Electric Fields,Circuits

Electric Fields; Emf,Currents,Potential Difference and Multiloop Circuits

Lecture 21

Coulomb's Law

$$|F| = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$$

$$\frac{1}{4\pi\varepsilon_0} = 8.99\times10^9\ \mathrm{N\cdot m^2/C^2}$$

Direction is determined by opposites attract and like charges repel one another.

Recall the Coulomb Force Problem on Two Charges

What is the force on q_0 due to q if q= 2 C , q_o = 3 C and the distance between them is 3 meters?

How about if q_o = 3 C ?

How about if q_o = 1.5 C? ….. $\left|F_{\text{on } q_0 \text{ due to } q}\right| = \frac{1}{4\pi\varepsilon_0}\frac{|q||q_o|}{r^2}$

Calculating the force exerted by q on any given charge you might place at the location of q_o gets repetitive. The only thing that changes is the value of q_o.

The Electric Field

$$\vec{\mathbf{E}}_q = \frac{\vec{\mathbf{F}}_{qq_o}}{q_o}$$

- We define the electric field associated with a charge or charge distribution to be the electrostatic force exerted per unit of charge on which the force acts.
- If we know **E**, the force, **F**, on any charge, q_o, is then given by:

- We can calculate **E** once and then get **F** for any charge easily.

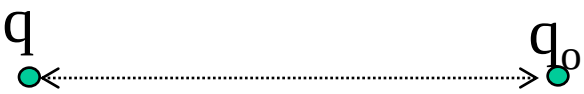
$$\vec{\mathbf{F}}_{qq_o} = q_o \vec{\mathbf{E}}_q$$

The Electric Field

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_0}$$

- From a point charge q, the force on q_0 is,

$$|F| = \frac{1}{4\pi\varepsilon_0}\frac{|q||q_0|}{r^2}$$



- Then, at q_0's location, the field associated with q is

$$|E| = \frac{|F|}{|q_0|} = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}$$

- Field is a vector. The direction is away from a positive q and toward a negative q. It is also always in the direction of **F** on a positive charge.

$$\vec{\mathbf{F}} = q_o\vec{\mathbf{E}}$$

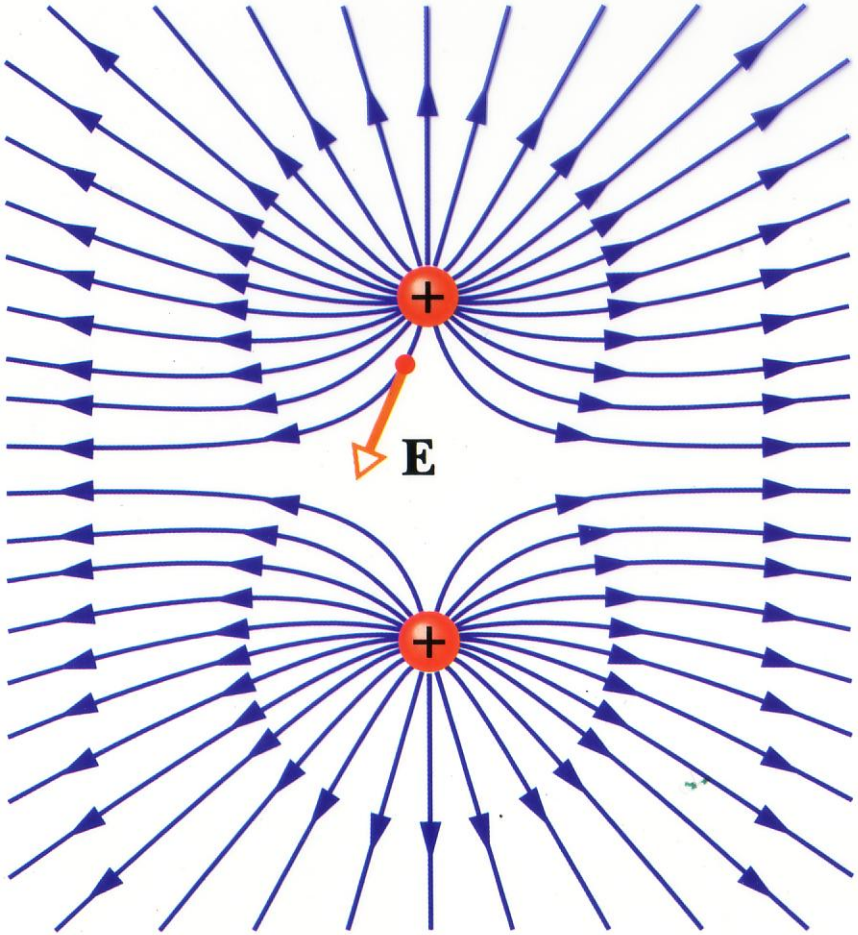


Figure 23-4

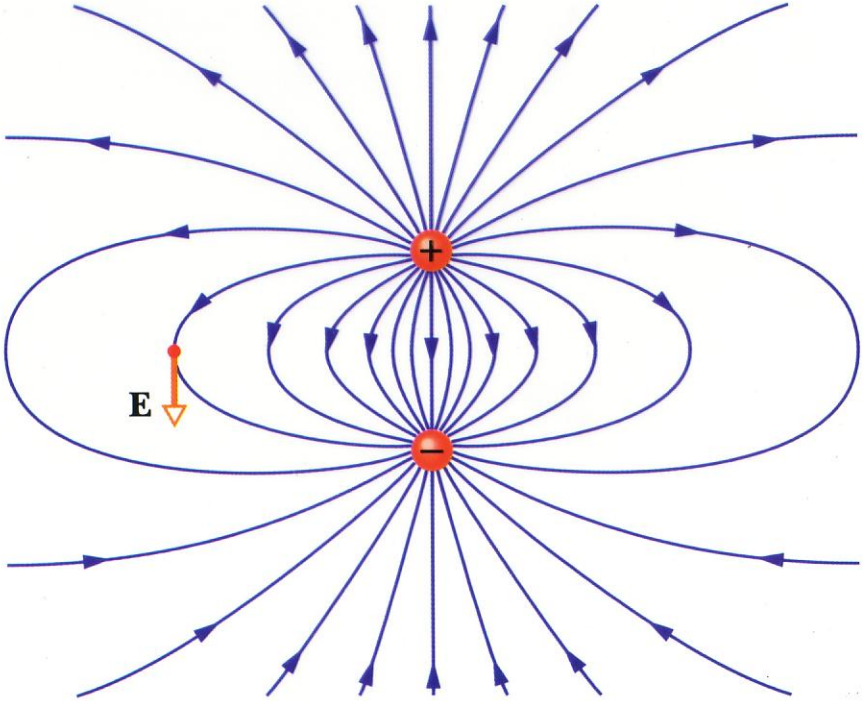
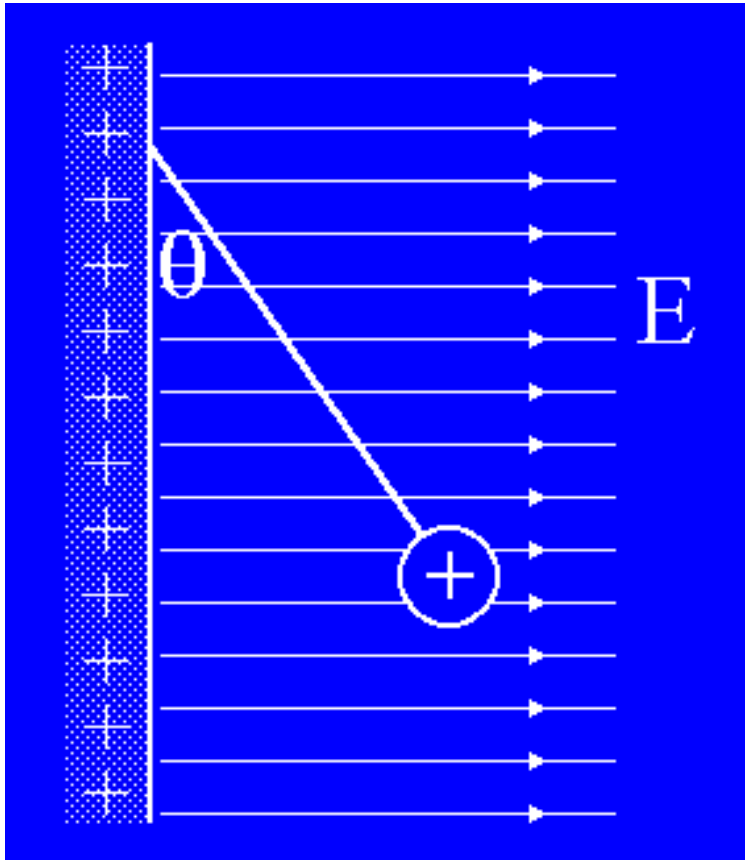
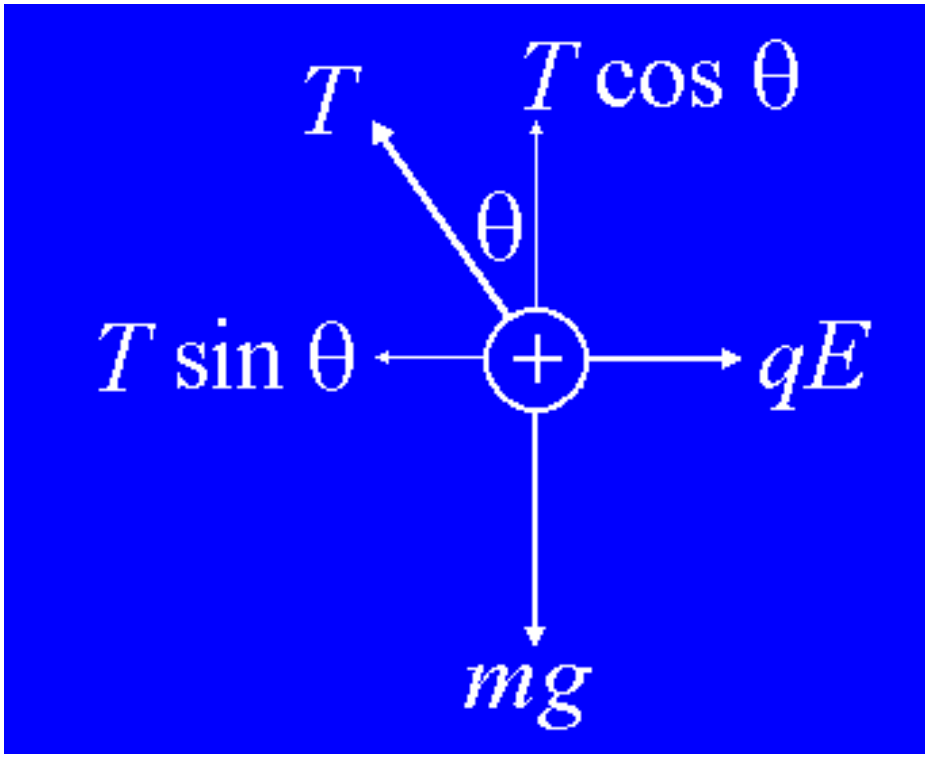


Figure 23-5

Example





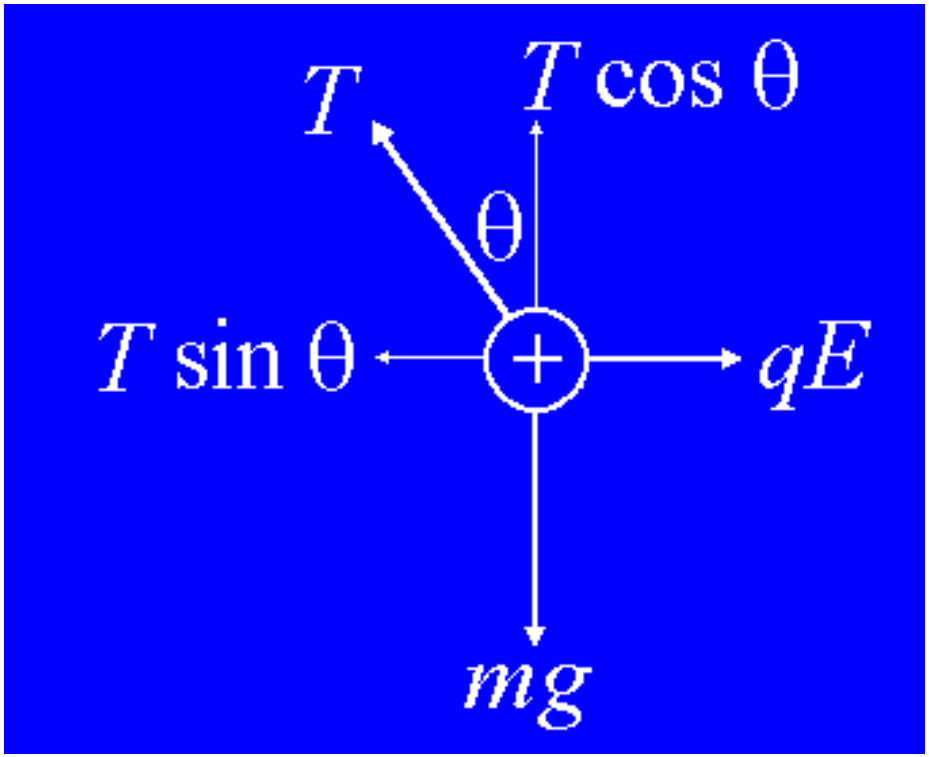
Example

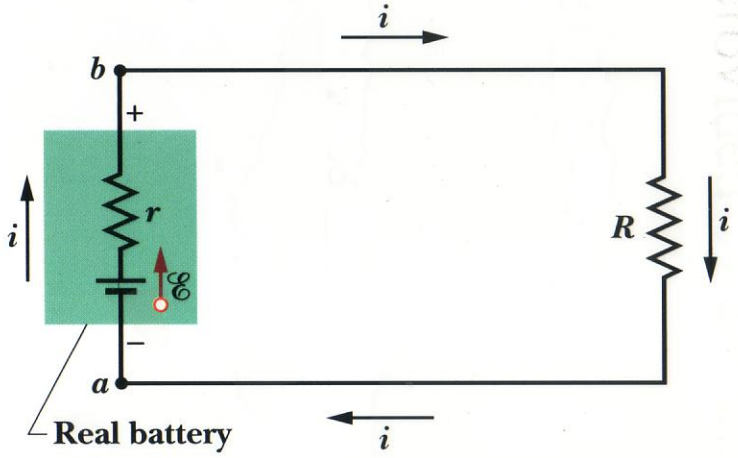
$$T\sin\theta = qE$$

$$T\cos\theta = mg$$

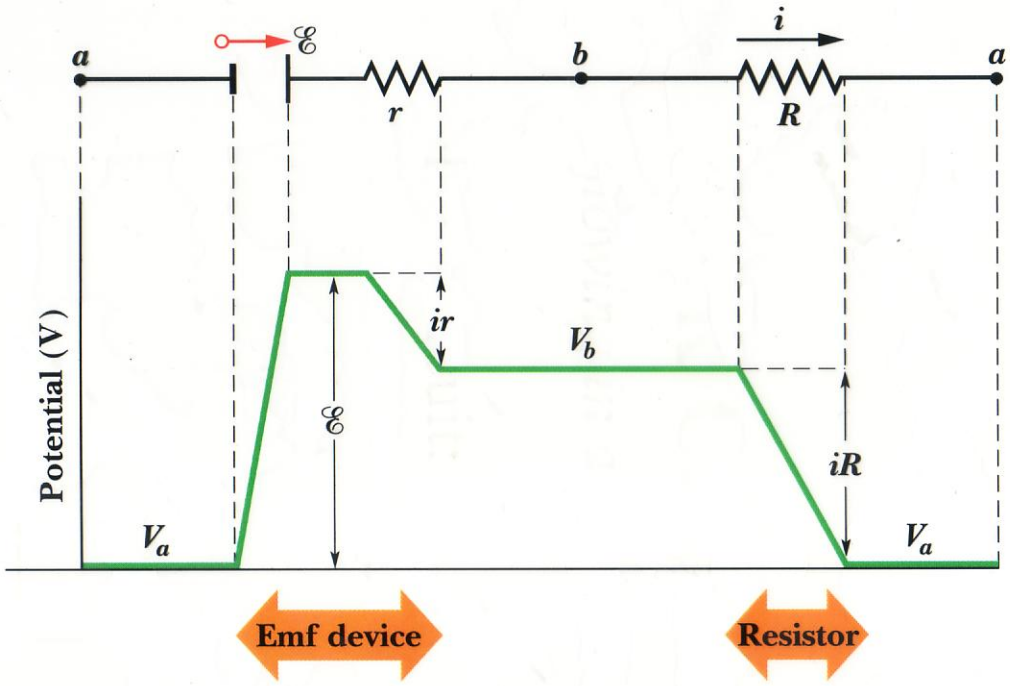
$$\frac{T\sin\theta}{T\cos\theta} = \frac{qE}{mg}$$

$$\tan\theta = \frac{qE}{mg}$$




i
b
+
r
i
ℰ
R
i
−
a
Real battery
i

(a)

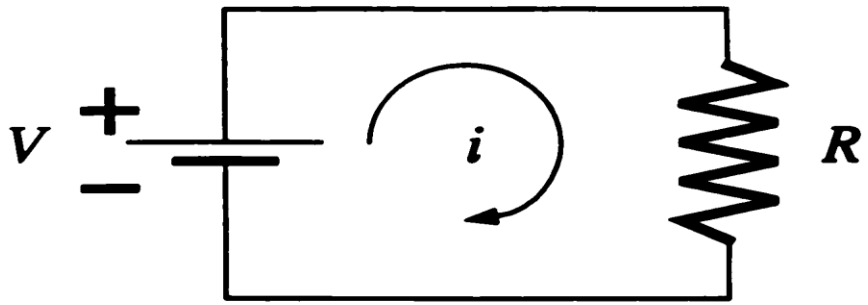

a
ℰ
r
b
i
R
a
Potential (V)
ir
V_b
ℰ
iR
V_a
V_a
Emf device
Resistor

(b)

Electric Circuits

"Current flowing in a loop or loops"

Simple, single loop circuit:

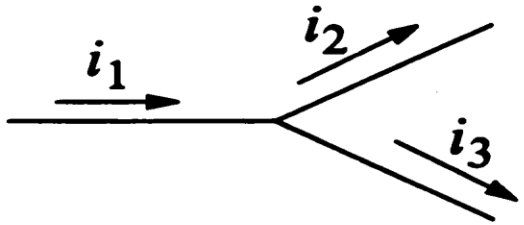


The voltage V is provided by an "emf device".

By Ohm's law, we have $V=iR$.

Some lingo:
"The *voltage drop* across the resistor is iR"

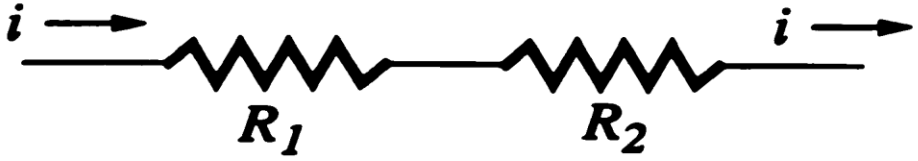
For multiloop circuits, remember:



$$i_1 = i_2 + i_3$$

Resistors in Series

If you have two resistors connected in series ...



... then the total voltage drop across them is ...

$$V = iR_1 + iR_2 = i(R_1 + R_2) = iR_{eq}$$

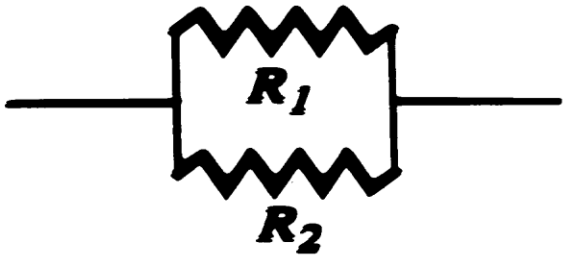
... where

$$R_{eq} = R_1 + R_2$$

"To find the equivalent resistance of
two resistors connected in series,
just add the two resistances."

Resistors in Parallel

If you have two resistors connected in parallel ...



... then the voltage drop across each of them is ...

$$V = i_1 R_1 = i_2 R_2$$

... and we can write ...

$$i = i_1 + i_2 = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{V}{R_{eq}}$$

where the equivalent resistance is given by

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

"To find the equivalent (reciprocal) resistance of two resistors connected in parallel, add the reciprocals of the two resistances."

Light Bulbs

Light bulbs are just glowing resistors.

They glow because they get very hot.

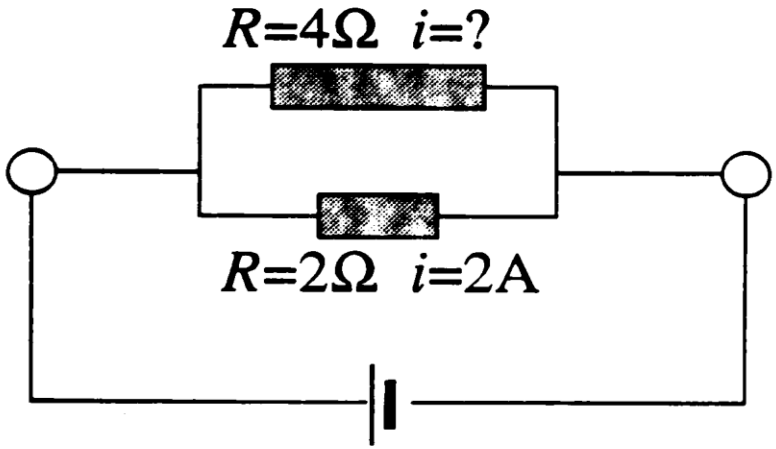
The heat energy is radiated away as light.

The brightness of the light is pretty much the same as the power that is radiated away, so

$$\text{Brightness} \approx P = \frac{V^2}{R} = i^2 R$$

Concept Test

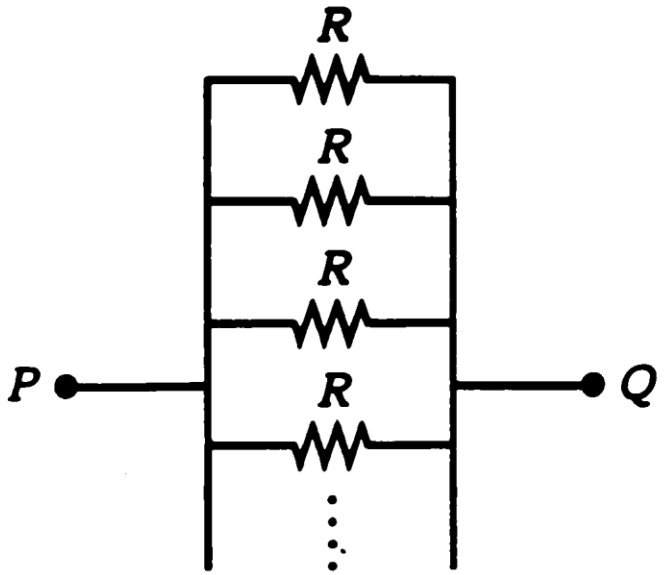
A constant potential V is applied across two resistors connected in parallel as shown.



The current through the 2Ω resistor is 2A. What is the current through the 4Ω resistor?

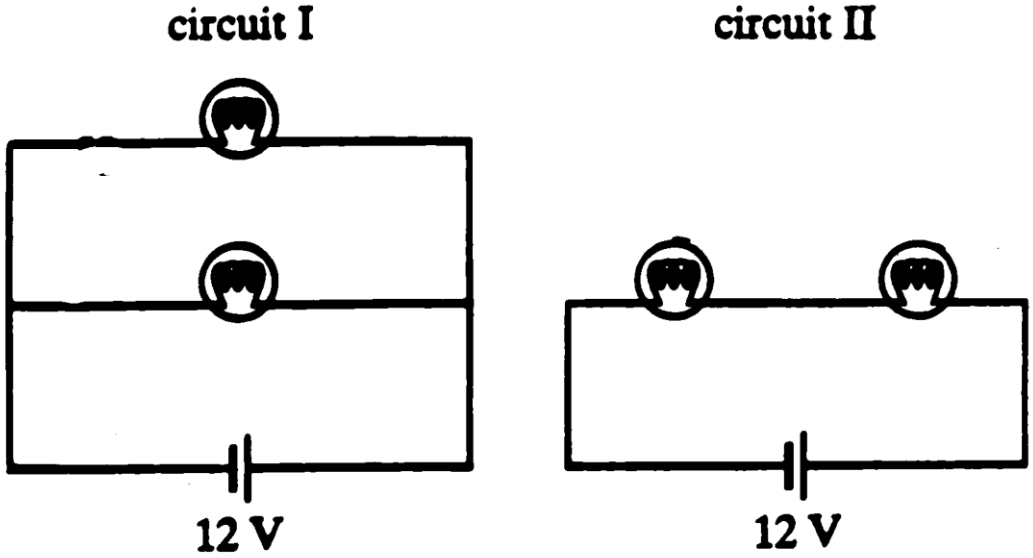
1. 0A
2. 1A
3. 2A
4. 4A
5. Need to know the voltage

As more identical resistors R are added to the parallel circuit shown here, the total resistance between points P and Q



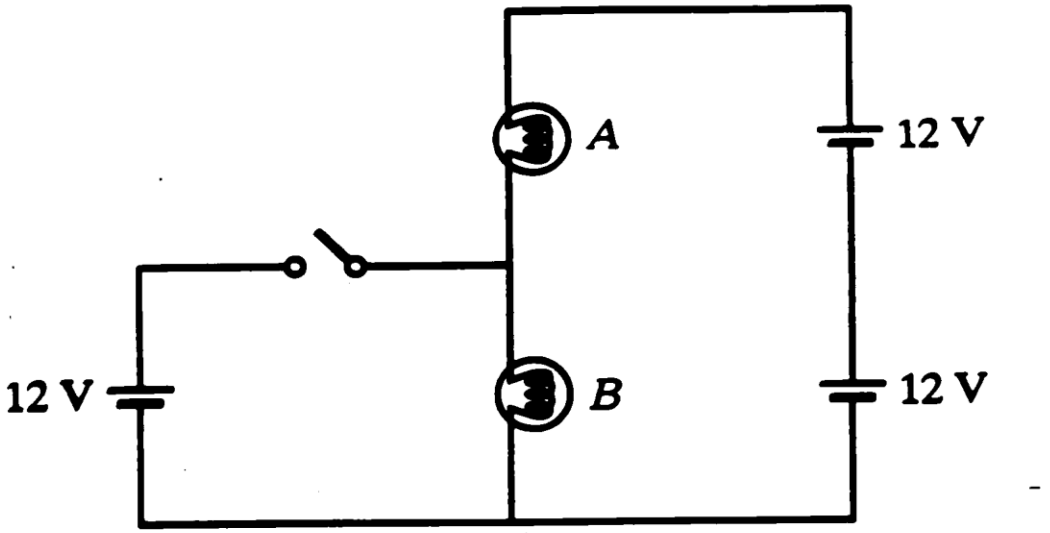
1. increases.
2. remains the same.
3. decreases.

If the four light bulbs in the figure are identical, which circuit puts out more light?



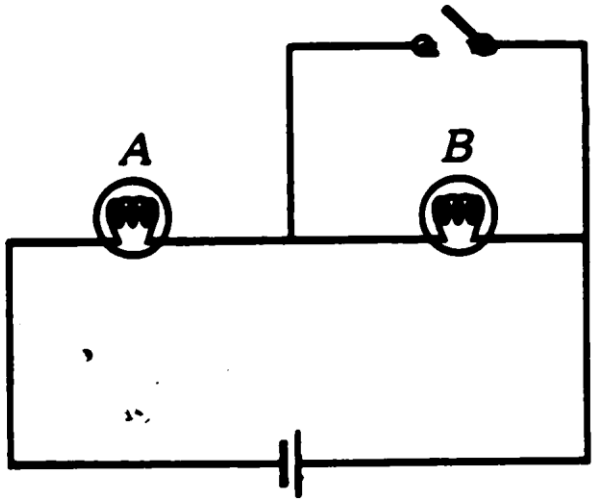
1. I.
2. The two emit the same amount of light.
3. II.

The light bulbs in the circuit are identical. When the switch is closed,



1. both go out.
2. the intensity of light bulb *A* increases.
3. the intensity of light bulb *A* decreases.
4. the intensity of light bulb *B* increases.
5. the intensity of light bulb *B* decreases.
6. some combination of 1–5 occurs.
7. nothing changes.

The circuit below consists of two identical light bulbs burning with equal brightness and a single 12 V battery. When the switch is closed, the brightness of bulb *A*



1. increases.
2. remains unchanged.
3. decreases.

Concept Test

A battery is connected to a 5Ω resistor which is immersed in water. The current through the resistor heats the water by 10°F in 10 minutes. If the 5Ω resistor is replaced by a 10Ω resistor, the water temperature increases by 10°F in

1. 2.5 minutes
2. 5 minutes
3. 10 minutes
4. 20 minutes
5. 40 minutes

Consider two identical resistors wired in series (one behind the other). If there is an electric current through the combination, the current in the second resistor is

1. equal to
2. half
3. smaller than, but not necessarily half

the current through the first resistor.