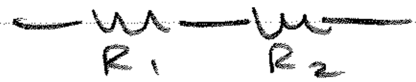
(A)

LECTURE 15 CONT

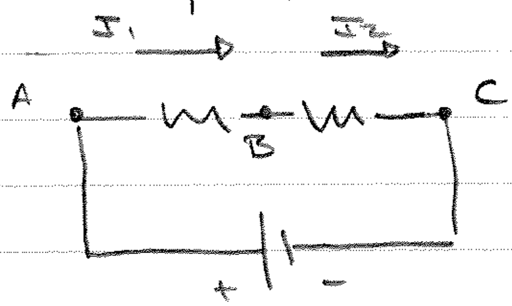
- MID SEMESTER SURVEY
- HW OVER SPRING BREAK
  - CIRCUITS, POWER CONSUMED BY RESISTOR, KIRCHOFF'S LAWS,
- DONE W/ CHS 17, 18 BY FRIDAY
- READ CH 19 OVER BREAK.
- READ SECS 17.6, 18.4, 18.5 TO DO NEXT WEEK'S HW.

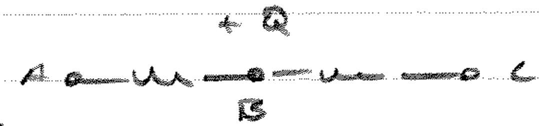
Lecture 15 cont

- **Series**



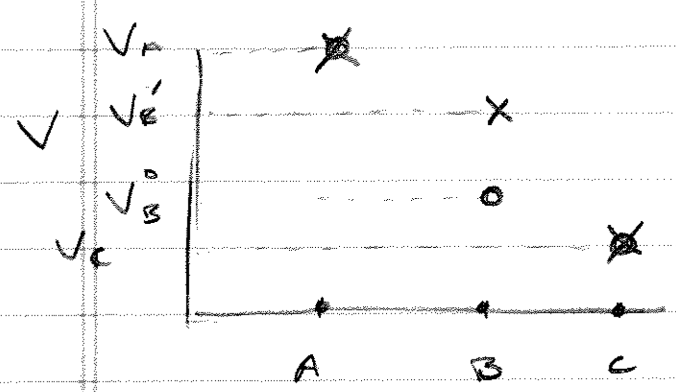
- Claim: current same, $R_1 = R_2$
- proof: they will be if they aren't already.





if $I_1 > I_2$, then rate of (+) charge into B > rate of charge out.

- What is influence on electric potential, i.e. voltages V_1, V_2?



o : before

x : after

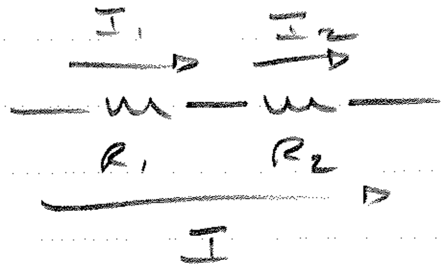
$V_1 = V_A - V_B$ gets smaller

(+) charge raises potential @ B.

$V_2 = V_B - V_C$ gets larger

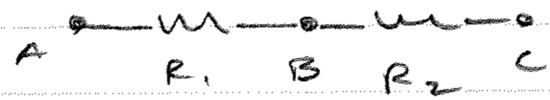
$V_A - V_C = V$ stays fixed by battery.

- SINCE R_1, R_2 DIDN'T CHANGE:
  - $I_1 = V_1/R_1$ SMALLER
  - $I_2 = V_2/R_2$ BIGGER
- I_1 AND I_2 GET CLOSER TOGETHER AS A RESULT OF CHARGE ACCUMULATION
- ACCUMULATION STOPS WHEN $I_1 = I_2$
- SO EVENTUALLY, WHEN ALL THE CURRENTS & VOLTAGES ARE STEADY ("IN STEADY STATE"), THE CURRENTS THROUGH EACH RESISTOR ARE THE SAME:



$I_1 = I_2 = I$ (CURRENT THROUGH SERIES COMBO)

- IN THIS CASE, VOLTAGE ACROSS SERIES COMBO GIVEN BY SUM OF VOLTAGE ACROSS EACH (NEXT PAGE):



$$V = V_A - V_C = V_A + (V_B - V_B) - V_C$$

$$= \left[V_A - V_B\right] + \left[V_B - V_C\right]$$

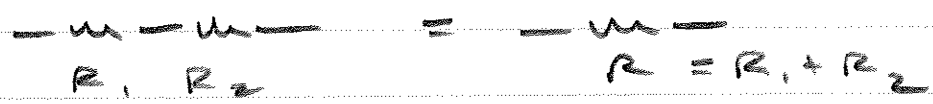
$$= V_1 + V_2$$

$$= IR_1 + IR_2 \quad \text{(OHM'S LAW)}$$

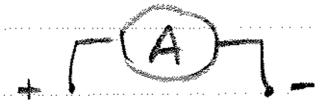
$$= I(R_1 + R_2)$$

$$\longrightarrow R = \frac{V}{I} = R_1 + R_2 \quad \checkmark$$

- SO WE CAN SAY: "RESISTORS IN SERIES ADD":

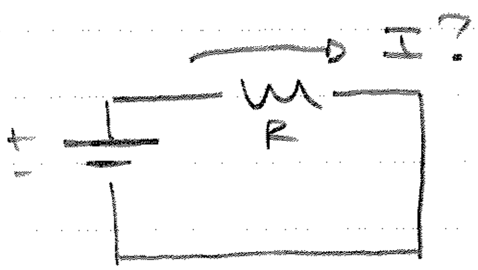


- APPLICATION: AMMETER
  - AN AMMETER IS A TWO TERMINAL DEVICE THAT MEASURES THE CURRENT TRAVELING IN/OUT OF ITS TWO TERMINALS:

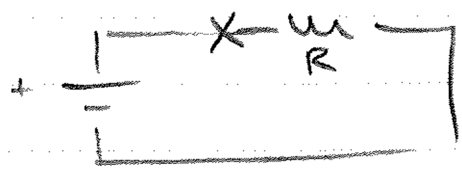


- ELECTRICALLY, IT LOOKS LIKE A RESISTOR!

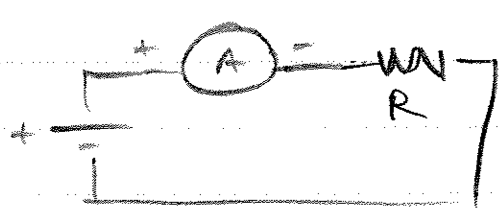
- A TYPICAL USE CASE IS TO MEASURE THE CURRENT THROUGH SOME RESISTANCE R



  - WE DO THIS BY BREAKING THE CIRCUIT BEFORE / AFTER THE RESISTOR:



AND INSERTING THE AMMETER BETWEEN THE TWO BROKEN ENDS!



Q: HOW SHOULD WE DESIGN OUR AMMETER SO THAT THE READING ON THE AMMETER BEST REPRESENTS THE CURRENT THROUGH R BEFORE WE BROKE THE CIRCUIT?

- MAKE AMMETER RESIS. LARGE?
- " " " SMALL?

A: W/ THE AMMETER IN SERIES W/ R, THEY HAVE A SERIES RESISTANCE OF $R + R_A$ ← AMMETER RESIS.

THE CURRENT THROUGH BOTH WE FOUND WAS EQUAL TO

$I = V/(R + R_A)$

- IF WE MAKE R_A SMALL, THEN:

$I \simeq V/R$, WHICH WAS THE CURRENT THROUGH R BEFORE WE BROKE THE CIRCUIT.

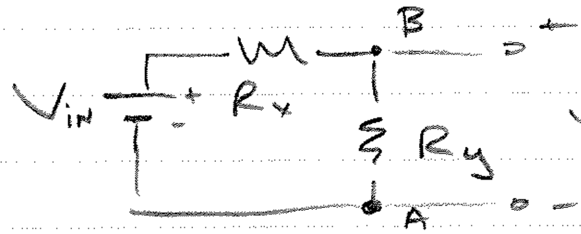
- IF WE MAKE R_A LARGE:

$I \simeq V/R_A << V/R$,

SO WE DO NOT GET AN ACCURATE MEASUREMENT UNLESS R_A SMALL, i.e. $R_A << R$

VOLTAGE DIVIDERS

- A COMMON & USEFUL CIRCUIT IS THE FOLLOWING "VOLTAGE DIVIDER":



  - IT TAKES AS AN INPUT A VOLTAGE V_{IN} & RETURNS A SMALLER VOLTAGE $V_{OUT} \equiv V_B - V_A$ AS AN OUTPUT.

  - HOW DOES V_{OUT} DEPEND ON V_{IN}, R_x, R_y?

- WELL, THE CURRENT THROUGH THE SERIES COMBINATION IS GIVEN BY

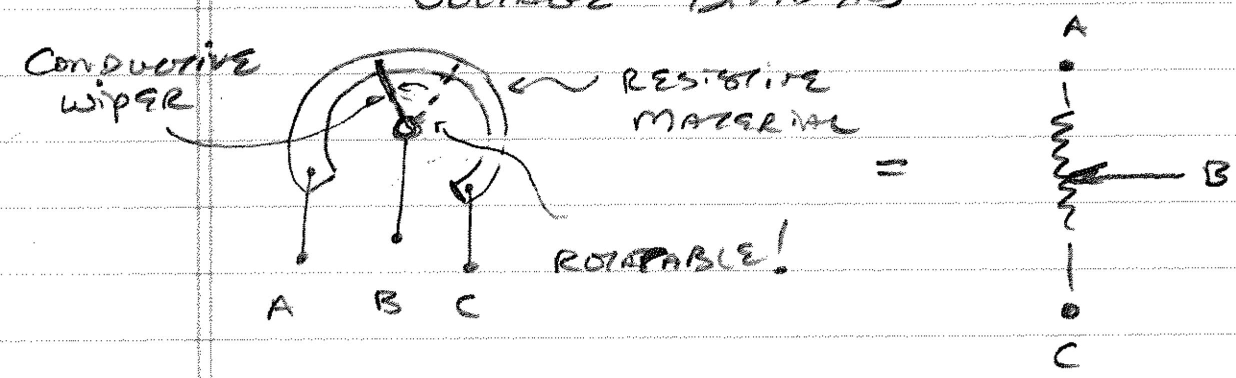
$$I = V_{IN}/R_x+R_y$$

- THIS CURRENTS TRAVELS THROUGH BOTH R_x & R_y, SO THE VOLTAGE $V_y = V_B - V_A = V_{OUT}$ ACROSS R_y IS

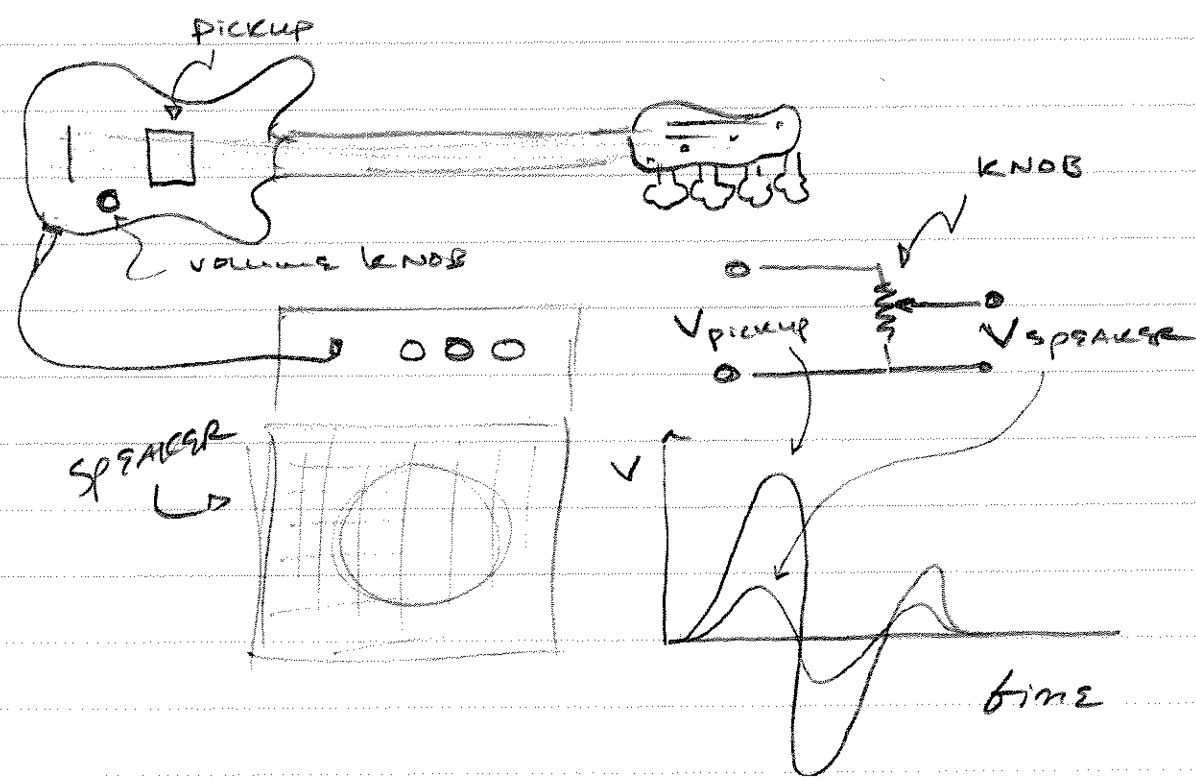
$$V_y = IR_y = V_{IN} \cdot \frac{R_y}{R_x+R_y}$$

- SO THAT THE OUTPUT VOLTAGE V_{out} IS EQUAL TO THE INPUT VOLTAGE V_{in} TIMES THE RATIO OF R_y TO THE TOTAL RESISTANCE $R_x + R_y$.

- POTENTIOMETERS ARE ADJUSTABLE VOLTAGE DIVIDERS:

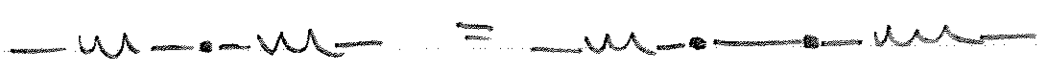


- USED AS VOLUME KNOBS ON STEREOS MUSICAL INSTRUMENTS:

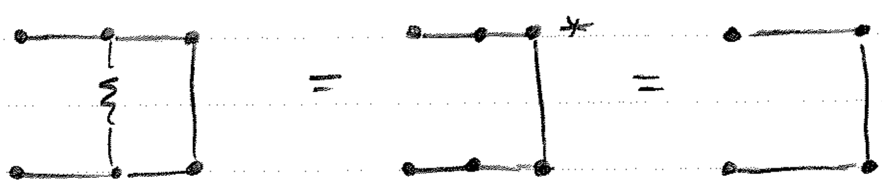


SHORTS & OPEN CIRCUITS

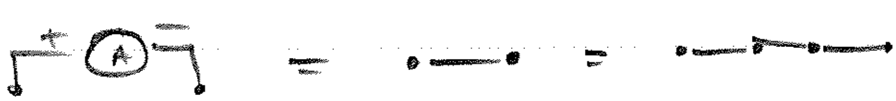
- "SHORT CIRCUIT" (OR "SHORT" FOR SHORT ☺):
  - A CONDUCTOR, I.E. A RESISTANCE SO LOW THAT WE CAN NEGLECT ANY VOLTAGE DROP ACROSS IT.
    - DOES NOT MEAN CURRENT IS ZERO!
  - DENOTED BY A WIRE: •——•
  - WE CAN ALWAYS ADD A SHORT CIRCUIT BETWEEN ANY TWO WAY JUNCTION W/OUT AFFECTING THE CIRCUIT:



- ALSO, ANY COMPONENTS IN PARALLEL W/ A SHORT CAN BE ELIMINATED* W/OUT AFFECTING THE REST OF THE CIRCUIT.



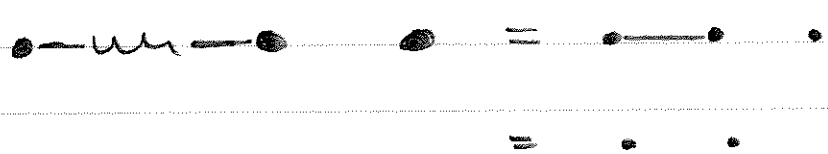
- AMMETERS ACT LIKE SHORTS, AS DO CLOSED SWITCHES:



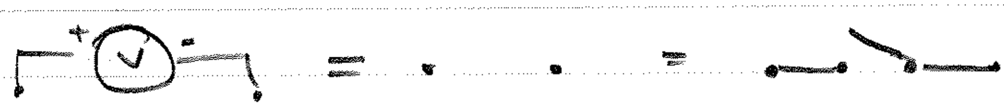
* I.E. REPLACED W/ OPEN CIRCUITS, DESCRIBED ON NEXT PAGE

- "OPEN CIRCUIT"
  - AN INSULATOR, I.E. A RESISTANCE SO LARGE THAT WE CAN NEGLECT ANY CURRENT TRAVELING THROUGH IT.
    - DOES NOT MEAN VOLTAGE IS ZERO!
  - DENOTED BY EMPTY SPACE: • •
  - CAN ADD OPEN CIRCUIT ACROSS ANY TWO POINTS:

- ANY COMPONENTS IN SERIES W/ AN OPEN CIRCUIT CAN BE ELIMINATED, I.E. REPLACED W/ SHORT CIRCUITS W/OUT AFFECTING REST OF CIRCUIT:

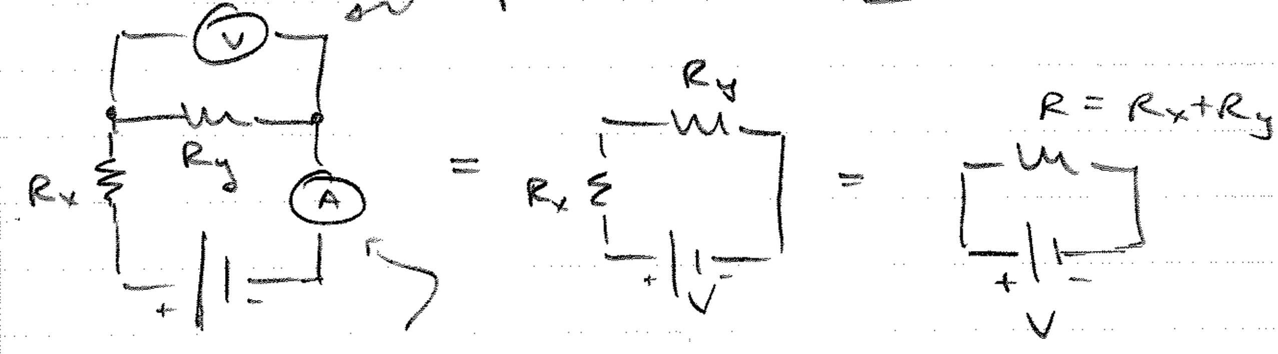


- VOLTMETERS ACT LIKE OPEN CIRCUITS, AS DO OPEN SWITCHES:



- APPLICATION: HW PROBLEM:

IN PARALLEL, DOES NOTHING

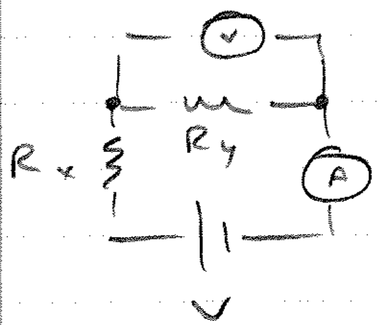


IN SERIES, DOES NOTHING

$$I = V/R = V/(R_x + R_y)$$

$$V_y = V \frac{R_y}{R_x + R_y}$$ (WE JUST HAVE VOLTAGE DIVIDER DESCRIBED EARLIER)

- PUTTING THE METERS BACK IN:



- AMMETER READS $I = V/(R_x + R_y)$
- VOLTMETER READS $V_y = V \frac{R_y}{R_x + R_y}$