(RC.L1.2-sols) Foundation Stage Solutions

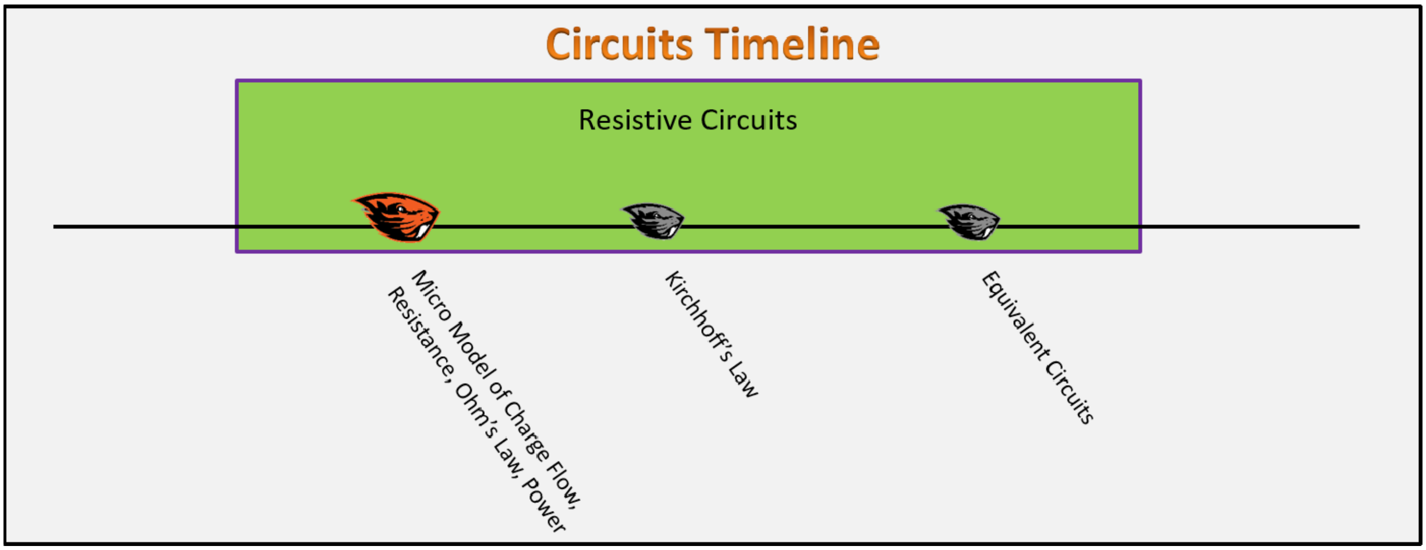
Thursday, March 29, 2018 8:34 PM

Circuits

Foundation Stage (RC.L1.2)

Lecture 1

Micro-model of Charge flow, Resistance, Ohm's Law, Power



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos ([Microscopic Charge Flow](#))
- **Knight** (College Physics : A strategic approach 3rd) ::
- ***Knight** (Physics for Scientists and Engineers 4th) ::
- **Giancoli** (Physics Principles with Applications 7th) ::

Warm up

RC.L1.2-01:

Description:

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

Problem Statement:

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Electric Force
- Charge
- Coulombs
- Electron
- Proton
- Neutron
- Conductor
- Charge transfer

Key Equations

$\Delta V = IR$	$I = \frac{\Delta q}{\Delta t}$
$\rho = \frac{1}{\sigma}$	$R = \rho \frac{L}{A}$

Key Concepts

- Coming soon to a lecture template near you.

Questions

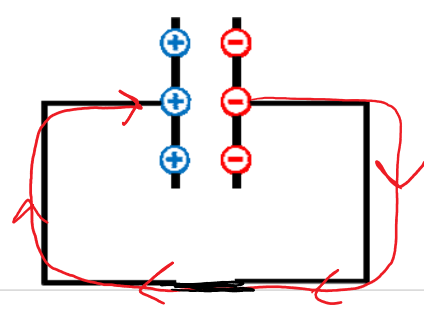
Act I: Microscopic Charge Flow

RC.L1.2-02:

Description: [?]

Learning Objectives: [?]

Problem Statement: Positive charges are placed on a metal plate which is held close to another metal plate which has an equal number of negative charges on it. What happens when we connect small wires attached to each plate?

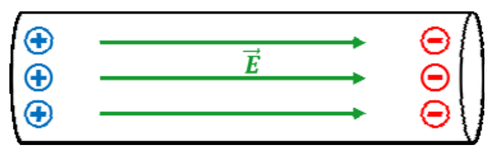


Current Flows!

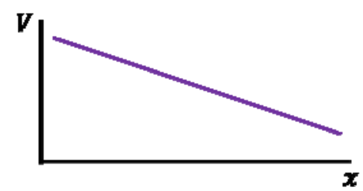
Three Explanations for Charge Flow (Current)

○ **Charge Gradient**

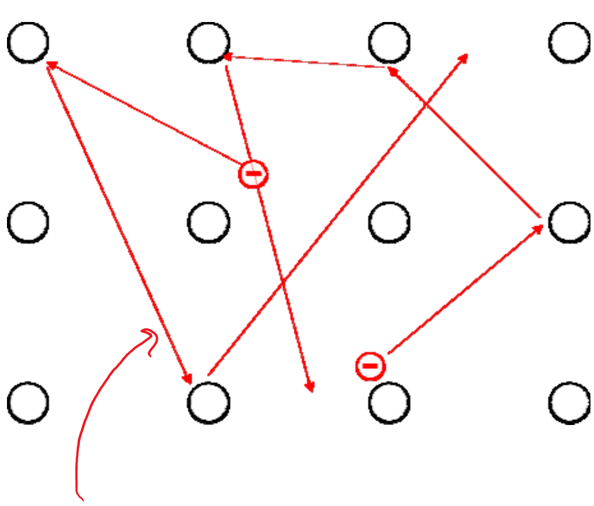
○ **Electric Field**



○ **Electric Potential "Hill"**

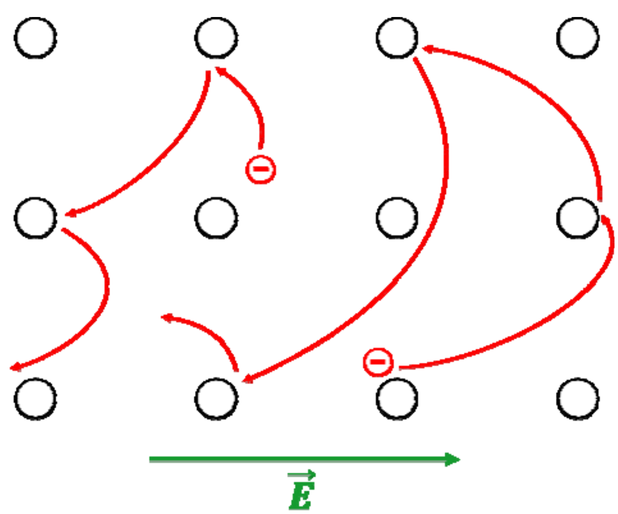


<u>Without Electric Field</u>



thermal

<u>With Electric Field</u>



← $\bar{v}$

	$\vec{E}$

thermal velocity is fast!

$\leftarrow \bar{v}$

average velocity, called the "drift velocity" is very slow

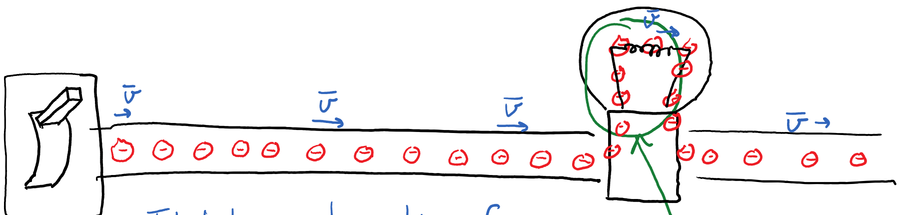
RC.L1.2-03:

Description: [?]

Learning Objectives: [?]

Problem Statement: Discuss with your neighbor what happens inside the wires when you turn on a light switch. Specifically, how long does it take the light to turn on?

(1) It turns on instantly
(2) The electricity travels at the speed of light to the lightbulb
(3) The electrons travel at some "pretty fast" speed to get to the lightbulb
(4) The electrons travel REALLY slowly to get to the lightbulb
(5) The lightbulb doesn't *exist* maaannn, it's just a construct of your *imagination*



It takes a long time for an electron to travel to the lightbulb, but all electrons in the wire start moving when switch is flipped ⇒ these electrons will light the bulb

RC.L1.2-04:

Description: [?]

Learning Objectives: [?]

Problem Statement: The drift velocity of electrons in copper with 0.1 Amp current is $10^{-5}\ m/s$. How far does an electron travel in an hour?

$$v = \frac{\Delta x}{\Delta t} \Rightarrow \Delta x = v \Delta t$$

$$\Delta x = \left(10^{-5} \tfrac{m}{s}\right)\left(3600\ s\right) = \underline{3.6\ cm} \ !!!$$

RC.L1.2-05:

Description: [?]

Learning Objectives: [?]

Problem Statement: Charges are not able to move *completely* freely through a wire, i.e. there is some resistance to their motion. If charges are flowing through a conducting wire, which one of the following statements are true?

(1) The electric field inside a conductor is zero.
(2) The electric potential difference between the ends of the wire is zero.
(3) The electric field is non-zero inside the wire.
(4) The electric potential difference between the ends of the wire is not zero.

Act II: Resistance and Resistivity

RC.L1.2-06:

Description: [?]

Learning Objectives: [?]

Problem Statement: You are attempting to make a resistive wire for melting ice off windows that will be connected to a constant voltage source. Which of the following quantities are independent of the length and radius of the wire you use?

(1) conductivity ~ σ
(2) conductance
(3) free electron density ~ n_e
(4) resistivity ~ ρ

(1) [illegible]
(2) conductance
(3) free electron density ~ n_e
(4) resistivity ~ ρ
(5) resistance
(6) current through the wire
(7) voltage difference across the wire

↖ ΔV determined by source

RC.L1.2-07:

Description: [?]

Learning Objectives: [?]

Problem Statement: You need to increase the radius of a resistive wire by a factor of 2, but keep the resistance the same. By what factor does the length need to change?

(1) 1/4
(2) 1/2
(3) 2/3
(4) 3/2
(5) 2
(6) 4
(7) 16

$$R = \rho \frac{L}{A} = \rho \frac{L}{\pi r^2}$$

two factors of radius

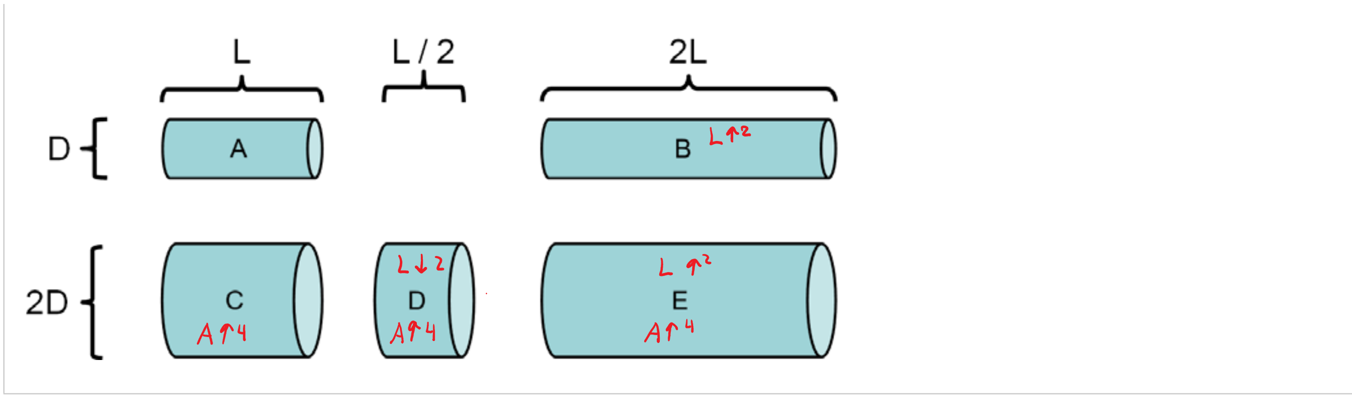
one of length

RC.L1.2-08:

Description: [?]

Learning Objectives: [?]

Problem Statement: The pictured resistors are made from the same material with a resistivity, ρ. Rank the resistances, R, of the resistors from least to greatest.



$R = \rho \frac{L}{A}$

$R_D < R_C < R_E < R_A < R_B$

Act III: Macroscopic Current Model, Ohm's Law, Power

RC.L1.2-09:

Description: Introducing the definition of current [?]

Learning Objectives: [?]

Problem Statement: An electric car accelerates for 8.0 s by drawing energy from its 320-V battery pack. During this time the current through the battery is 163 A. How many Coulombs of charge were transferred through the battery?

(1) 40 C
(2) 800 C
(3) 1300 C
(4) 14,400 C
(5) 25,600 C

$I = \frac{\Delta q}{\Delta t}$ $\quad [A] = \frac{[C]}{[s]}$

$\Rightarrow \Delta q = I \Delta t = (163\ A)(8\ s) = 1304\ C$

RC.L1.2-10:

Description: [?]

Learning Objectives: [?]

Problem Statement: If the 320 V are multiplied by the Coulombs of charge transferred through the battery during this time, what type of quantity would result?

(1) Force
(2) Electric Potential
(3) Energy
(4) Electric Field
(5) Current
(6) Resistance
(7) Work

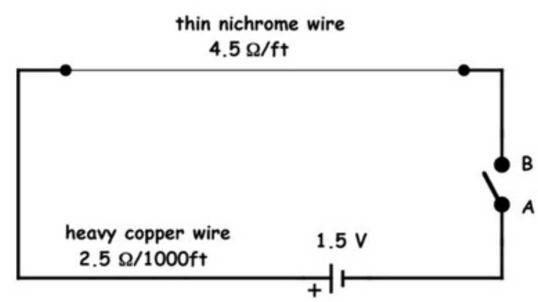
$U = qV$

RC.L1.2-11:

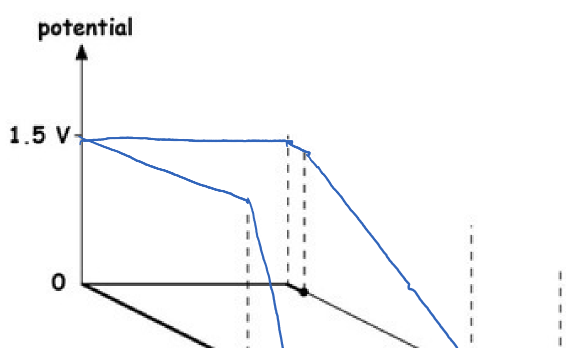
Description: [?]

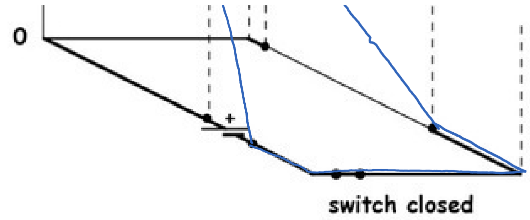
Learning Objectives: [?]

Problem Statement: Refer to the circuit constructed here:



In the 3D diagram below, sketch the potential around the circuit shown above when the switch is closed.





$\Delta V = I R$

copper wire has small resistance

$\Rightarrow$ little voltage "drop"

nichrome has large resistance

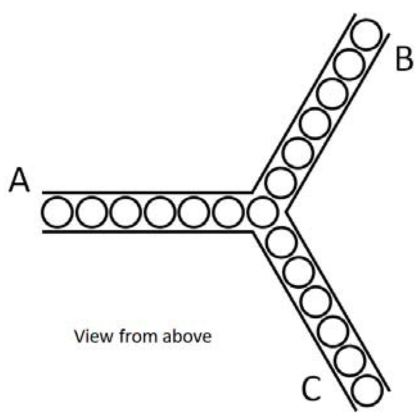
$\Rightarrow$ lots of voltage drop

RC.L1.2-12:

Description: [?]

Learning Objectives: [?]

Problem Statement: Consider the Y-shaped tube shown below. Suppose 2 balls per second are stuffed into the opening at A. The number of balls per second that come out of the tube at B is



(1) always equal to 2
(2) always smaller than or equal to 2
(3) always larger than or equal to 2
(4) equal to 1
(5) depends on what happens at C

\# balls in = # balls out

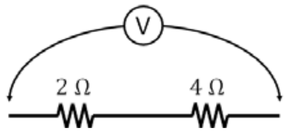
$\Delta N_A = \Delta N_B + \Delta N_C$

RC.L1.2-13:

Description: [?]

Learning Objectives: [?]

Problem Statement: A constant potential difference *V* is applied across two resistors connected in series as shown. The current through the 2 Ω resistor is 2 A.



(a) What is the current through the 4 Ω resistor?

(1) 0 A
(2) 1 A
(3) 2 A
(4) 4 A
(5) Need to know voltage difference, V

current in = current out

(b) What is the voltage across each resistor?

$\Delta V = I R$

$\Delta V_1 = (2A)(2\Omega) = 4V$

$\Delta V_2 = (2A)(4\Omega) = 8V$

(c) What is the power dissipated by the 2 ohm resistor?

$P = I^2 R = I \Delta V = \frac{\Delta V^2}{R}$

$P = 8 W$

RC.L1.2-14:

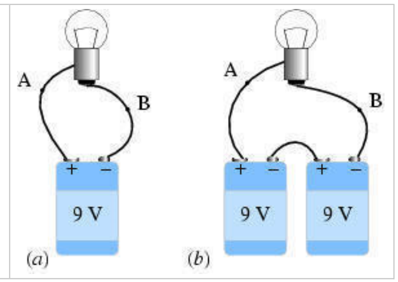
Description: [?]

Learning Objectives: [?]

Problem Statement: A light bulb is connected to a 9-V battery. If a second battery is added in a series as shown in (*b*), how many of the following change?

- The current *I* at A
- The potential difference V_{AB} between A and B
- The resistance *R* of the light bulb

property of light bulb



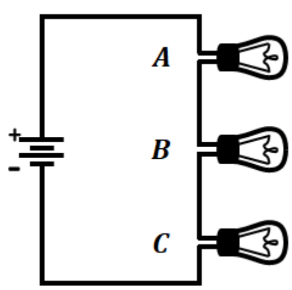
(1) All three
(2) Two
(3) One
(4) It depends

RC.L1.2-15:

Description: [?]

Learning Objectives: [?]

Problem Statement: Consider the following circuit with three light bulbs of equal resistance.



(a) Rank the relative brightness of each bulb.

A = B = C

(a) Rank the relative brightness of each bulb.

A = B = C

(b) If $R_1 < R_2 = R_3$, What will be the relative brightness of each bulb?

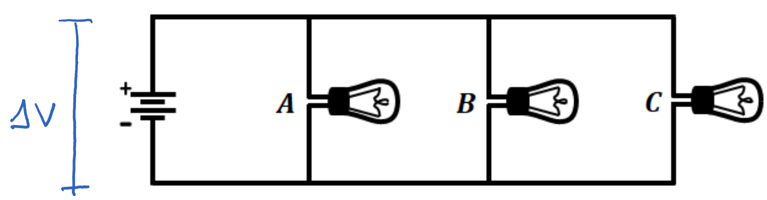
$P = I^2 R$ (I^2: same for each) $\Rightarrow P_A < P_B = P_C$

RC.L1.2-16:

Description: [?]

Learning Objectives: [?]

Problem Statement: Consider the following circuit with three light bulbs. Which equation would be most useful for determining the relative brightness of each bulb if the relative resistances are known?



(1) $\Delta V = IR$
(2) $P = \frac{\Delta V^2}{R}$
(3) $P = I\Delta V$
(4) $P = I^2 R$

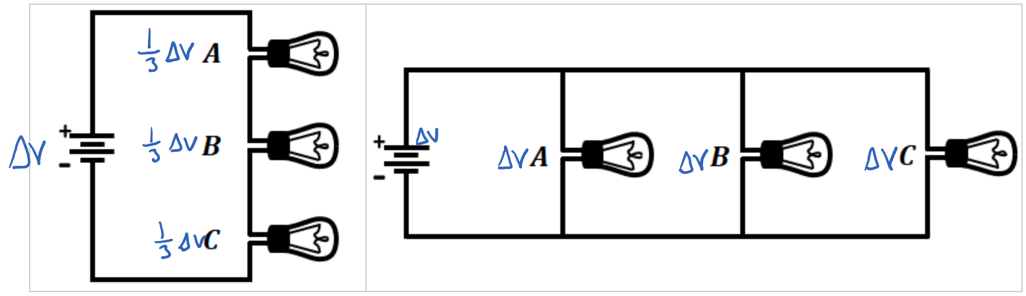
ΔV = same for each
R = known

RC.L1.2-17:

Description: [?]

Learning Objectives: [?]

Problem Statement: Consider the two circuits with three identical light bulbs and an identical voltage source. Which circuit will have brighter bulbs?



(1) Series
(2) Parallel
(3) Equal

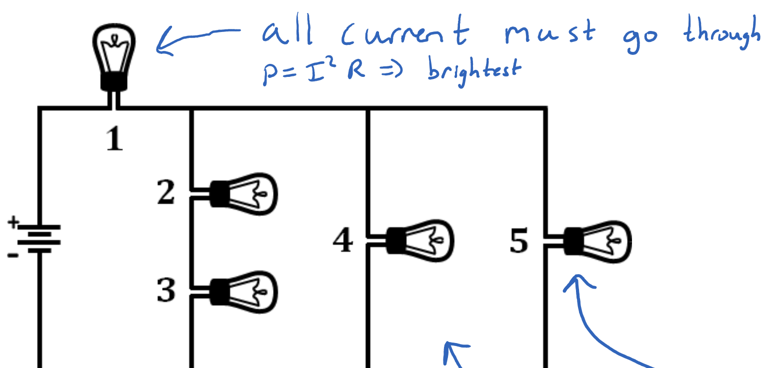
$P = \frac{\Delta V^2}{R}$

RC.L1.2-18:

Description: [?]

Learning Objectives: [?]

Problem Statement: Consider the following circuit with five equal resistance light bulbs. What is the relative brightness of each bulb?



½ the voltage drop of and

(1) 1 > 2 = 3 > 4 = 5
(2) 1 < 2 = 3 < 4 = 5

(1) 1 > 2 = 3 > 4 = 5
(2) 1 < 2 = 3 < 4 = 5
(3) 1 > 2 = 3 = 4 = 5
(4) 1 > 4 = 5 > 2 = 3
(5) 1 < 4 = 5 < 2 = 3

$\frac{1}{2}$ the voltage drop of) and)

$P = \frac{\Delta V^2}{R} \Rightarrow$ 4 & 5 > 2 & 3

RC.L1.2-19:

Description: [?]

Learning Objectives: [?]

Problem Statement: 3.5 A of current is flowing through a 4.2 Ohm resistor. Find:

a) The voltage drop across the resistor.

$\Delta V = I R$

$= (3.5\ A)(4.2\ \Omega) = 14.1\ V$

b) The power dissipated by the resistor.

$P = I^2 R = \frac{\Delta V^2}{R} = I \Delta V = 49.35\ W$

c) How much potential energy each electron is losing by traveling through the resistor.

$U = q \Delta V = (1.6 \times 10^{-19}\ C)(14.1\ V)$

$= 2.256 \times 10^{-18}\ J$

Conceptual questions for discussion

1. Coming soon to a lecture template near you.

Hints

RC.L1.2-01: No hints.

RC.L1.2-02: No hints.

RC.L1.2-03: No hints.

RC.L1.2-04: No hints.

RC.L1.2-05: No hints.

RC.L1.2-06: No hints.

RC.L1.2-07: No hints.

RC.L1.2-08: No hints.

RC.L1.2-09: No hints.

RC.L1.2-10: No hints.

RC.L1.2-11: No hints.

RC.L1.2-12: No hints.

RC.L1.2-13: No hints.

RC.L1.2-14: No hints.

RC.L1.2-15: No hints.

RC.L1.2-16: No hints.

RC.L1.2-17: No hints.