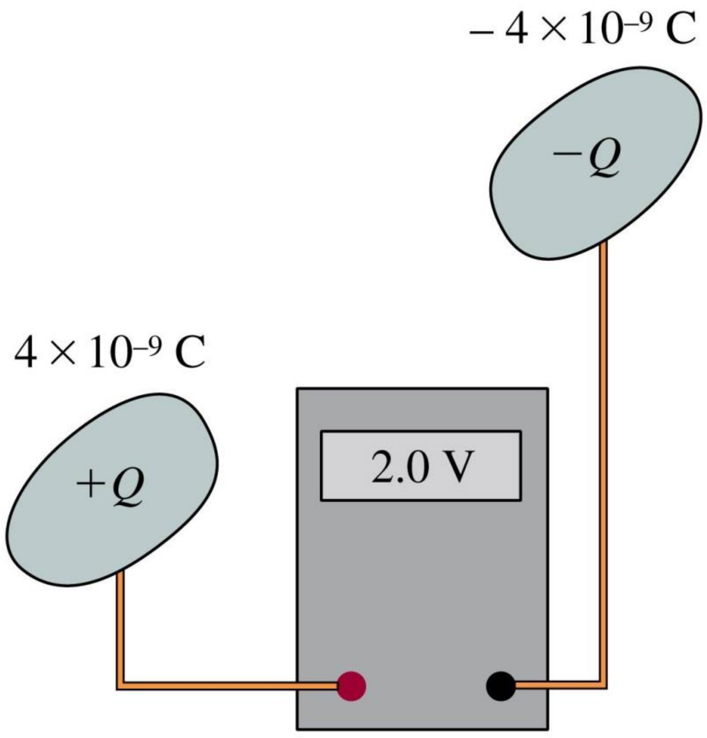
b) 4 nF.

c) 2 nF.

d) 1 nF.

e) Some other value.

$$C = \frac{Q}{\Delta V}$$



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?

MODEL: Assume the battery is ideal and the capacitor is a parallel-plate capacitor.

SOLVE a. From the definition of capacitance,

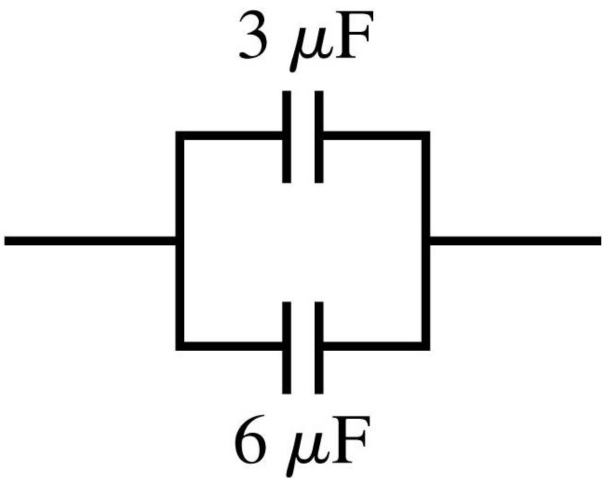
$$A = \frac{dC}{\epsilon_0} = 5.65\ \mathrm{m}^2$$

b. The charge is $Q = C\,\Delta V_C = 1.5\times10^{-6}$ C = 1.5 μC.

ASSESS: The surface area needed to construct a 1.0 μF capacitor (a fairly typical value) is enormous. We'll see how the area can be reduced by inserting an insulator between the capacitor plates.

Capacitance

Q.73 The equivalent capacitance is



a) 9 μF.

b) 6 μF.

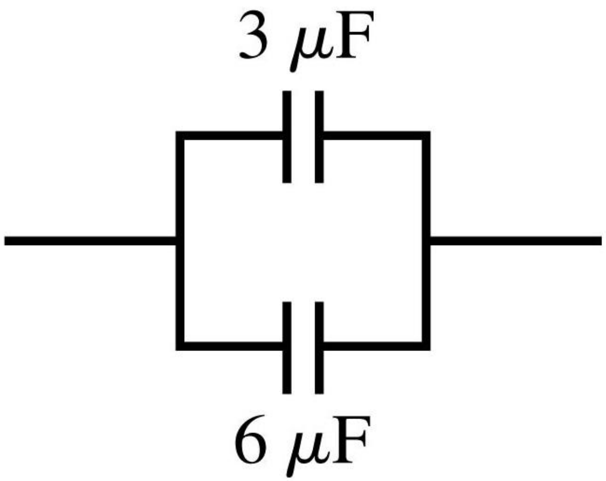
c) 3 μF.

d) 2 μF.

e) 1 μF.

Capacitance

Q.73 The equivalent capacitance is



a) 9 μF. Parallel => add

b) 6 μF.

c) 3 μF.

d) 2 μF.

e) 1 μF.

Capacitance

Q.74 The equivalent capacitance is

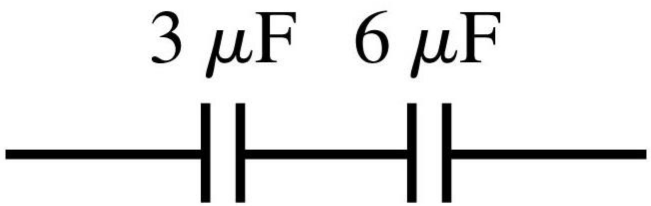
a) 9 μF.

b) 6 μF.

c) 3 μF.

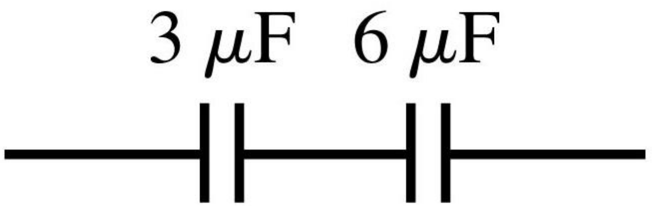
d) 2 μF.

e) 1 μF.



Capacitance

Q.74 The equivalent capacitance is



a) 9 μF.

b) 6 μF.

c) 3 μF.

d) 2 μF. Series => inverse of sum of inverses

e) 1 μF.