## DC Circuits

M 2/6/06

- Resistance Review
- Following the potential around a circuit
- Multiloop Circuits
- RC Circuits

**Homework for today:**

Read Chapters 26, 27
Chapter 26 Questions 1, 3, 10
Chapter 26 Problems 1, 17, 18, 35, 77

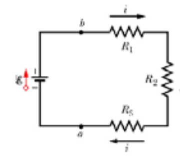
**Homework for tomorrow:**

Chapter 27 Questions 1, 3, 5
Chapter 27 Problems 7, 19, 49
WileyPlus assignment: Chapters 26, 27

## Review: Series and Parallel Resistors

**Series:**

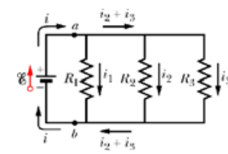
$$R = R_1 + R_2 + R_3$$



*Why?*

**Parallel:**

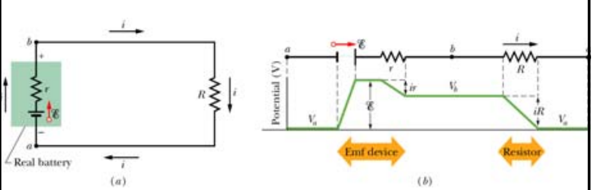
$$1/R = 1/R_1 + 1/R_2 + 1/R_3$$



*Why?*

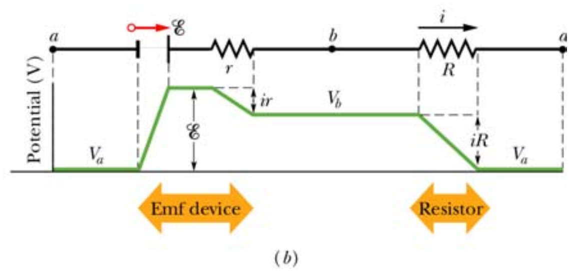
## Following the Potential

**Study Fig. 27-4 in the text to see how the potential changes from point to point in a circuit.**



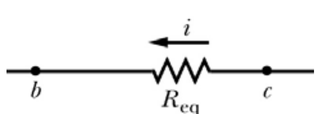

Note the net change around the loop is zero.

## Following the Potential




Note the net change around the loop is zero.

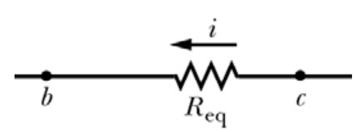
## Q.27-1



**With the current *i* flowing as shown, which is at the *higher potential,* point *b* or point *c*?**

1) B is higher
2) C is higher
3) They are the same
4) Not enough information

## Solution

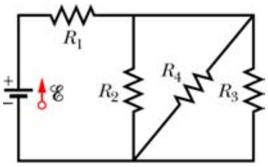


With the current ***i*** flowing as shown, which is at the ***higher potential,*** point ***b*** or point ***c***?

**Solution:** Current flows from high to low potential just like water flows down hill.

**(1) *b* is higher** **(2) *c* is higher**
**(3) they're the same** **(4) not enough info**

## Example: Problem 27-30



$\mathcal{E} = 6.0\,V \quad R_1 = 100\,\Omega$

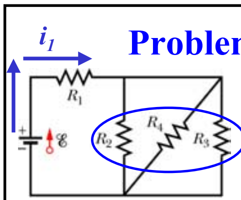
$R_2 = R_3 = 50\,\Omega$

$R_4 = 75\,\Omega$

**(a)** Find the equivalent resistance of the network.

**(b)** Find the current in each resistor.

## Problem 27-30 (part a)



$\mathcal{E} = 6.0\,V \quad R_1 = 100\,\Omega$

$R_2 = R_3 = 50\,\Omega$

$R_4 = 75\,\Omega$

**(a)** Find the equivalent resistance of the network.

$1/R_{234} = 1/R_2 + 1/R_3 + 1/R_4 = 16/300$

$So \quad R_{234} = 300/16 = 19\,\Omega$

*Now* $R_1$ *and* $R_{234}$ *are in series so*

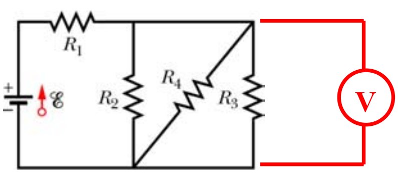
$R_{eq} = R_1 + R_{234} = 100\,\Omega + 19\,\Omega = \underline{119\,\Omega}$

**(b)** Now current $\quad i_1 = \mathcal{E}/R_{eq} = 50\,mA$

## Problem 27-30 (part b)

**(b)** Find the current in each resistor.

First note that $i_2R_2 = i_3R_3 = i_4R_4$.



$V = iR_{234}$

$= .050\,A \times 19\,\Omega$

$= 0.95\,V$

So
$i_2 = V/R_2 = .95/50 = 19\,mA$
$i_3 = V/R_3 = .95/50 = 19\,mA$
$i_4 = V/R_4 = .95/75 = 12\,mA$

**Check: These three add up to $i_1$ = 50 mA.**

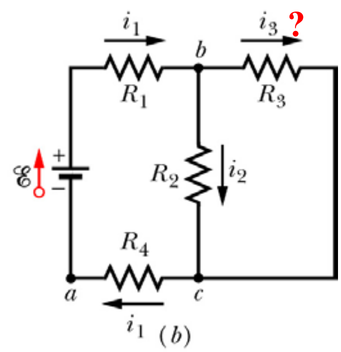
## Q.27-2

$R_2 = 2\,\Omega$

$R_3 = 3\,\Omega$

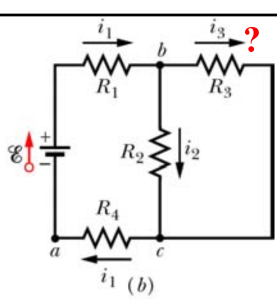
$i_2 = 6\,A$

$i_3 = ?$



**Calculate $i_3$, find the closest single-digit number (0-9).**

## Q.27-2



$R_2 = 2\,\Omega$

$R_3 = 3\,\Omega$

$i_2 = 6\,A$

$i_3 = ?$

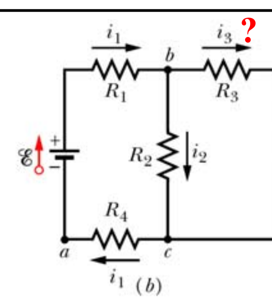
1) 1 A
2) 2 A
3) 3 A
4) 4 A
5) 5 A
6) 6 A
7) 7 A
8) 8 A
9) 9 A

## Q.27-2

$R_2 = 2\,\Omega$

$R_3 = 3\,\Omega$

$i_2 = 6\,A$



$V_b - V_c = i_2R_2 = i_3R_3$

$\therefore i_3 = \frac{i_2R_2}{R_3} = \frac{2}{3}i_2 = 4\,A$

**4**

## More Complicated Circuits

**How do we solve a problem with more than one emf and several loops? We can't do it just by series and parallel resistor combinations.**

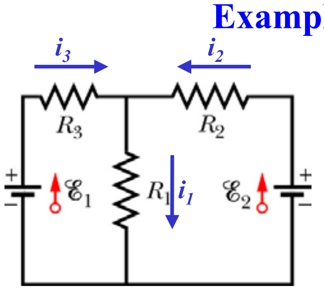
**?**

## Rules for Multiloop Circuits

- ***The net voltage change around any loop is zero.***
  **"Energy conservation"**
- ***The net current into any junction is zero.***
  **"Charge conservation"**

**Using these two rules we can always get enough equations to solve for the currents if we are given the emfs and resistances.**

## Example




$\mathcal{E}_1 = 24\,V$

$\mathcal{E}_2 = 12\,V$

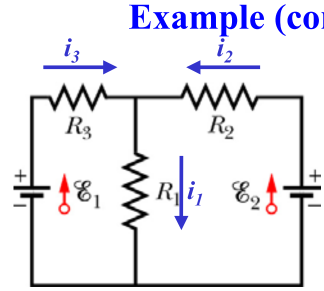
$R_1 = 5\,\Omega$

$R_2 = R_3 = 30\,\Omega$

***Find all currents!***

First define unknowns: $i_1, i_2, i_3$

## Example (continued)




Left-hand loop:

$\mathcal{E}_1 - i_3 R_3 - i_1 R_1 = 0$

Right-hand loop:

$\mathcal{E}_2 - i_2 R_2 - i_1 R_1 = 0$

Junction:

$i_1 = i_2 + i_3$

Algebra: solve 3 equations for 3 unknowns $i_1, i_2, i_3$

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Loop and junction equations:

$\mathcal{E}_1 - i_3 R_3 - i_1 R_1 = 0$ $\qquad i_1 = i_2 + i_3$

$\mathcal{E}_2 - i_2 R_2 - i_1 R_1 = 0$

Put in the given numbers and also replace $i_1$ by $i_2+i_3$:

$5i_1 + 30i_3 = 5i_2 + 35i_3 = 24$

$5i_1 + 30i_2 = 35i_2 + 5i_3 = 12$

Solve two equations in two unknowns to get:

$i_2 = 250\,mA \qquad i_3 = 650\,mA$

Add to get $\qquad i_1 = i_2 + i_3 = 900\,mA$

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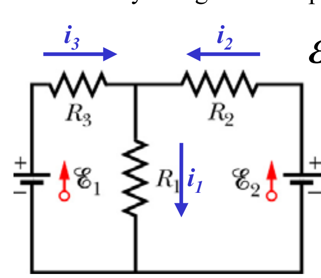
Check by using outer loop:




$\mathcal{E}_1 - i_3 R_3 + i_2 R_2 - \mathcal{E}_2$

$= 0\ ?$

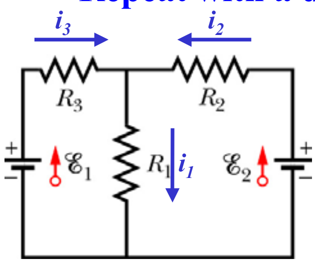
$24 - 30(.65 - .25) - 12$

$= 12 - 30 \times .40$

$= 12 - 12$

$= 0$

## Repeat with a different $R_1$




$\mathcal{E}_1 = 24V$

$\mathcal{E}_2 = 12V$

$R_1 = 40\Omega$

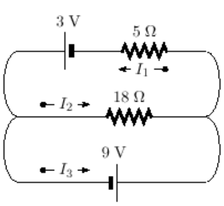
$R_2 = R_3 = 30\Omega$

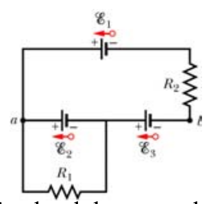
Exercise for the student: Same equations give ***negative*** $i_2$ in this case! This means ***current going downward*** through right-hand battery.

## Back to Basics

- Examples that don't involve so much algebra, but focus on the ideas of current and voltage.
- Even though you have a multiloop circuit so you need to write down the equations from the loop rule and the junction rule, you may not have to actually solve simultaneous equations.

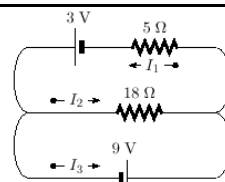
## Simpler Examples




Textbook homework problem 27-19

Both these problems can be solved for ***one unknown at a time,*** without messy algebra.




$9 + 18 \times I_2 = 0 \qquad I_2 = -0.5\ A$

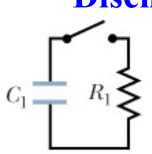
$9 - 5 \times I_1 + 3 = 0 \qquad I_1 = \frac{12}{5} = 2.4\ A$

$I_3 = I_1 - I_2 = 2.9\ A$

**Check:**

$P_{in} = 9I_3 + 3I_1 = 33.3\ W \qquad P_{out} = 5I_1^2 + 18I_2^2 = 33.3W$

## Discharging a Capacitor




Capacitor has charge $Q_0$.
At time t=0, close switch.
What is charge q(t) for t>0?

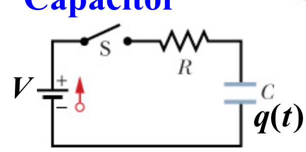
Obviously q(t) is a function which decreases gradually, approaching zero as t approaches infinity.

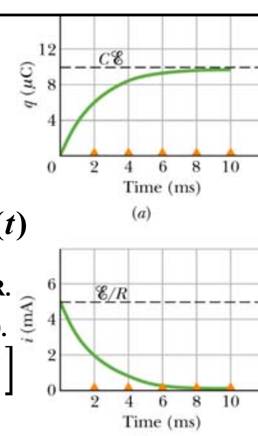
What function would do this? $q(t) = Q_0 e^{-t/\tau}$

But what is the time constant $\tau$?

Analyze circuit equation: find $\tau = RC$

## Charging a Capacitor




For small t, q=0 and i=V/R.

For large t, q=CV and i=0.

$q(t) = CV\left[1 - e^{-t/\tau}\right]$

$\tau = RC$

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Chapter 27 Problems 7, 19, 49
WileyPlus assignment: Chapters 26, 27

# Exam #1