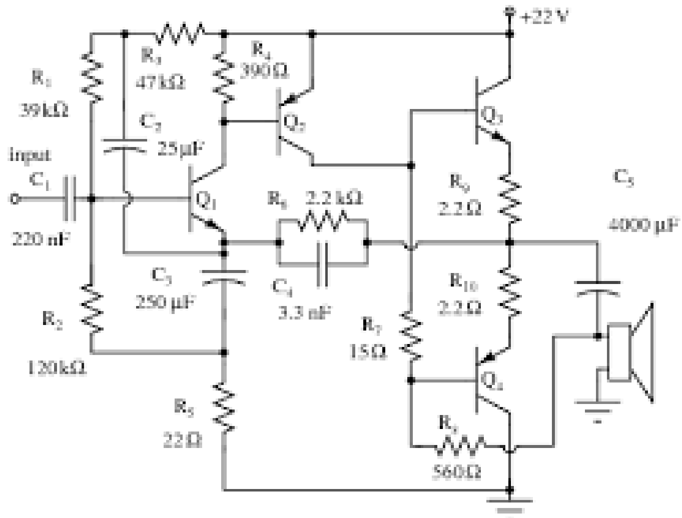
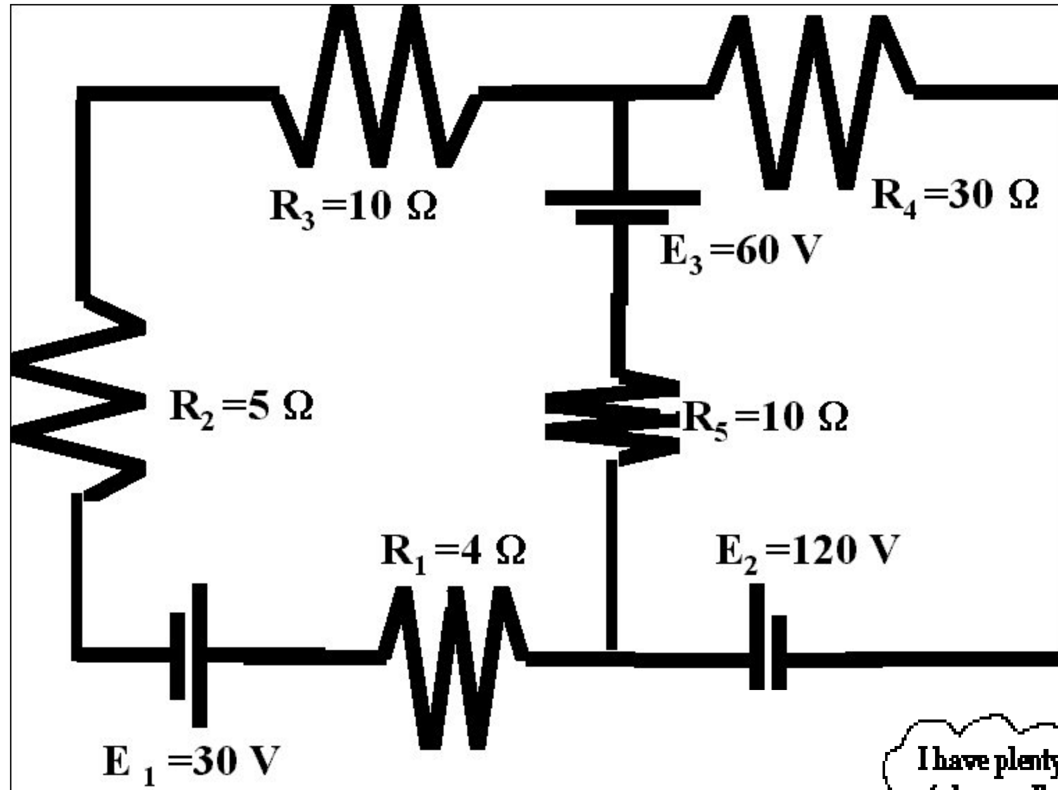
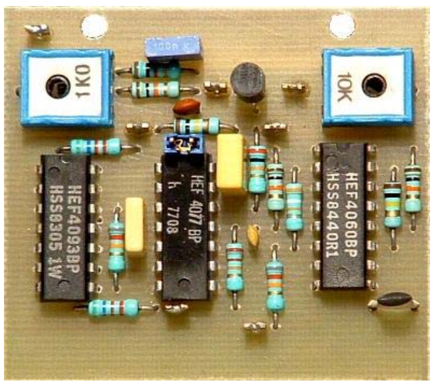


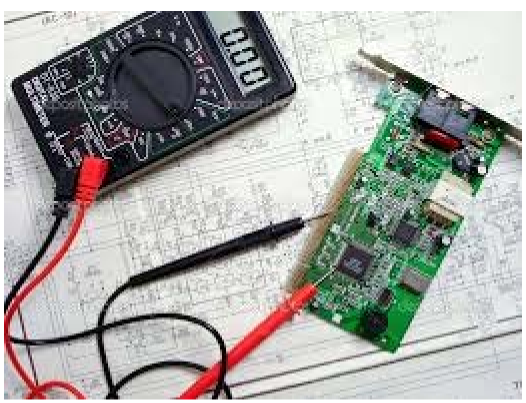
+22 V
R_1 39 kΩ
R_3 47 kΩ
R_4 390 Ω
C_2 25 µF
input
C_1 220 nF
Q_1
Q_2
Q_3
Q_4
R_6 2.2 kΩ
C_4 3.3 nF
C_3 250 µF
R_2 120 kΩ
R_5 22 Ω
R_7 15 Ω
R_9 2.2 Ω
R_{10} 2.2 Ω
R_8 560 Ω
C_5 4000 µF

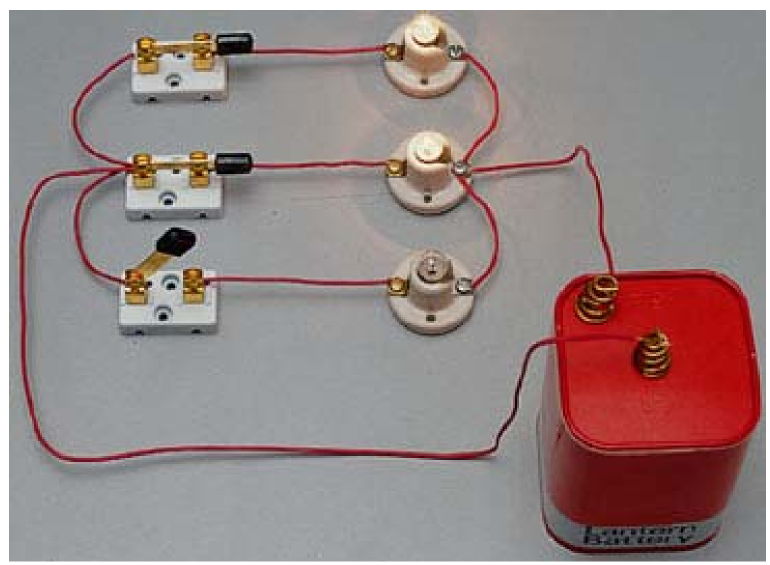


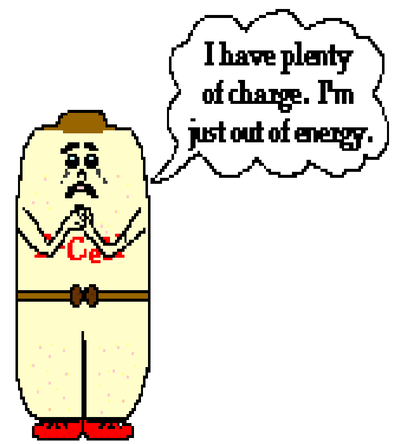
$R_3 = 10\ \Omega$
$R_4 = 30\ \Omega$
$E_3 = 60$ V
$R_2 = 5\ \Omega$
$R_5 = 10\ \Omega$
$R_1 = 4\ \Omega$
$E_2 = 120$ V
$E_1 = 30$ V



1K0
10K

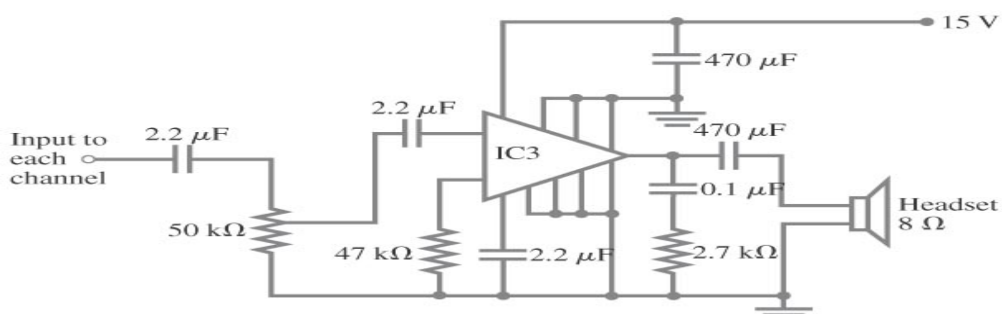






I have plenty of charge. I'm just out of energy.

Chapter 26
DC Circuits



What is an EMF $\mathcal{E}$

There are devices that “push” charges around. We say these are sources of the Electromotive force, **EMF** $\mathcal{E}$ which is not a Vector force. The name is historical.

Example: a battery is an EMF that moves charges around by Chemical reaction.

EMF is not a potential difference but is measured in volts.

Since it represents the energy behind the charges it is Moving. (its unit is Volt=Joule/Coulomb).

In general: chemical, mechanical, or E&M energy devices that transform to electrical energy have an EMF, a measure of that transformation and the energy being given to the charges it moves around.

E&M devices means Electromagnetic and refers here to devices that Use light, radiations and magnetism to move charges around.

26-1 EMF and Terminal Voltage

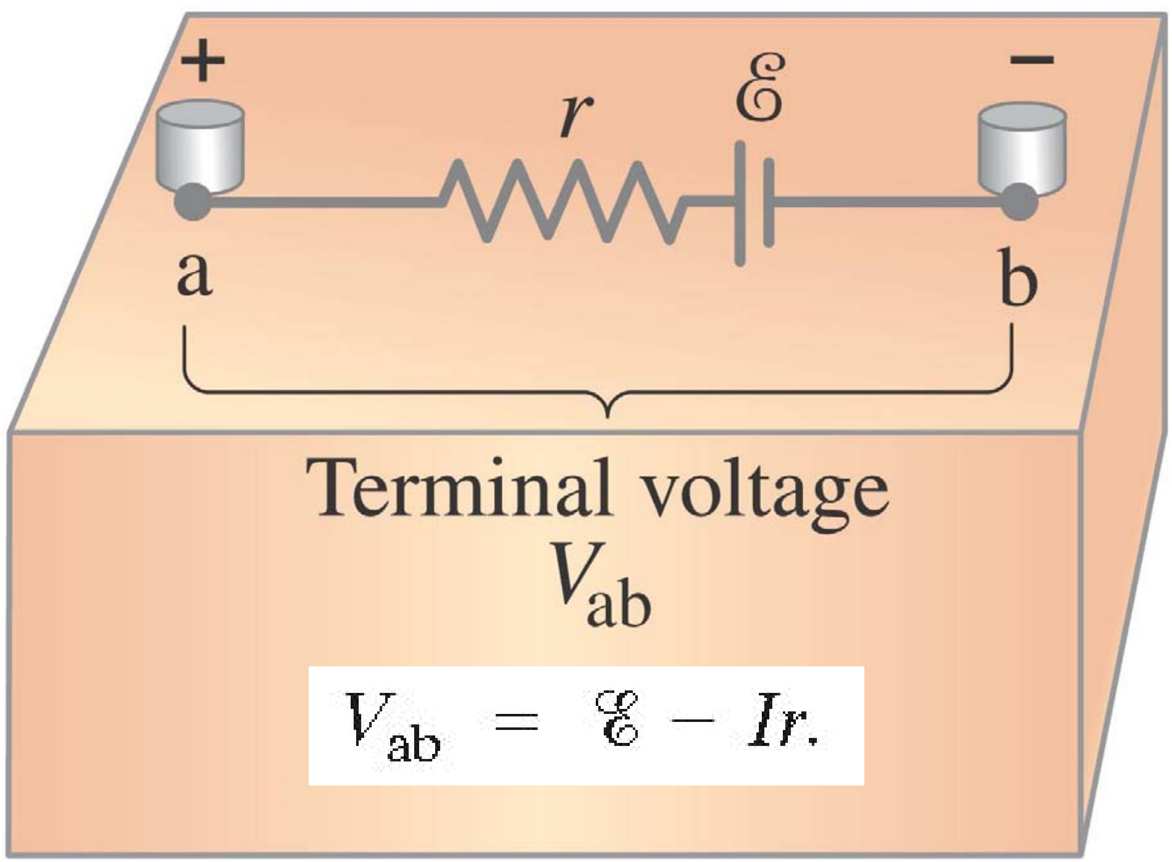
Electric circuit needs battery or generator to produce current – these are sources of EMF.

Battery is a nearly constant voltage source(not constant current which depends on external resistance), but does have a small internal resistance, which reduces the actual voltage from the ideal IDEAL EMF:$\mathcal{E}$

So the actual battery voltage is the Terminal voltage V_{ab} which represents the energy behind the charge available, the EMF (created by chemical reaction) minus the loss due to internal resistance. Ie. $V_{ab} = \mathcal{E} - Ir.$

26-1 EMF and Terminal Voltage

The internal resistance behaves as though it were in series with the emf. The drop in energy Ir depends on I which depends on the outside circuit

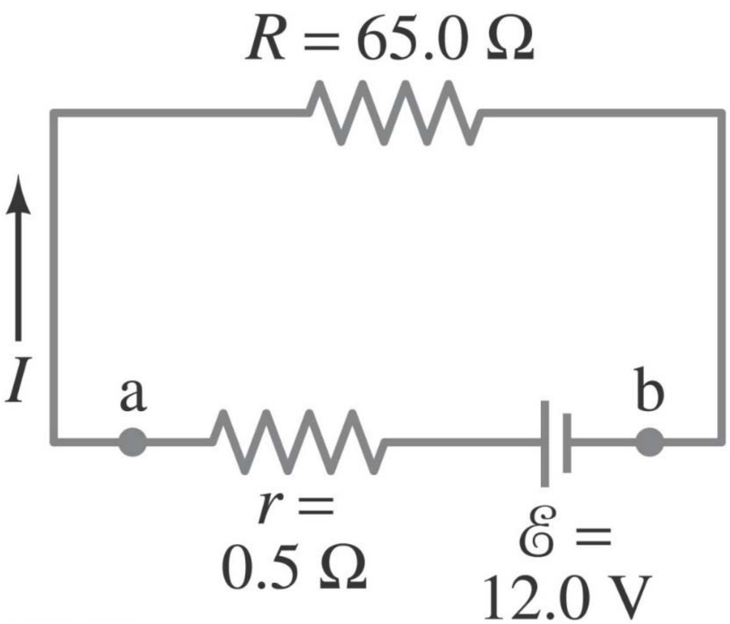


26-1 EMF and Terminal Voltage

Example 26-1: Battery with internal resistance. $V_{ab} = \mathcal{E} - Ir.$

A 65.0-Ω resistor is connected to the terminals of a battery whose emf is 12.0 V and whose internal resistance is 0.5 Ω. Calculate

(a) the current in the circuit, (b) the terminal voltage of the battery, V_{ab}, and (c) the power dissipated in the resistor R and in the battery's internal resistance r. IN CLASS $V_{ab} = \mathcal{E} - Ir.$



E =12.0V R=65.0 Ω r= 0.5 Ω

$V_{ab}=IR = E - Ir$

$I = E/(R+r) = 12.0V/65.5\Omega$

$=0.183A$

$V_{ab} = E - Ir =$

$12.0V - 0.183A(0.5\ \Omega) = 11.9V$

$P_R = I^2R = (0.183)^2(65.0\ \Omega) = 2.18W$

$P_r = I^2 r = (0.183)^2(0.5\ \Omega) = 0.02W$

HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation.

75. When a 20.0-ohm resistor is connected across the terminals of a 12.0-V battery, the terminal voltage of the battery falls 0.30 V. What is the internal resistance of this battery?

76. What is the theoretical maximum current that can be drawn from a 1.50-V battery with an internal resistance of 0.30 ohm?

77. An AA 1.5-V flashlight battery typically has an internal resistance of 0.30Ω.
A. What is its terminal voltage when it supplies 48 mA to a load?
B. What power does it deliver to the load?

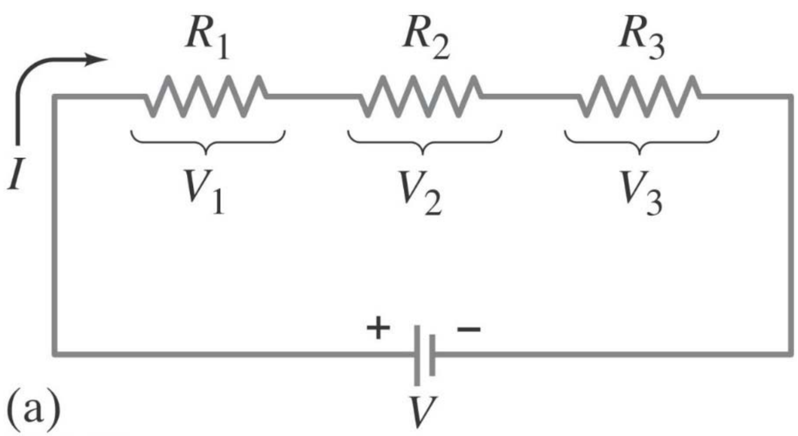
78. A bank of batteries with a terminal voltage of 50 V dissipates internally 20 W while delivering 1 A to a load.
What is its EMF?

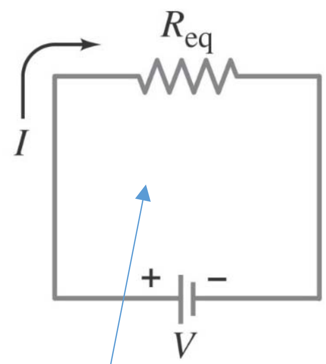
CIRCUITS WITH RESISTORS IN SERIES AND PARALLEL IS A VERY IMPORTANT SITUATION TO UNDERSTAND SINCE MANY DEVICES DEPEND ON SUCH CIRCUITS

WE WILL NOW LOOK AT A NUMBER OF SUCH CIRCUITS.

26-2 Resistors in Series

A series connection has a single path from the battery, through each circuit element in turn, then back to the battery as shown.





We can think that charge drops in Energy at the resistors Losing the original terminal voltage value

The current through each resistor is the same; the voltage drop or loss of energy depends on the resistance. The sum of the voltage drops across the resistors equals the battery terminal voltage: or total loss of energy through the R's =original V_{ab}

$V=V_1 + V_2 + V_3 \ = IR_1 + IR_2 + IR_3$ By Ohms law

$= I(R_1 + R_2 + R_3) = IR_{equivalent}$ or for series circuits

$$R_{eq} = R_1 + R_2 + R_3 .$$

26-2 Resistors in Parallel (see bulbs below)

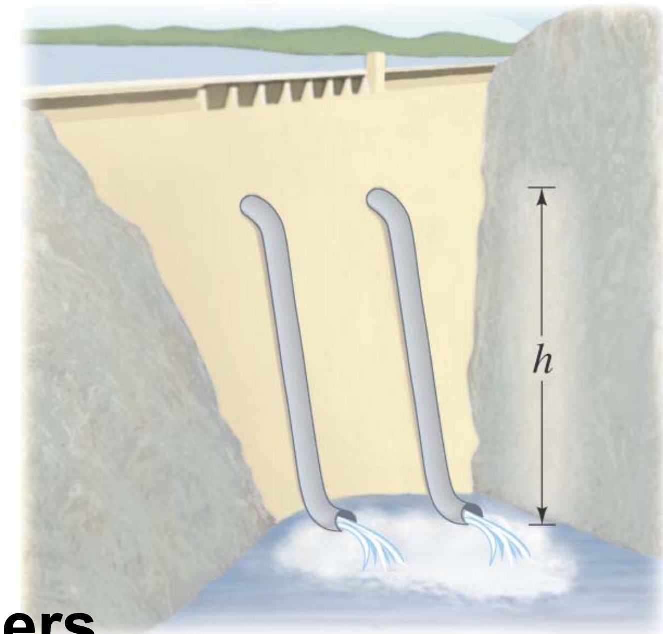
An analogy using water may be helpful in visualizing parallel circuits. The water (current) splits into two streams; each falls the same height, and the total current is the sum of the two currents.

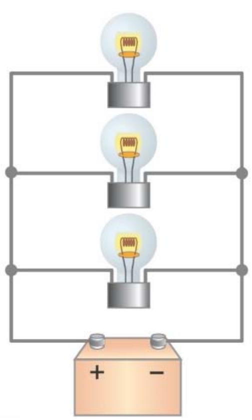
Three bulbs all at the same potential

Like the height of water in the dam

The current from the battery splits

Into three paths.



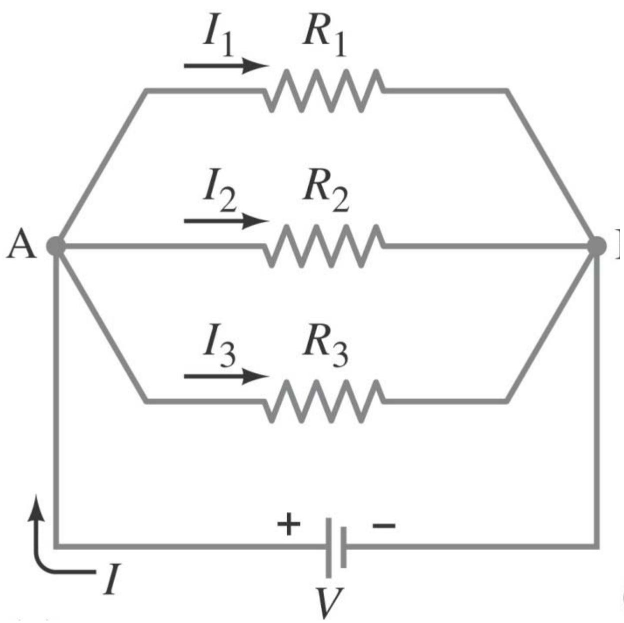


b)

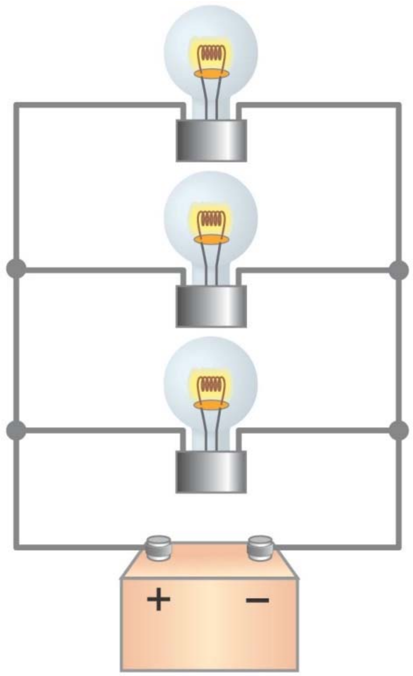
If one bulb died will the others Also die? If they were in series and one died Would the others die?

26-2 Resistors in Parallel

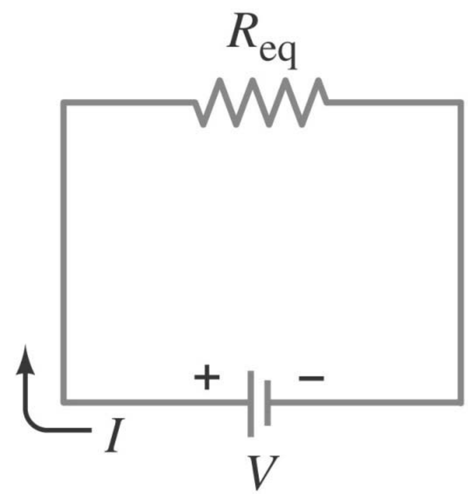
A parallel connection splits the current; the voltage across each resistor is the same:



(b)



(c)



$$I = I_1 + I_2 + I_3$$

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}.$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

Ex. 2 in Parallel

$1/R_{eq} = 1/R_1 + 1/R_2$

$1/R_{eq} = (R_1 + R_2)/R_1 R_2$

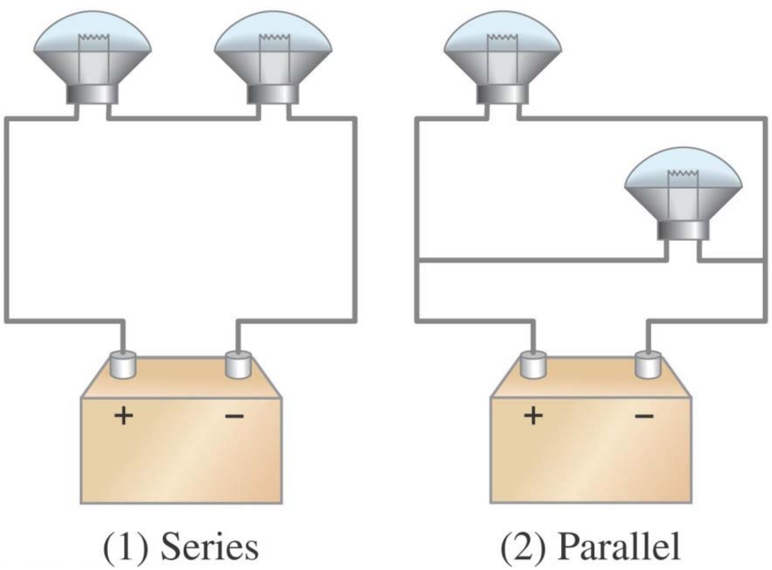
$R_{eq} = R_1 R_2 /(R_1 + R_2)$

[parallel]

26-2 Resistors in Series and in Parallel

Conceptual Example 26-2: Series or parallel?

(a) The light bulbs in the figure are identical(same R). Which configuration produces more light? (b) Which way do you think the headlights of a car are wired? Ignore change of filament resistance *R* with current.



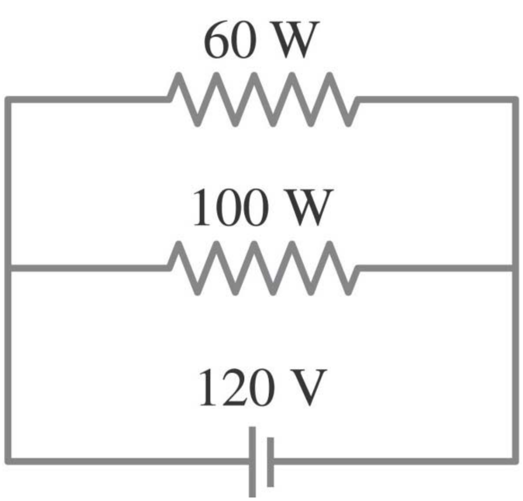
Serial R_{eq}=2R I_s=V/R_{EQ} =(1/2)V/R
P=I_sV =(1/2)V^2 /R

Parallel R_{eq} =R/2 I_p =V/R_{EQ} =2V/R
Since P=I_pV=2V^2 /R
is the brightness
Parallel are brighter by 4 times!

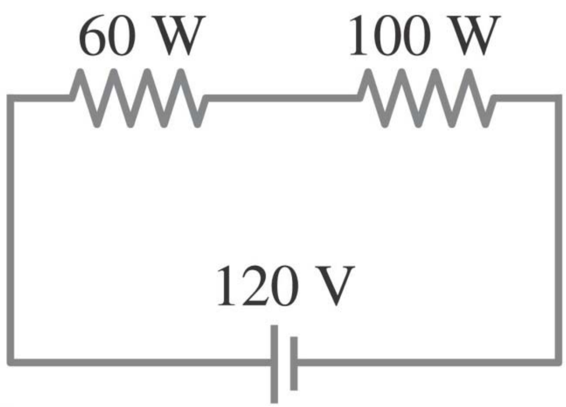
26-2 Resistors in Series and in Parallel

Conceptual Example 26-3: An illuminating surprise.

A 100-W, 120-V lightbulb and a 60-W, 120-V lightbulb are connected in two different ways as shown. In each case, which bulb glows more brightly? Ignore change of filament resistance with current (and temperature). CLASS?



Both rated for 120V so 100W Is brighter



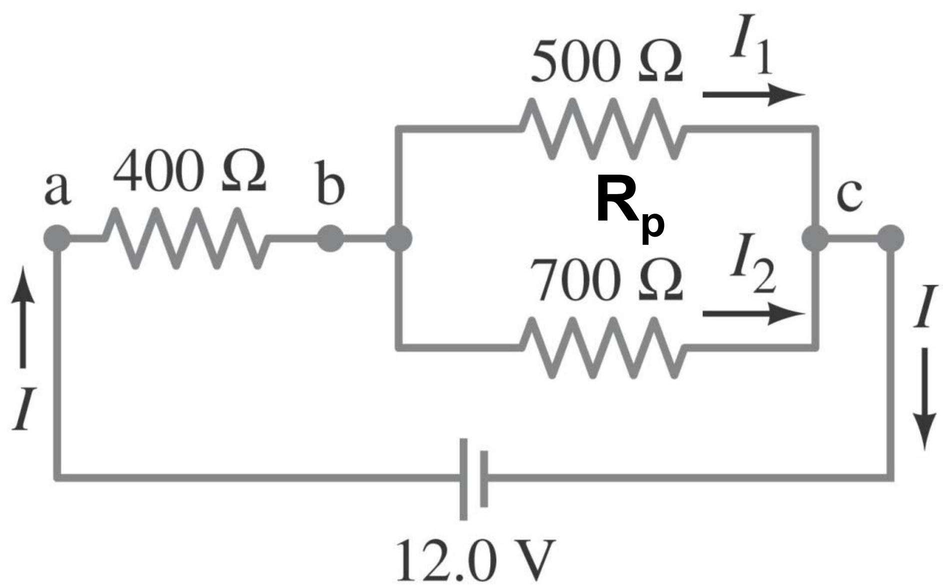
Since $P=V^2/R$ $R_{60} = 120^2/60 = 240\Omega$ and $R_{100} = 120^2/100 = 144\Omega$

Current is same in both ie $I=V/R_{eq} = 120/384$ The brightness $P=I^2R$ Means Higher R wins….60W burns brighter!

26-2 Resistors in Series and in Parallel

Example 26-4: Circuit with series and parallel resistors.

How much current is drawn from the battery shown? CLASS?



R_{eq} =? Thus $I=V/R_{eq}$

$1/R_p = 1/500 + 1/700$

$R_p = 290\Omega$

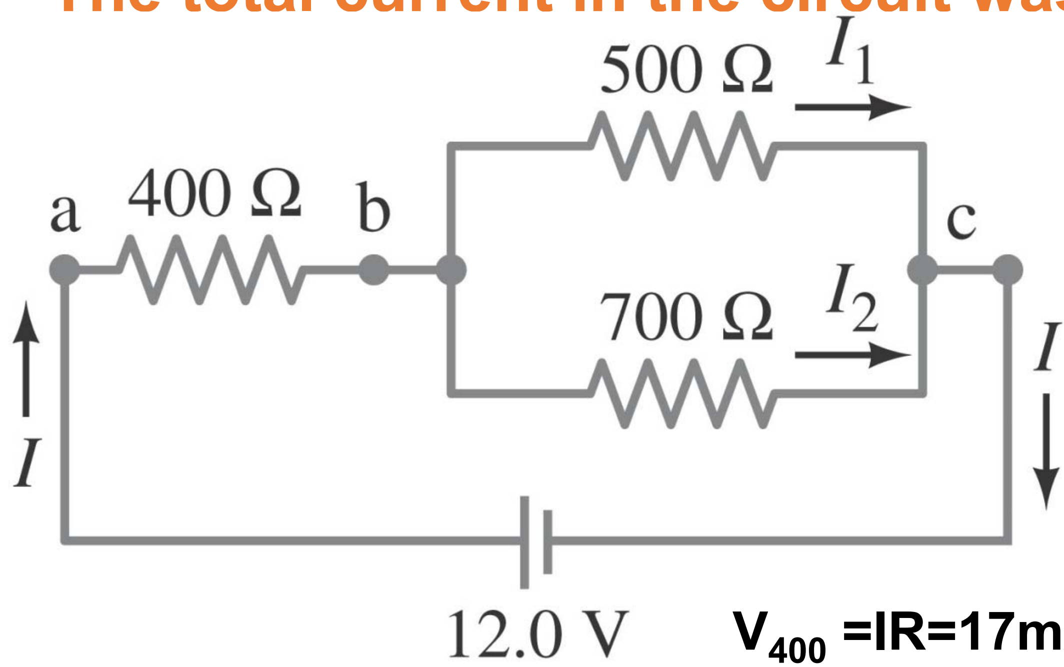
$R_{eq} = 400+290 = 690\Omega$

and $I=V/R_{eq} = 12/690 = 17mA$

26-2 Resistors in Series and in Parallel

Example 26-5: Current in one branch.

What is the current through the 500-Ω resistor shown? (Note: This is the same circuit as in the previous problem.) The total current in the circuit was found to be 17 mA.



What is V that is on the 500 Ω?
We need that V_{500}
Then we could get $I_{500}=V_{500}/500\ \Omega$

Original 12V reduced by Voltage Drop at 400 Ω we know Total current =17ma goes thru The 400 Ω and splits at parallel R'

V_{400} =IR=17mA x 400 Ω =7V

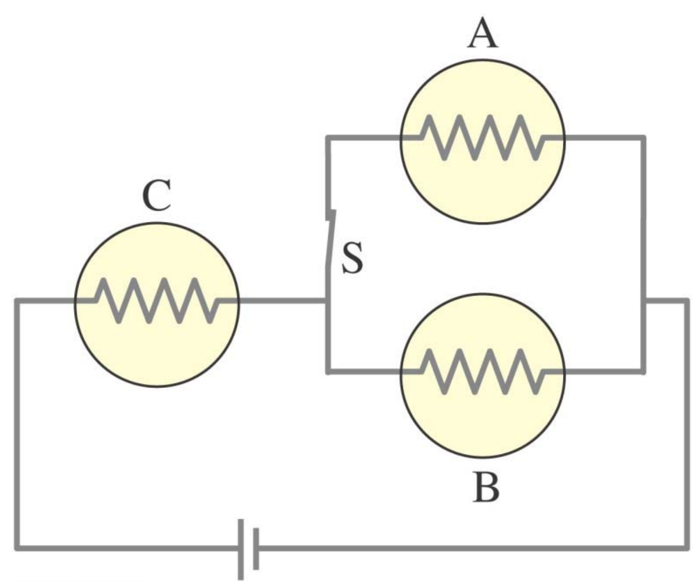
V_{500} =12-7=5V so I_{500} =5V/500 Ω =10mA

NOTE: I_{700} =5V/700 Ω =7mA so I_{total} =10mA+7mA =17mA

26-2 Resistors in Series and in Parallel

Conceptual Example 26-6: Bulb brightness in a circuit.

The circuit shown has three identical light bulbs, each of resistance *R*. (a) When switch S is closed, how will the brightness of bulbs A and B compare with that of bulb C? (b) What happens when switch S is opened? Use a minimum of mathematics in your answers. class?



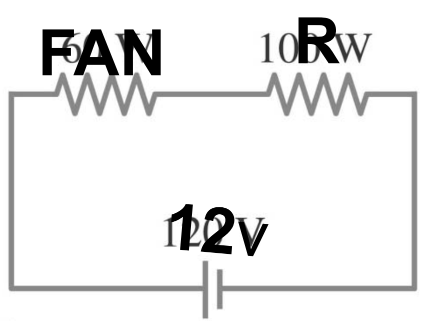
. When S is closed, the bulbs in parallel have an equivalent resistance equal to half that of the series bulb. Therefore, the voltage drop across them is smaller. In addition, the current splits between the two of them. Bulbs A and B will be equally bright, but much dimmer than C.
b. With switch S open, no current flows through A, so it is dark. B and C are now equally bright, and each has half the voltage across it, so C is somewhat dimmer than it was with the switch closed, and B is brighter.

26-2 Resistors in Series and in Parallel

Example 26-7: A two-speed fan.

One way a multiple-speed ventilation fan for a car can be designed is to put resistors in series with the fan motor. The resistors reduce the current through the motor and make it run more slowly. Suppose the current in the motor is 5.0 A when it is connected directly across a 12-V battery. (a) What series resistor should be used to reduce the current to 2.0 A for low-speed operation? (b) What power rating should the resistor have? Class?

I_{fan} =5A (NO R), V=12V R_{fan} =?



NO R WE HAVE

$V = I_{fan} R_{fan}$ $R_{fan} = V/I_{fan} = 12/5 = 2.4\Omega$

(app. R depends on speed)

(a)R=? I=2A $V_{fan} = IR_{fan} = 2A \times 2.4\Omega = 4.8V$

$V_R = 12 - 4.8 = 7.2V$ with I=2A ,$R = V_R / I = 7.2V/2A = 3.6\Omega$

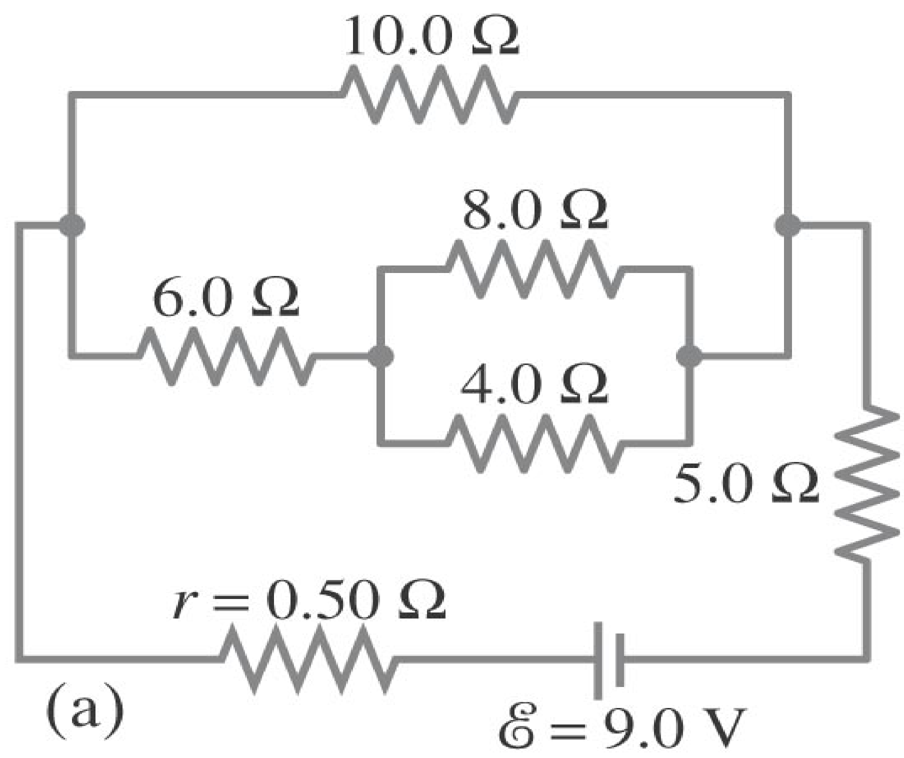
(b) $P_R = V_R I = 7.2V*2A = 14.4W$ Engineers play it safe 20W!

Example 26-8: Analyzing a circuit. Step by step breakdown!

A 9.0-V battery whose internal resistance *r* is 0.50 Ω is connected in the circuit shown. (a) How much current is drawn from the battery? (b) What is the terminal voltage of the battery? (c) What is the current in the 6.0-Ω resistor? CLASS?

Class what is R_{eq} OF ALL TO GET PART (a.) $I = V/R_{eq}$

recall FOR || R_1 & R_2 $R_{eq} = R_1R_2/(R1+R_2)$



A 9.0-V battery whose internal resistance *r* is 0.50 Ω is connected in the circuit shown. (a) How much current is drawn from the battery? (b) What is the terminal voltage of the battery? (c) What is the current in the 6.0-Ω resistor?

(a) Inner || first

I: R_{eq1} =8x4/(8+4)=32/12=2.7

II: inner series

R_{eq2} =6+2.7=8.7

III: new || 10 &8.7

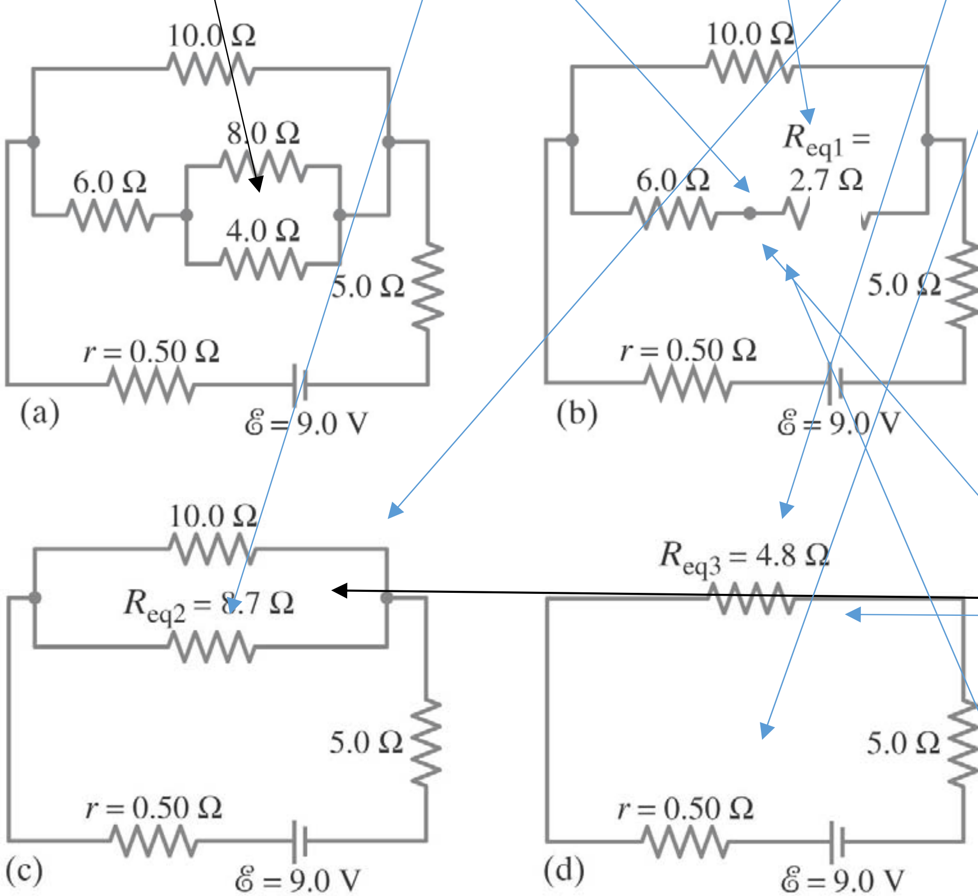
text error

R_{eq3} =10 x 8.7/(18.7)=4.7 (4.8)

IV: Last fig

R_{eq} =4.8+5.0+0.5==10.3Ω

V: I=ℰ/R_{eq} =9V/10.3Ω=0.87A



(b) EMF – INTERNAL V DROP

V=ℰ -Ir =8.6V

(c) $I_{6\Omega}$ =$I_{8.7\Omega}$ (6+2.7)

$V_{8.7}$ = V_{10}

$V_{8.7}$ =ℰ –Ir-$IR_{5\Omega}$ ==IX4.8=4.2V

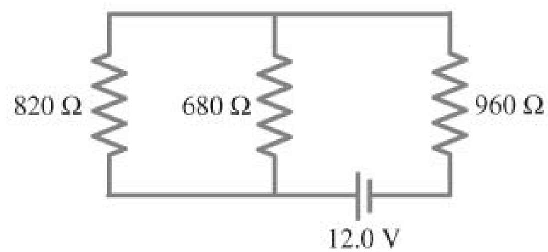
9-0.87x0.50 -0.87x5 = 4.2V

$I_{6\Omega}$ =$V_{8.7}$ /8.7= 4.2/8.7=0.48A

HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation.

79. A battery with a Terminal Voltage of 12 V, Connected to resistors, R1 = 3Ω, and R2 = 1Ω. First in a. In Series, second situation, b. in parallel
What current flows through each resistor, and what voltage drop occurs across each resistor for each situation a. and b.? 2502

80.. a. Equivalent resistance? of fig->
b. Total current leaving battery?
c. Voltage drop across the 820Ω. ?
HINT: Parallel or series or both? Think!



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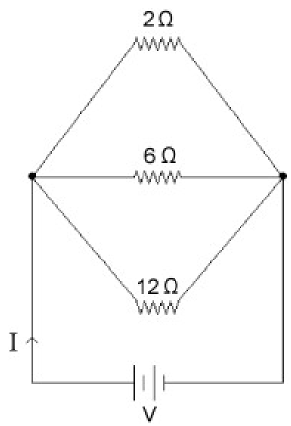
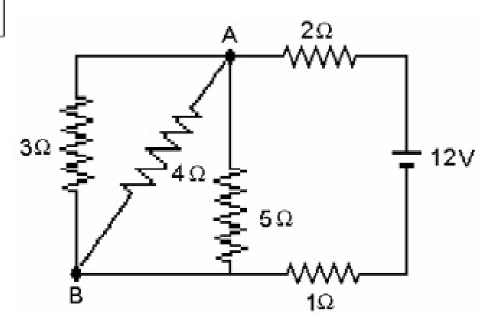


81. a. Equivalent resistance of this fig->
b. I=6A what is current in 12Ω?
HINT: Parallel or series or both? Think

m2627

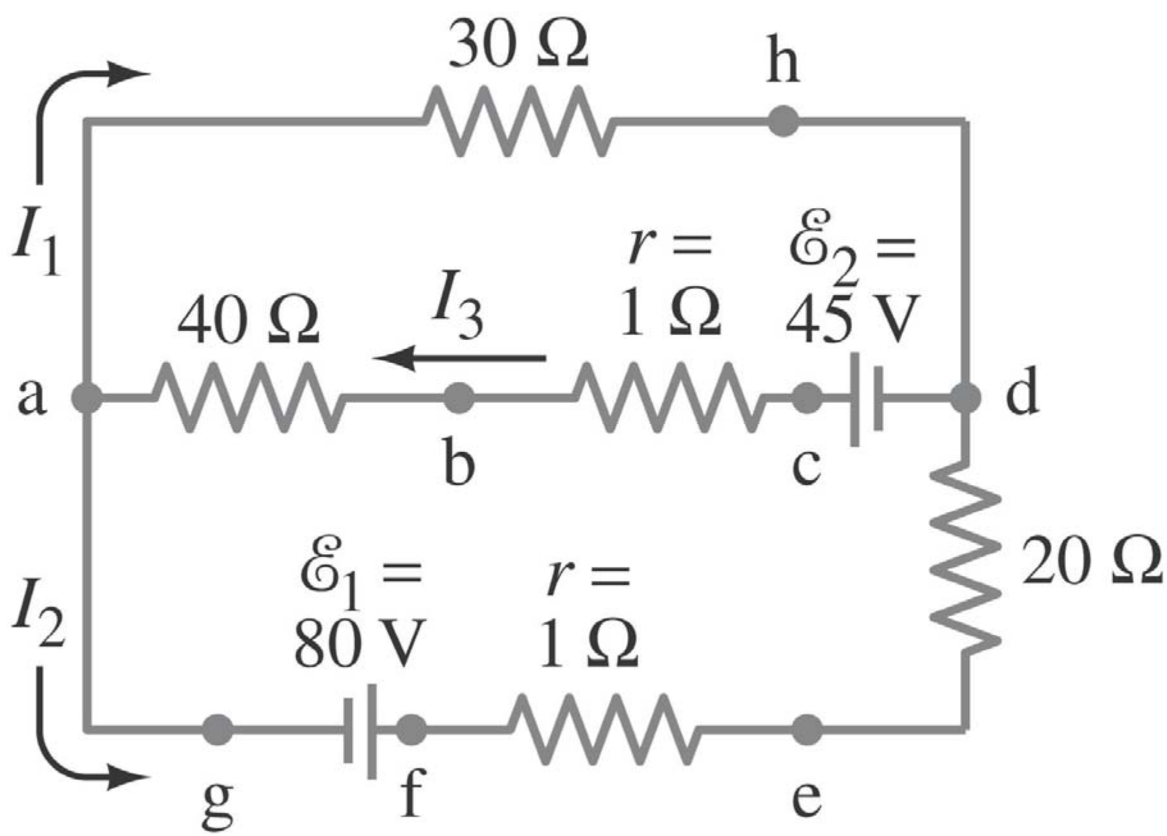


82..Fig->Current in a. 1Ω b. 3 Ω and c. 4Ω ?
HINT: Parallel or series or both? Think!

26-3 Kirchhoff's Rules

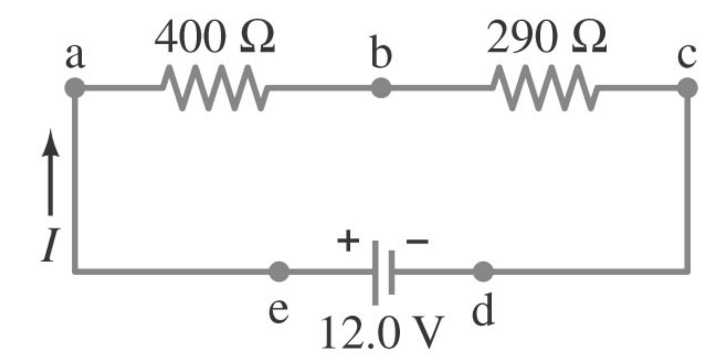
Some circuits cannot be broken down into series and parallel connections. NOTE: multiple sources of EMF!

For these circuits we use Kirchhoff's rules.

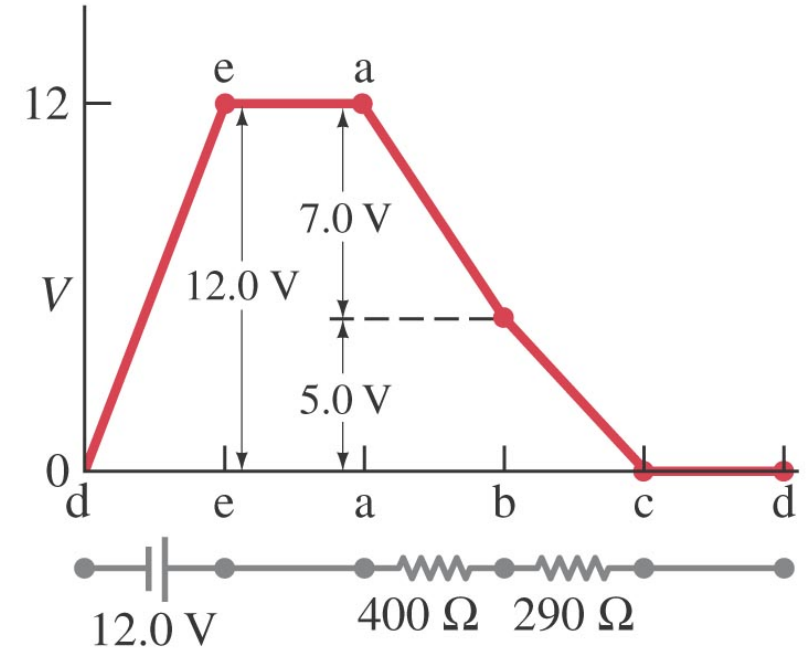


26-3 Kirchhoff's Rules

Loop rule: The sum of the changes in potential around a closed loop is zero.



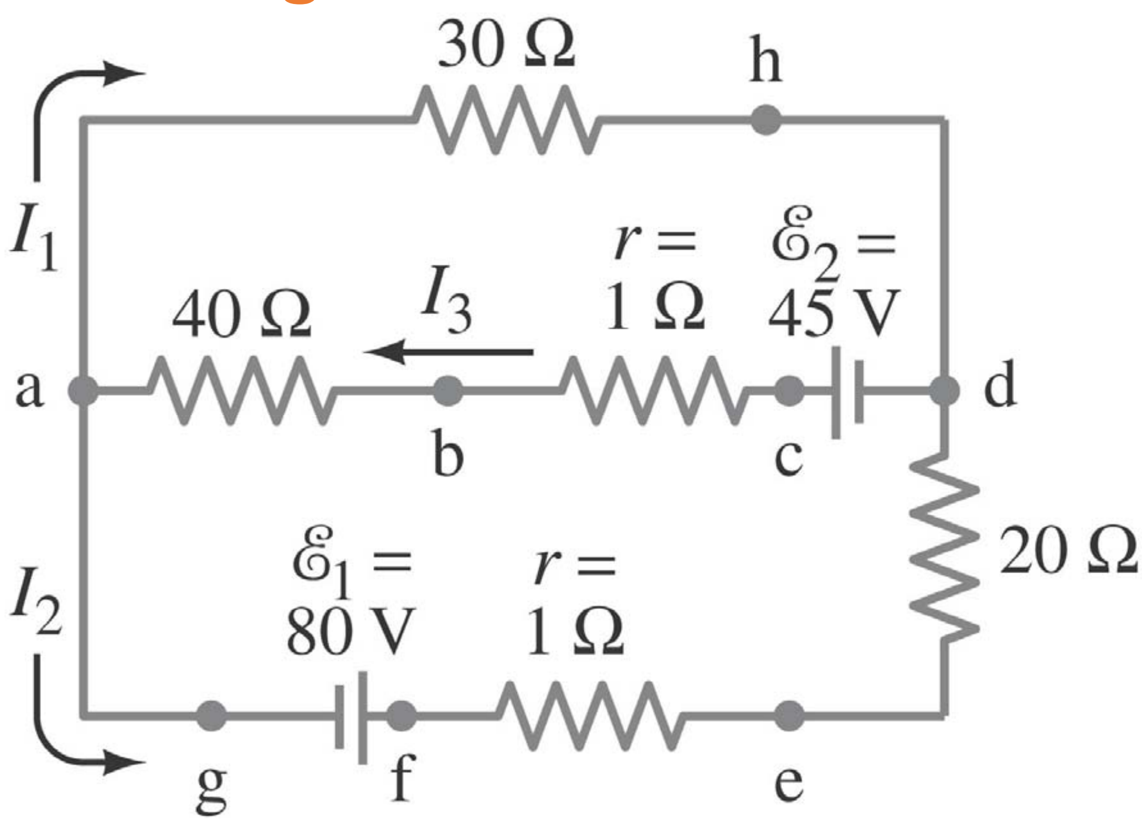
Follow the + charge around!



V=IR–> 12–400I–290I=0

26-3 Kirchhoff's Rules

Junction rule: The sum of currents entering a junction equals the sum of the currents leaving it.



$I_3 = I_1 + I_2$

At "d" ???

Problem Solving: Kirchhoff's Rules

1. Label each current, including its direction. If you choose the wrong direction the solution will come out negative for the current.

2. Identify what are the unknowns. Usually currents.

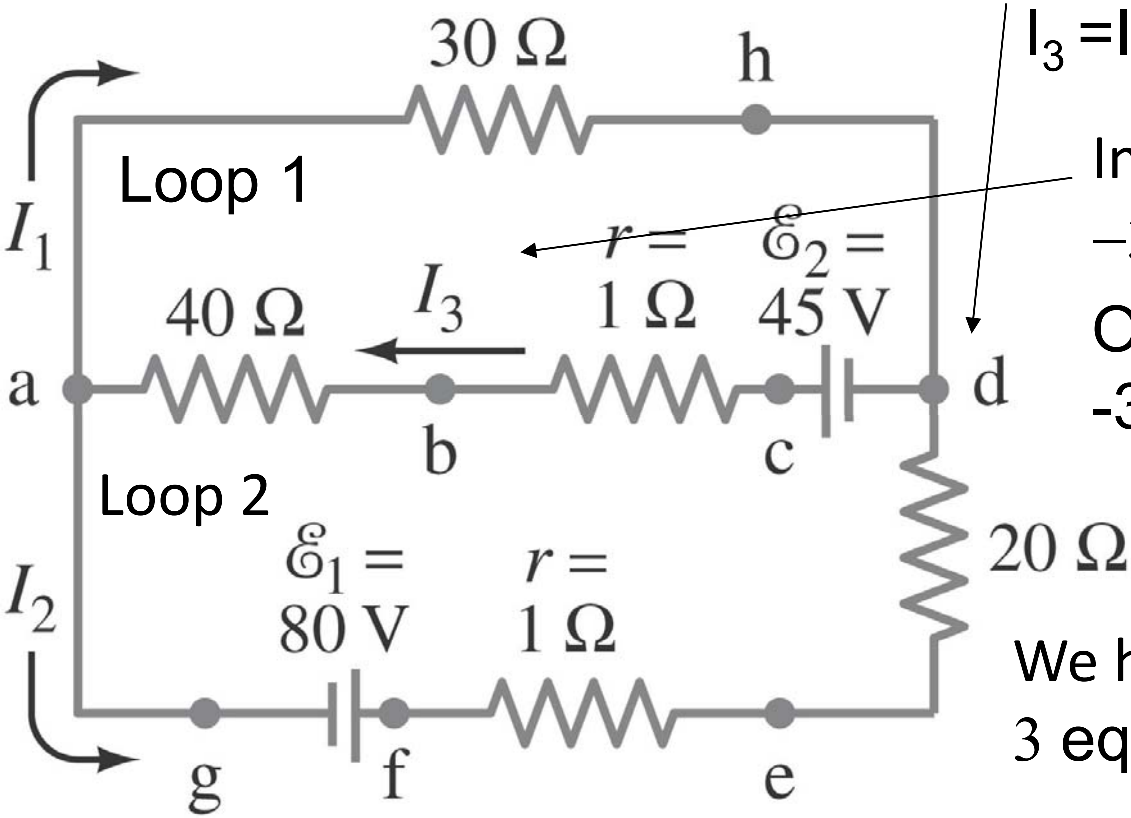
3. Apply junction and loop rules; you will need as *many independent equations as there are unknowns*. EG. 3 equations for 3 unknowns but you will most likely have a redundant 4^{th} equation. Pick the simplest algebraic equations for your solution.

4. Solve the equations, being careful with signs. If the solution for a current is negative, that current is in the opposite direction from the one you have chosen.

Example 26-9: Using Kirchhoff's rules.

Calculate the currents I_1, I_2, and I_3 in the three branches of the circuit in the figure. (3 unknown I's whose directions we are assuming):

Generating Equations:



At junction d or a:

$I_3 = I_1 + I_2$

Inner Loop1 Clock wise(CW):

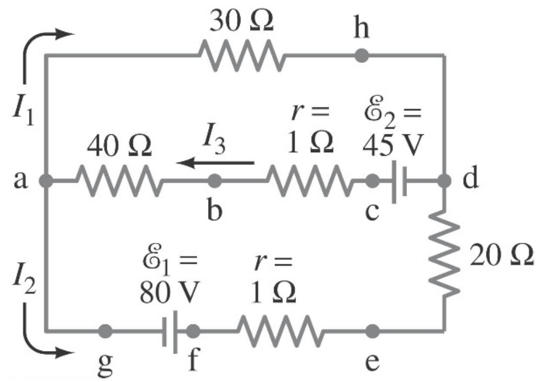
$-30I_1 + 45 - I_3 - 40I_3 = 0$

Outer loop CW!

$-30I_1 + 20I_2 + I_2 - 80 = 0$

We have now
3 equations for 3 unknowns!

Inner loop2 CW: REDUNCANT $40I_3 + I_3 - 45 + 20I_2 + I_2 - 80 = 0$



Solving the equations for I's
Setup standard 3 equations 3 unknowns

$I_3 = I_1 + I_2$ -> $I_1 + I_2 - I_3 = 0$

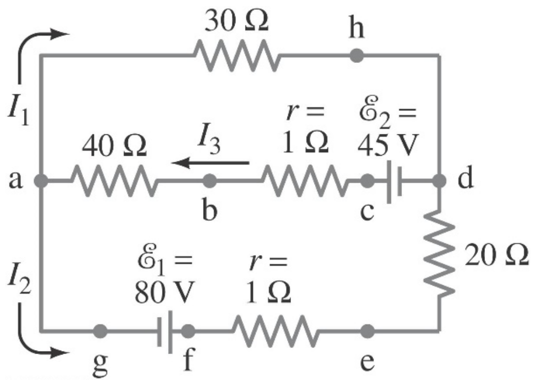
$-30I_1 + 45 - I_3 - 40I_3 = 0$ -> $-30I_1 - 41I_3 = -45$

$-30I_1 + 20I_2 + I_2 - 80 = 0$ -> $-30I_1 + 21I_2 = 80$

2 ways to solve: 1:algebraic substitution 2: Determinants

1 algebra: we note both I_3 and I_2 can be gotten in terms of I_1
From the last two equations and then substituting into the
First equation solves I_1 from which we get I_2 and I_3
Solve this now in class!

$I_1 =$ $I_2 =$ $I_3 =$



Algebraic Solution

I: $I_1 + I_2 - I_3 = 0$

II: $-30I_1 \quad -41I_3 = -45$

III: $-30I_1 + 21I_2 = 80$

II:-> $I_3 = -45/-41 + (30/-41)I_1 = 45/41 + (30/41)I_1 = 1.1 - 0.73I_1$

III: -> $I_2 = +80/21 + (30/21)I_1 = 3.8 + 1.4I_1$

sub these last 2 into I:

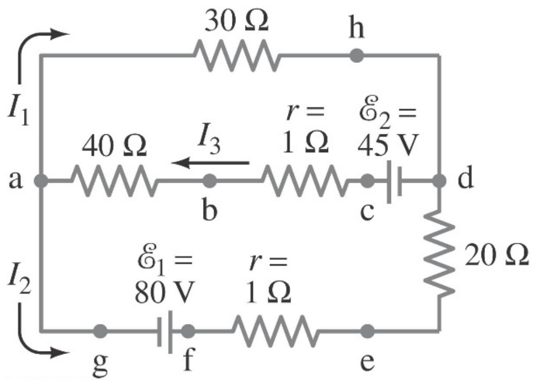
I: _> $I_1 + 3.8 + (1.4)I_1 - (1.1 - 0.7I_1) = 0$

-> $+3.1I_1 = -2.7$

$I_1 = -0.87A$

> I_2 = 2.6 A

I_3 = 1.7 A



Determinant Solution coefficients are the key

$$\begin{array}{rrrcr} I_1 & + \; I_2 & - I_3 & = & 0 \\ -30I_1 & 0 & -41I_3 & = & -45 \\ -30I_1 & +21I_2 & 0 & = & 80 \end{array}$$

Determinant of 2 x2 for 2 unknowns
Is Formed by products along
+ upper right - lower right

$a_1x + b_1y = c_1$
$a_2x + b_2y = c_2$
solution of x,y->

$$x = \frac{\begin{vmatrix} c_1 & b_1 \\ c_2 & b_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}} = \frac{c_1b_2 - b_1c_2}{a_1b_2 - b_1a_2}$$

$$y = \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}} = \frac{a_1c_2 - c_1a_2}{a_1b_2 - b_1a_2}$$

We have a 3 x 3 fro 3 unknowns but some
Of the coefficients are zero-> easier to calculate!

$$\left.\begin{array}{l} a_1x + b_1y + c_1x = d_1 \\ a_2x + b_2y + c_2x = d_2 \\ a_3x + b_3y + c_3x = d_3 \end{array}\right\}$$

$$D = \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}, \quad D_x = \begin{vmatrix} d_1 & b_1 & c_1 \\ d_2 & b_2 & c_2 \\ d_3 & b_3 & c_3 \end{vmatrix},$$

$$x = \frac{D_x}{D}, \quad y = \frac{D_y}{D} \text{ and } z = \frac{D_z}{D}.$$

$$D_y = \begin{vmatrix} a_1 & d_1 & c_1 \\ a_2 & d_2 & c_2 \\ a_3 & d_3 & c_3 \end{vmatrix}, \quad D_z = \begin{vmatrix} a_1 & b_1 & d_1 \\ a_2 & b_2 & d_2 \\ a_3 & b_3 & d_3 \end{vmatrix},$$

$$\det \begin{pmatrix} a & b & c \\ e & f & g \\ i & j & k \end{pmatrix} = afk + bgi + cej - [ifc + jga + keb]$$

Determinant Solution

Think of I's as

x y z

$$I_1 + I_2 - I_3 = 0$$

$$-30I_1 \quad 0 \quad -41I_3 = -45$$

$$-30I_1 + 21I_2 \quad 0 = 80$$

$$\left.\begin{array}{l} a_1x + b_1y + c_1x = d_1 \\ a_2x + b_2y + c_2x = d_2 \\ a_3x + b_3y + c_3x = d_3 \end{array}\right\}$$

$$D = \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}, \quad D_x = \begin{vmatrix} d_1 & b_1 & c_1 \\ d_2 & b_2 & c_2 \\ d_3 & b_3 & c_3 \end{vmatrix},$$

$$x = \frac{D_x}{D}, \quad y = \frac{D_y}{D} \text{ and } z = \frac{D_z}{D}. \quad D_y = \begin{vmatrix} a_1 & d_1 & c_1 \\ a_2 & d_2 & c_2 \\ a_3 & d_3 & c_3 \end{vmatrix}, \quad D_z = \begin{vmatrix} a_1 & b_1 & d_1 \\ a_2 & b_2 & d_2 \\ a_3 & b_3 & d_3 \end{vmatrix},$$

$$\det \begin{pmatrix} a & b & c \\ e & f & g \\ i & j & k \end{pmatrix} = afk + bgi + cej - [ifc + jga + keb]$$

$$D = \begin{vmatrix} 1 & 1 & -1 \\ -30 & 0 & -41 \\ -30 & 21 & 0 \end{vmatrix} = -41 \times -30 + -1 \times -30 \times 21 - (21 \times -41) = 2721$$

$$I_1 = x = D_x / D = 0.86 \text{ A}$$

$$D_x = \begin{vmatrix} 0 & 1 & -1 \\ -45 & 0 & -41 \\ 80 & 21 & 0 \end{vmatrix} = -41 \times 80 + -1 \times -45 \times 21 = -2335$$

$$D_y = \begin{vmatrix} 1 & 0 & -1 \\ -30 & -45 & -41 \\ -30 & 80 & 0 \end{vmatrix} = -1 \times -30 \times 80 - (-30 \times -45 \times -1 + 80 \times -41 +) = 7030$$

$$I_2 = y = D_y / D = 2.6 \text{ A}$$

$$D_z = \begin{vmatrix} 1 & 1 & 0 \\ -30 & 0 & -45 \\ -30 & 21 & 80 \end{vmatrix} = -45 \times -30 - (21 \times -45 + 80 \times -30) = 4695$$

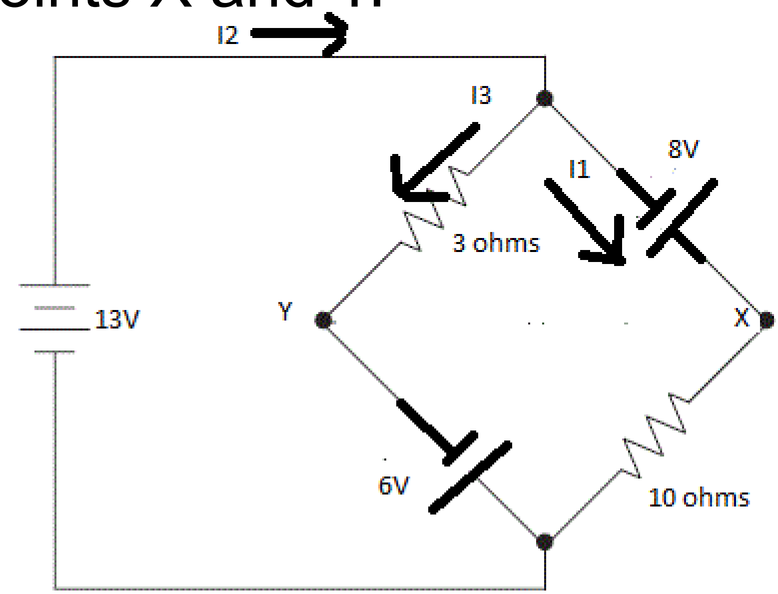
$$I_3 = z = D_z / D = 1.7 \text{A}$$

HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation(unless they are not too large or small in this case).

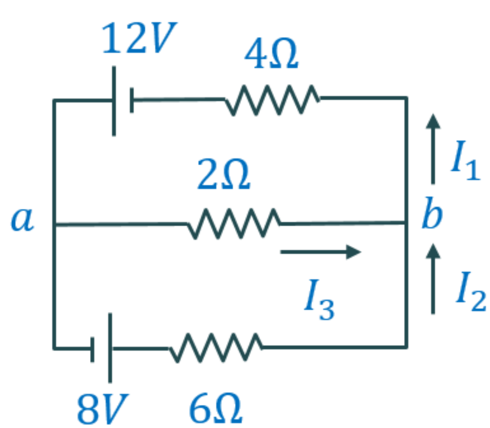
83. a. Solve for the currents

b. what is the voltage between points X and Y.

Hint: Kirchhoff's law is easy here for the I's

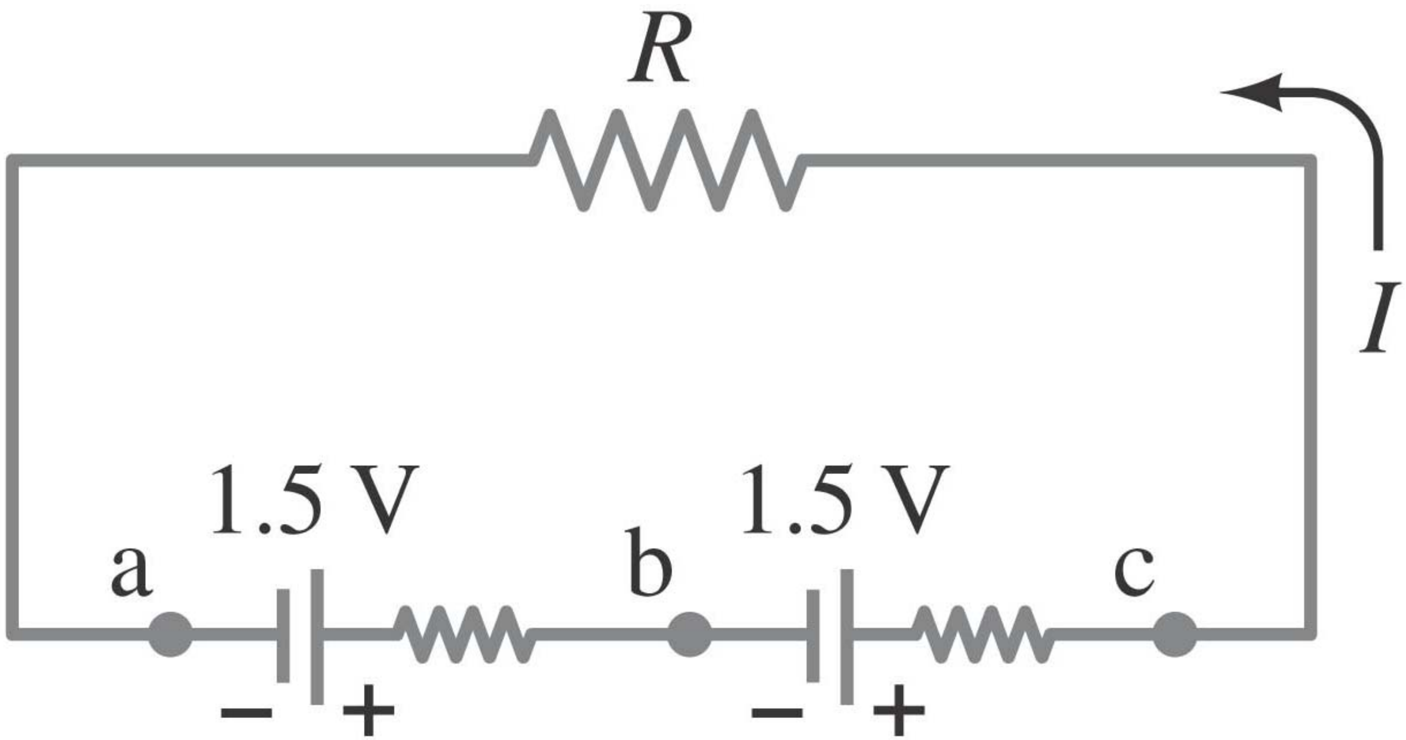


84. Solve for the currents in this circuit: Use Kirchhoff's law



****26-4 Series and Parallel EMFs; Battery Charging

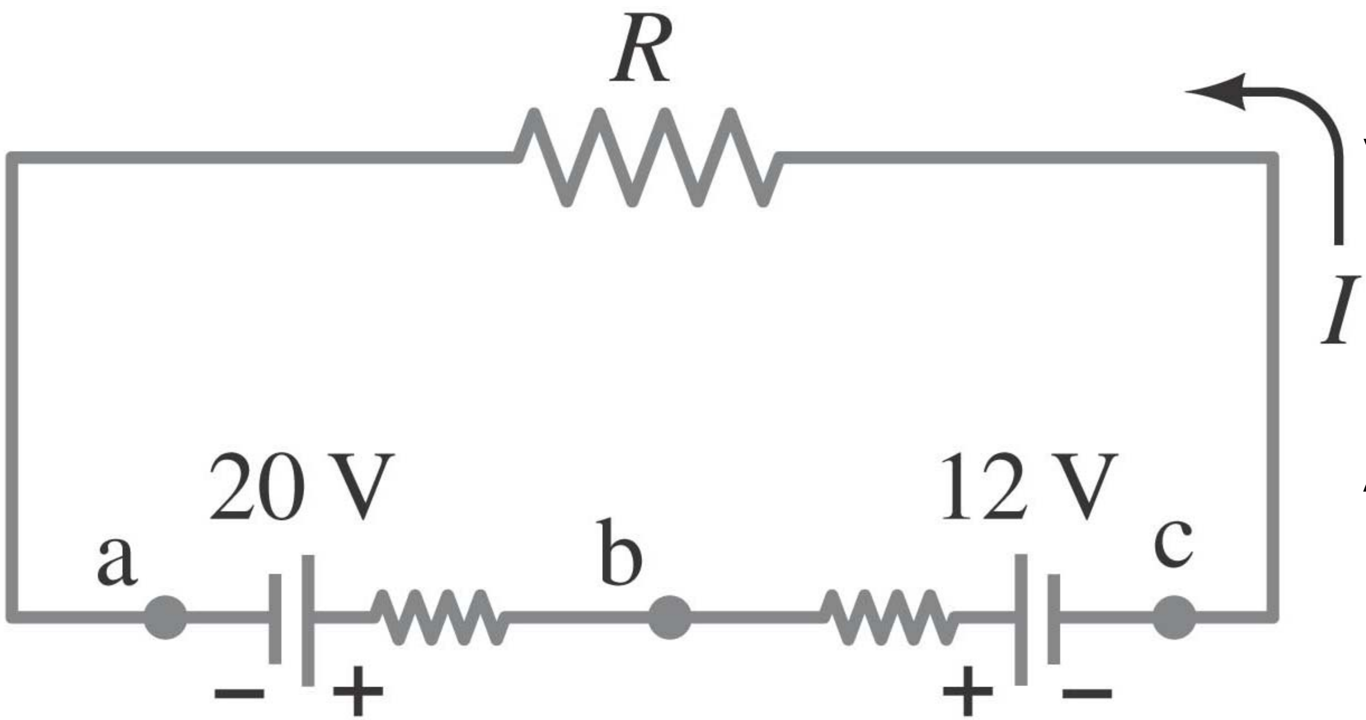
EMFs in series in the same direction: total voltage is the sum of the separate voltages.



$V = \Sigma V = 3.0V$

26-4 Series and Parallel EMFs; Battery Charging

EMFs in series, opposite direction: total voltage is the difference, but the lower-voltage battery is charged.

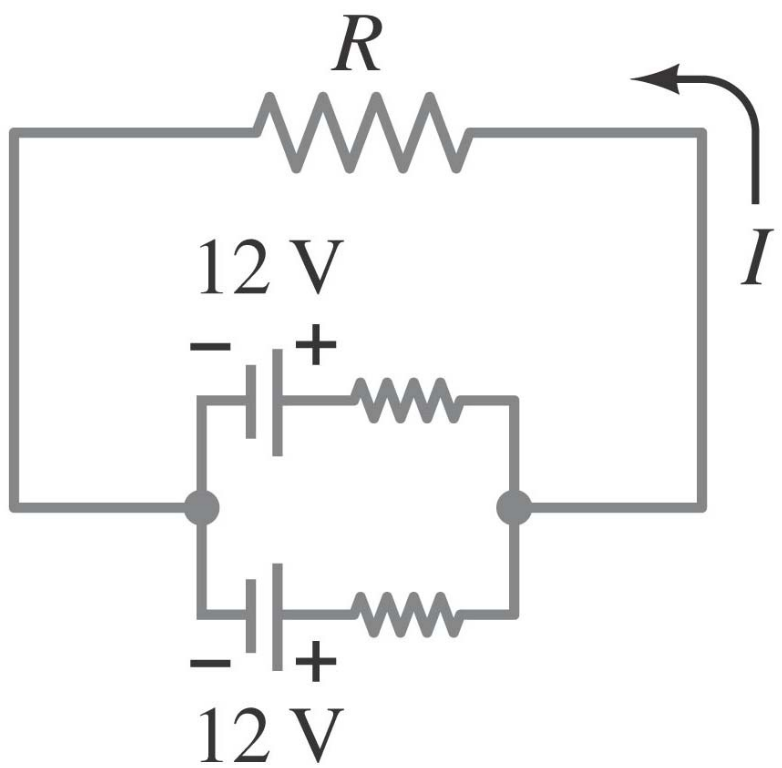


Ditto for running
Car Alternator
V across 12V
Battery must be
Higher for it to
Be charged by
Alternator
13-15V if 12 or
Less Alternator
Is not working
You got a problem

26-4 Series and Parallel EMFs; Battery Charging

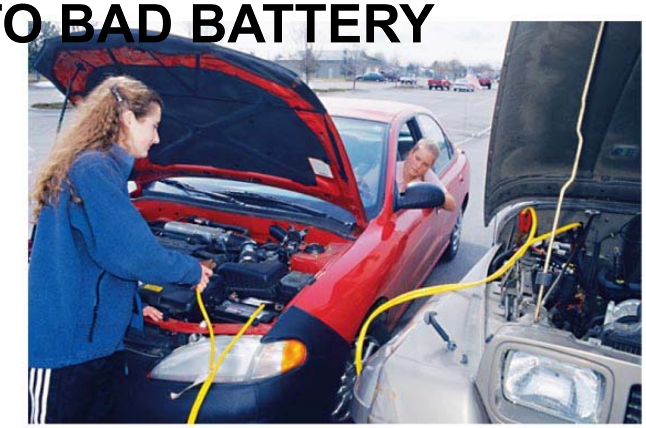
EMFs in parallel only make sense if the voltages are the same; this arrangement can produce more Energy than a single emf. Since each produces ½ current then losses due to internal r are less and the arrangement can last

Longer than a single emf.



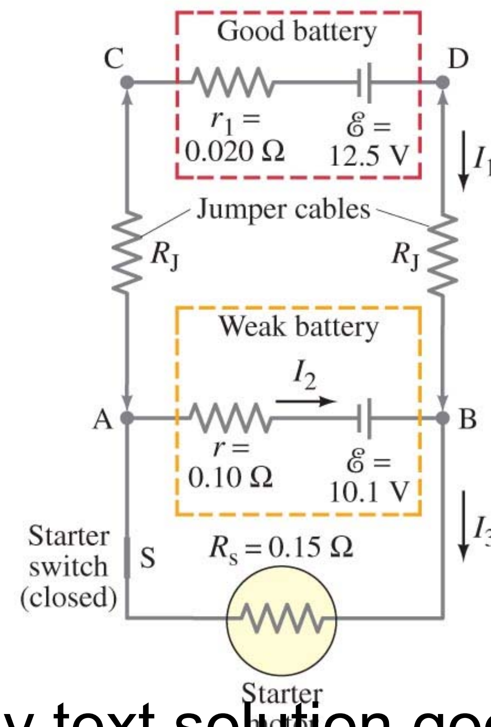
26-4 Series and Parallel EMFs; Battery Charging

WARNING: NEVER HOOK GROUND(BLACK) TO BAD BATTERY ONLY TO CAR BODY:
POSSIBLE EXPLOSION OF BAD ONE



Example 26-10: Jump starting a car.

A good car battery is being used to jump start a car with a weak battery. The good battery has an emf of 12.5 V and internal resistance 0.020 Ω. Suppose the weak battery has an emf of 10.1 V and internal resistance 0.10 Ω. Each copper jumper cable is 3.0 m long and 0.50 cm in diameter, and can be attached as shown. Assume the starter motor can be represented as a resistor R_s = 0.15 Ω. Determine the current through the starter motor (a) if only the weak battery is connected to it, and (b) if the good battery is also connected.

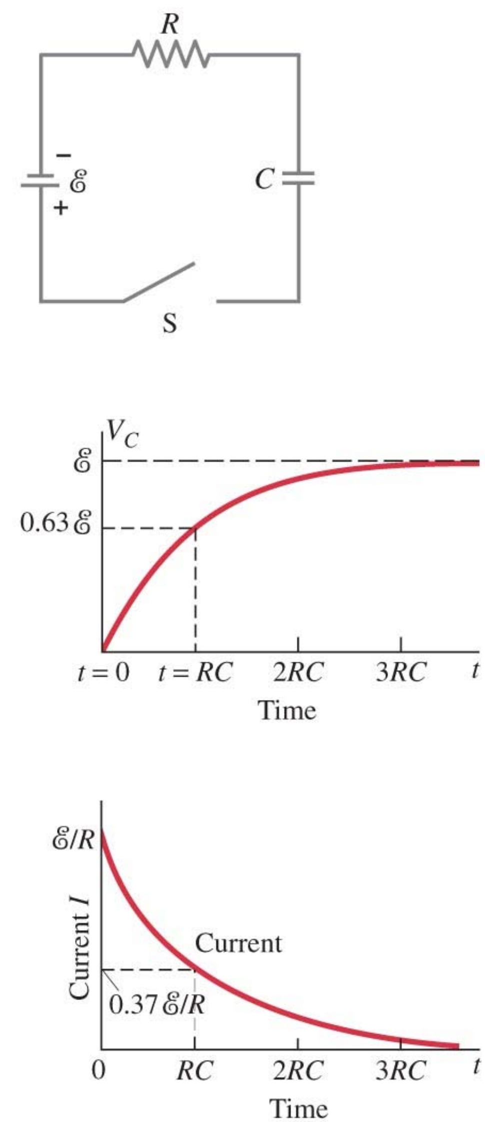


Study text solution good Example of Kirchkoff's rules!

HW: Be sure to read and understand section 26-4 Series and Parallel EMF’s
similar to lab work

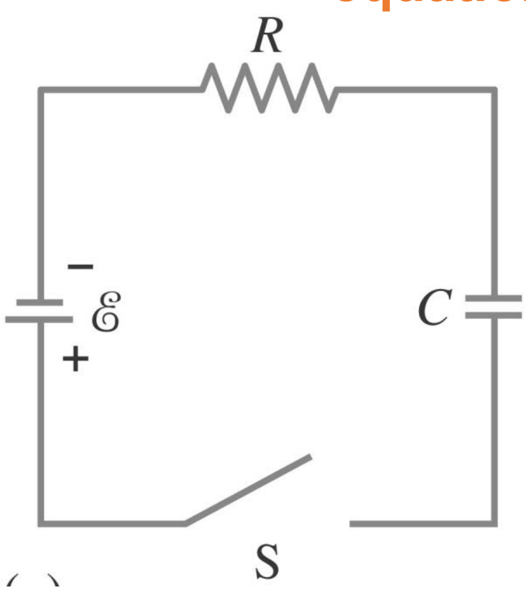
26-5 Circuits Containing Resistor and Capacitor (*RC* Circuits)

When the switch is closed, the capacitor will begin to charge. As it does, the voltage across it increases, and the current through the resistor decreases.



26-5 Circuits Containing Resistor and Capacitor (*RC* Circuits)

To find the voltage V(t) as a function of time, we write the equation for the voltage changes around the loop:



$\mathscr{E} = IR + \frac{Q}{C}$. **Since *I* = *dQ*/*dt*, then find Q(t)**

E = dQ/dt R +Q/C -> E – Q/C =RdQ/dt ->

dQ/(E –Q/C) =dt/R-> dQ/(CE – Q)=dt/RC

Solve by sub U=CE –Q ; dU=-dQ (Q-> 0 to (

dU/U =-dt/RC -> lnU $]_{CE}^{U}$

=ln(CE -Q) $]_0^Q$ = -t/RC $]_0^t$

=ln(CE –Q) –ln(CE) =ln(CE –Q)/(CE)=-t/RC

Recall . ln(A/B)= ln A – ln B and lny=x-> y=e^x

(CE –Q)/CE =$e^{-t/RC}$

Q=? Note: Q(t)

$$Q = C\mathscr{E}\left(1 - e^{-t/RC}\right).$$

26-5 Circuits Containing Resistor and Capacitor (*RC* Circuits)

The voltage across the capacitor is $V_C = Q/C$:

$$Q = C\mathcal{E}\left(1 - e^{-t/RC}\right).$$

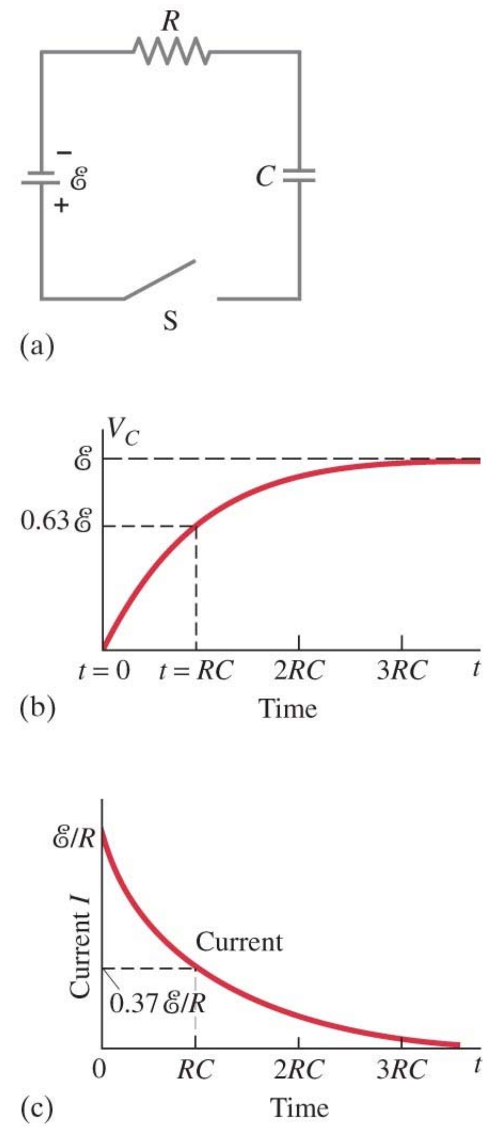
$$V_C = \mathcal{E}\left(1 - e^{-t/RC}\right).$$

The quantity *RC* that appears in the exponent is called the time constant of the circuit:

$$\tau = RC.$$

The current at any time *t* can be found by differentiating the charge:

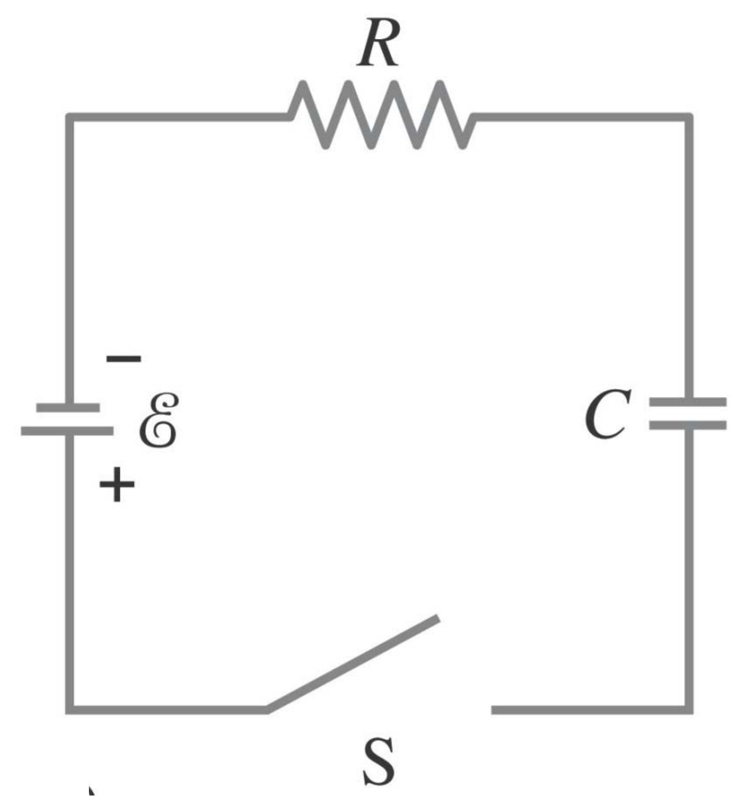
$$I = \frac{dQ}{dt} = \frac{\mathcal{E}}{R}e^{-t/RC}.$$



26-5 Circuits Containing Resistor and Capacitor (*RC* Circuits)

Example 26-11: *RC* circuit, with emf.

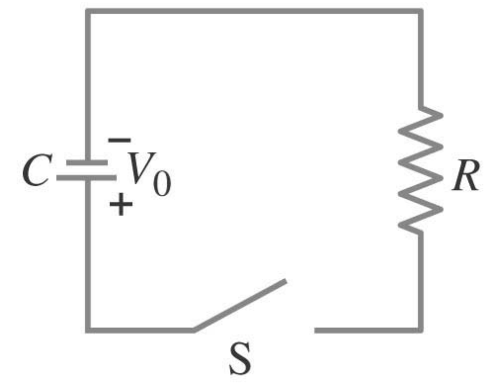
The capacitance in the circuit shown is $C = 0.30\ \mu\text{F}$, the total resistance is 20 kΩ, and the battery emf is 12 V. Determine (a) the time constant, (b) the maximum charge the capacitor could acquire, (c) the time it takes for the charge to reach 99% of this value, (d) the current I when the charge Q is half its maximum value, (e) the maximum current, and (f) the charge Q when the current I is 0.20 its maximum value.



Study Solution

26-5 Circuits Containing Resistor and Capacitor (*RC* Circuits)

If an isolated charged capacitor is connected across a resistor, it discharges:



(a)

Q/C=IR

At capacitor we know charge flows Out =I =-dQ/dt

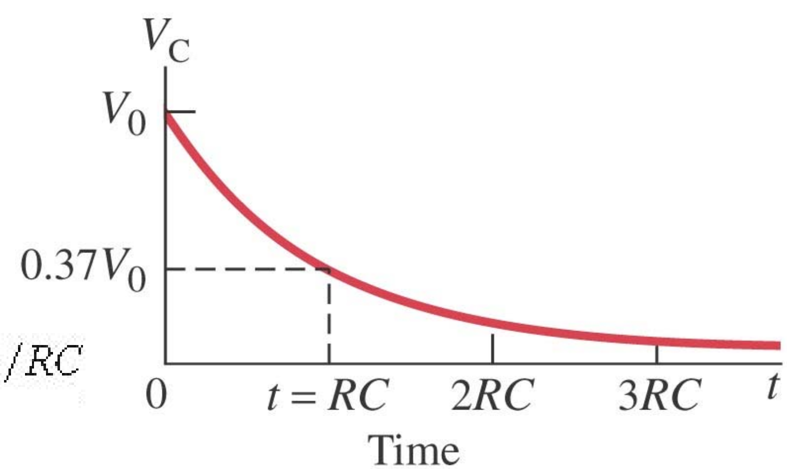
Q/C = -dQ/dtR -> dQ/Q = -t/RC

t: 0->t Q: Q_0 ->Q

Thus lnQ/Q_o = -t/RC

Or

$$Q = Q_0 e^{-t/RC}.$$



since V_o =Q_o /C V_c =Q/C $V_C = V_0 e^{-t/RC}$

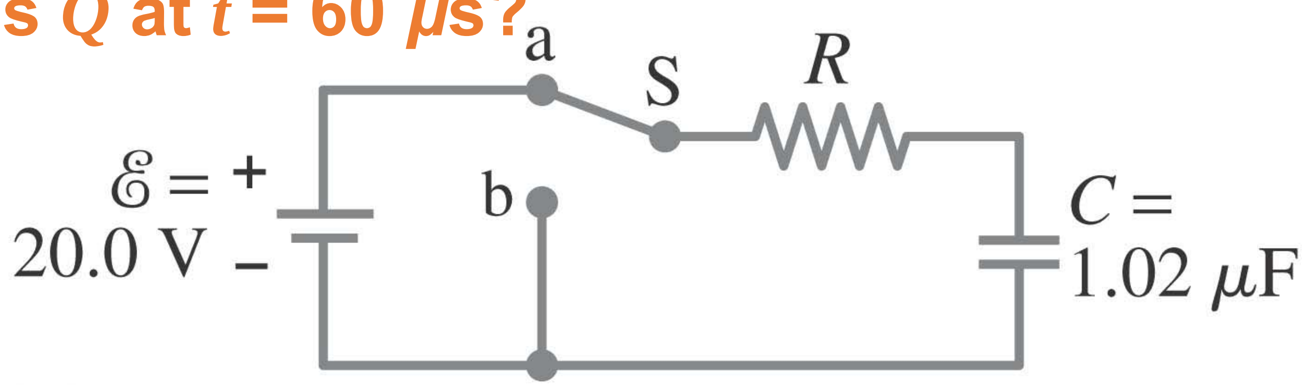
$$I = -\frac{dQ}{dt} = \frac{Q_0}{RC} e^{-t/RC} = I_0 e^{-t/RC}.$$

Ie $Q_o/C = V_o$ & $V_o/R = I_o$

26-5 Circuits Containing Resistor and Capacitor (*RC* Circuits)

Example 26-12: Discharging *RC* circuit.

In the *RC* circuit shown, the battery has fully charged the capacitor, so $Q_0 = C\mathcal{E}$. Then at $t = 0$ the switch is thrown from position a to b. The battery emf is 20.0 V, and the capacitance $C = 1.02\ \mu\text{F}$. The current I is observed to decrease to 0.50 of its initial value in 40 μs. (a) What is the value of Q, the charge on the capacitor, at $t = 0$? (b) What is the value of R? (c) What is Q at $t = 60\ \mu\text{s}$?

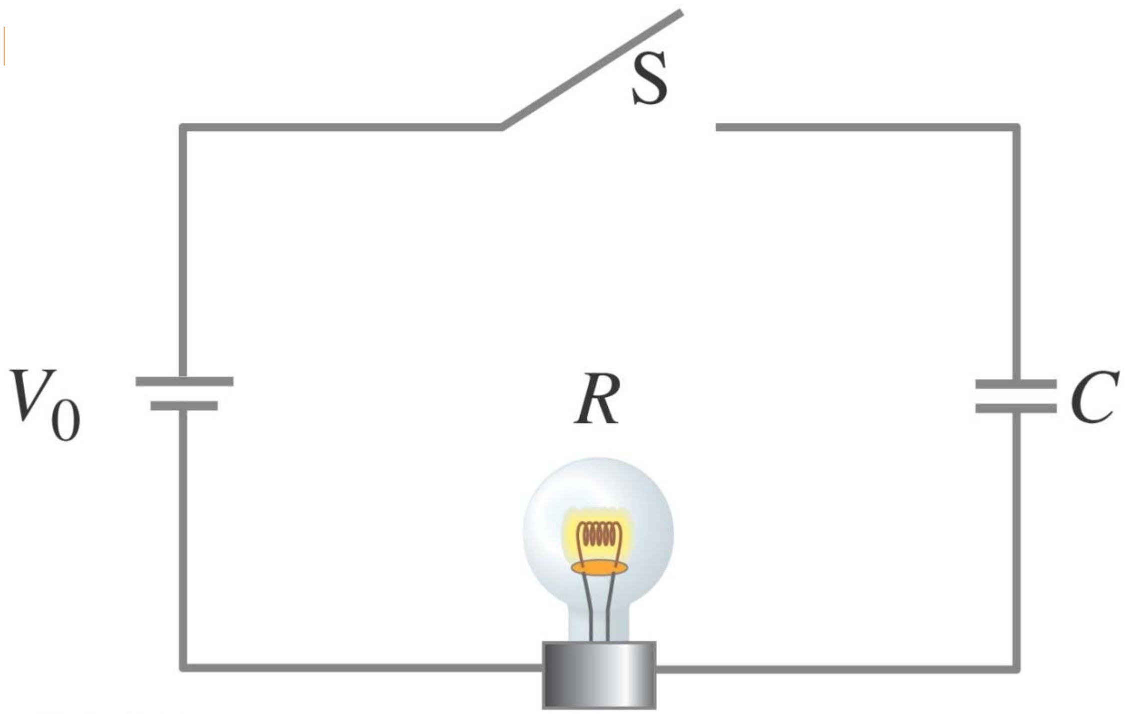


STUDY SOLUTION

26-5 Circuits Containing Resistor and Capacitor (*RC* Circuits)

Conceptual Example 26-13: Bulb in *RC* circuit.

In the circuit shown, the capacitor is originally uncharged. Describe the behavior of the lightbulb from the instant switch S is closed until a long time late

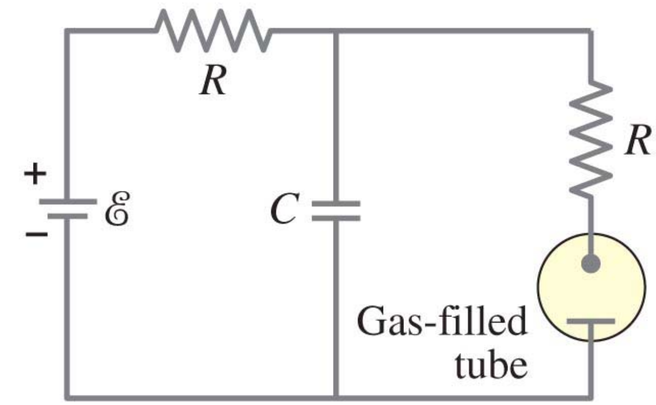


26-5 Circuits Containing Resistor and Capacitor (*RC* Circuits)

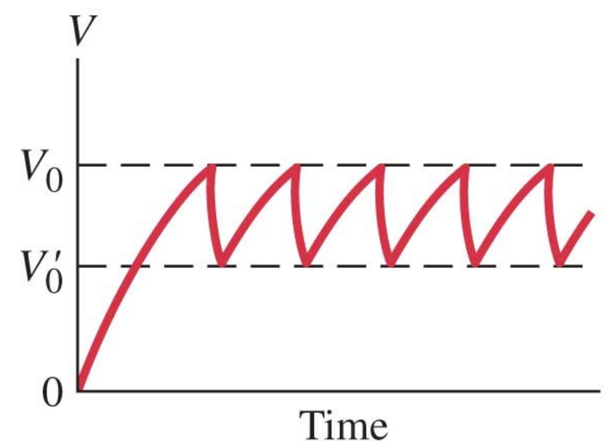
Example 26-14: Resistor in a turn signal.

Estimate the order of magnitude of the resistor in a turn-signal circuit.

See ESTIMATE SOLUTION



(a)



APPS: SAWTOOTH FOR BLINKING LIGHT. =Flasher unit, windshield wipers Heart pacemaker etc!

26-6 Electric Hazards

Most people can "feel" a current of 1 mA; a few mA of current begins to be painful. Currents above 10 mA may cause uncontrollable muscle contractions, making rescue difficult. Currents around 100 mA passing through the torso can cause death by ventricular fibrillation.

Higher currents may not cause fibrillation, but can cause severe burns.

Household voltage can be lethal if you are wet and in good contact with the ground. Be careful!

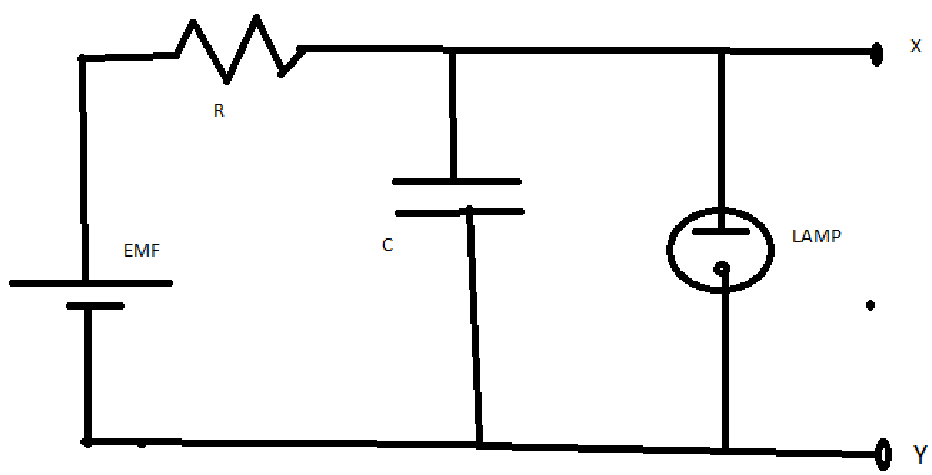
HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation(unless they are not too large or small in this case).

85. A 6 μF capacitor is charged through a 5 kΩ resistor by a 500 V power supply. How long does it require to acquire 99 percent of its final charge?

86. A A camera flash lamp has a capacitor with a time constant of 2.2sec If the capacitor charges through 200kΩ, what is the capacitance?

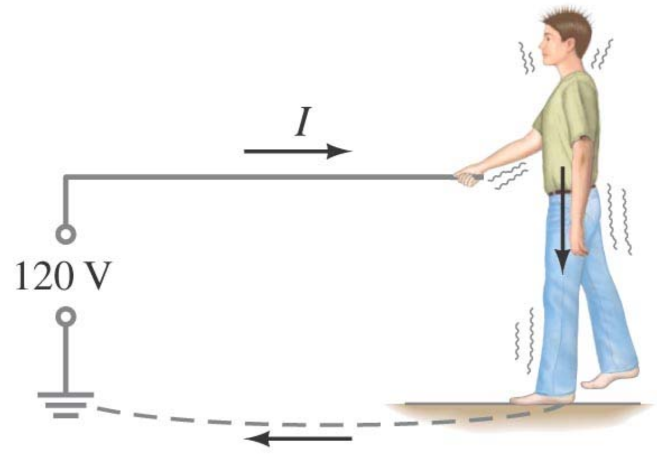
87.A miniature neon lamp (see fig) consist of two electrodes embedded in a Glass capsule filled with Neon gas. When the voltage applied to the tube Reaches 70 V , a gas discharge occurs (flash of orange light). A short time Due to the behavior of the gas the voltage goes to zero and again climbs backTo 70 V producing another flash. This is a relaxation oscillator circuit that can be used to create a pulsating voltage to terminals X and Y as shown here. What is the pulsating frequency for this circuit if V =120 V, R=100kΩ and C =2μF?

HINT Frequency =1/period
Period is the time between
Flashes in this case.



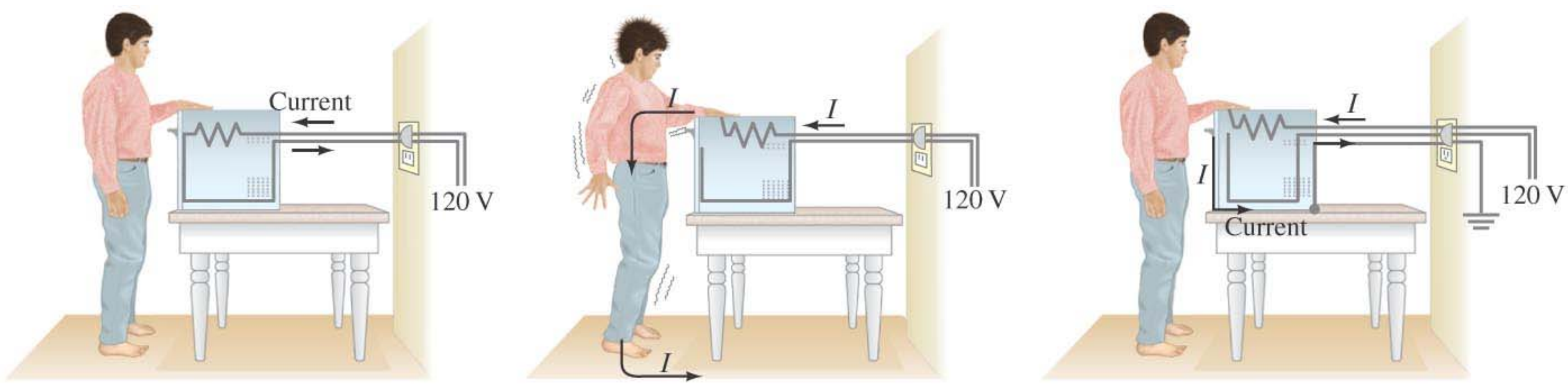
26-6 Electric Hazards

A person receiving a shock has become part of a complete circuit.



26-6 Electric Hazards

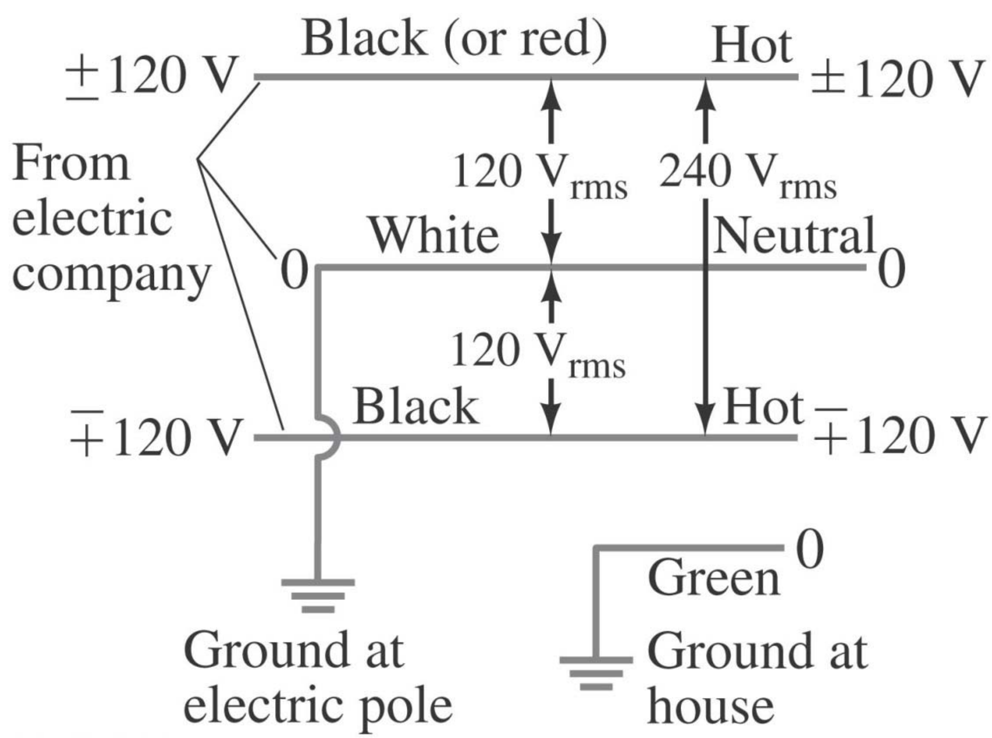
Faulty wiring and improper grounding can be hazardous. Make sure electrical work is done by a professional.



26-6 Electric Hazards

The safest plugs are those with three prongs; they have a separate ground line.

Here is an example of household wiring – colors can vary, though! Be sure you know which is the hot wire before you do anything.

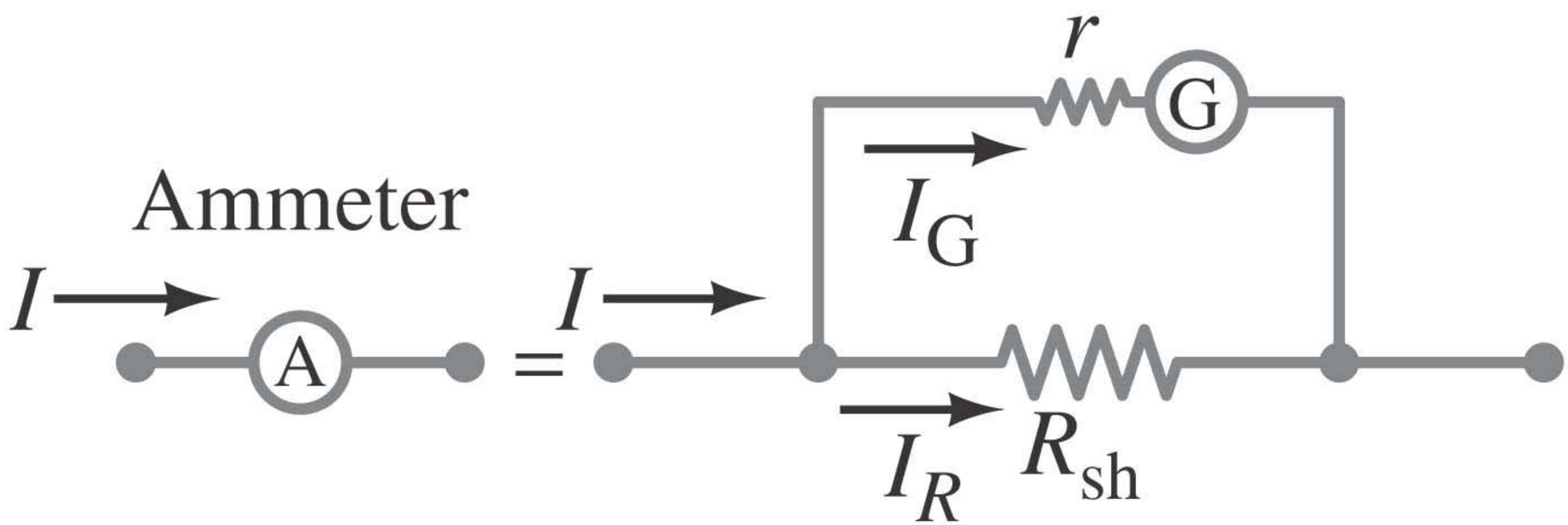


Skip 26-7

26-7 Ammeters and Voltmeters

An ammeter measures current; a voltmeter measures voltage. Both are based on galvanometers, unless they are digital.

The current in a circuit passes through the ammeter; the ammeter should have low resistance so as not to affect the current.



26-7 Ammeters and Voltmeters

Example 26-15: Ammeter design.

Design an ammeter to read 1.0 A at full scale using a galvanometer with a full-scale sensitivity of 50 μA and a resistance r = 30 Ω. Check if the scale is linear.

26-7 Ammeters and Voltmeters

A voltmeter should not affect the voltage across the circuit element it is measuring; therefore its resistance should be very large.

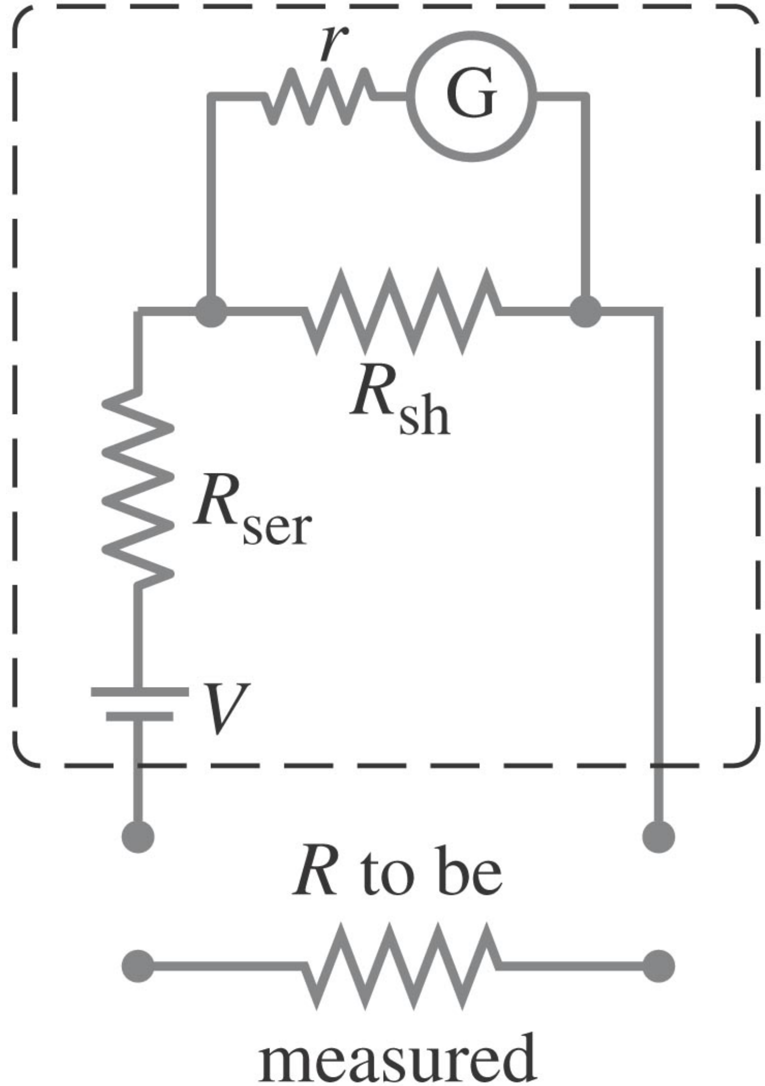
26-7 Ammeters and Voltmeters

Example 26-16: Voltmeter design.

Using a galvanometer with internal resistance 30 Ω and full-scale current sensitivity of 50 μA, design a voltmeter that reads from 0 to 15 V. Is the scale linear?

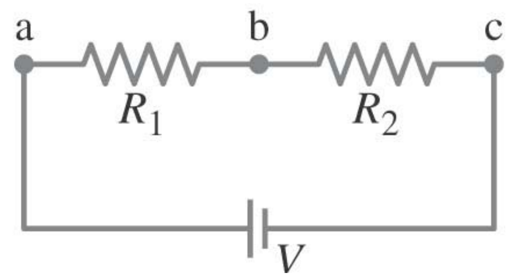
26-7 Ammeters and Voltmeters

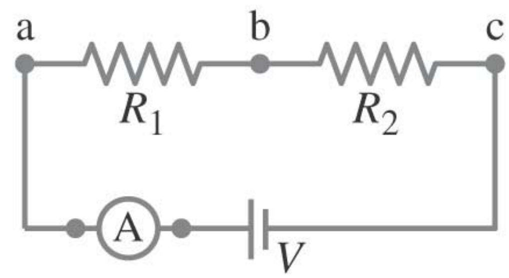
An ohmmeter measures resistance; it requires a battery to provide a current.

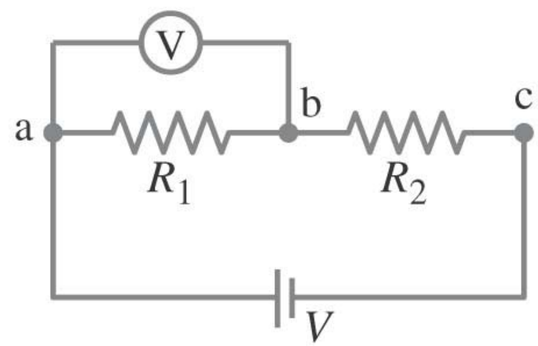


26-7 Ammeters and Voltmet

Summary: An ammeter must be in series with the current it is to measure; a voltmeter must be in parallel with the voltage it is to measure.

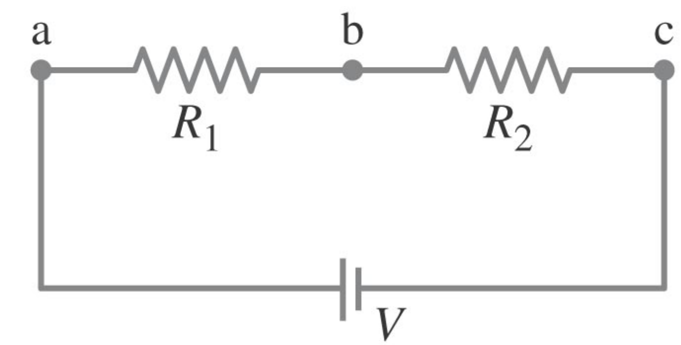






26-7 Ammeters and Voltmeters

Example 26-17: Voltage reading vs. true voltage.



Suppose you are testing an electronic circuit which has two resistors, R_1 and R_2, each 15 kΩ, connected in series as shown in part (a) of the figure. The battery maintains 8.0 V across them and has negligible internal resistance. A voltmeter whose sensitivity is 10,000 Ω/V is put on the 5.0-V scale. What voltage does the meter read when connected across R_1, part (b) of the figure, and what error is caused by the finite resistance of the meter?