Flight Controls and Basic Electronic

October 29, 2018

Overview

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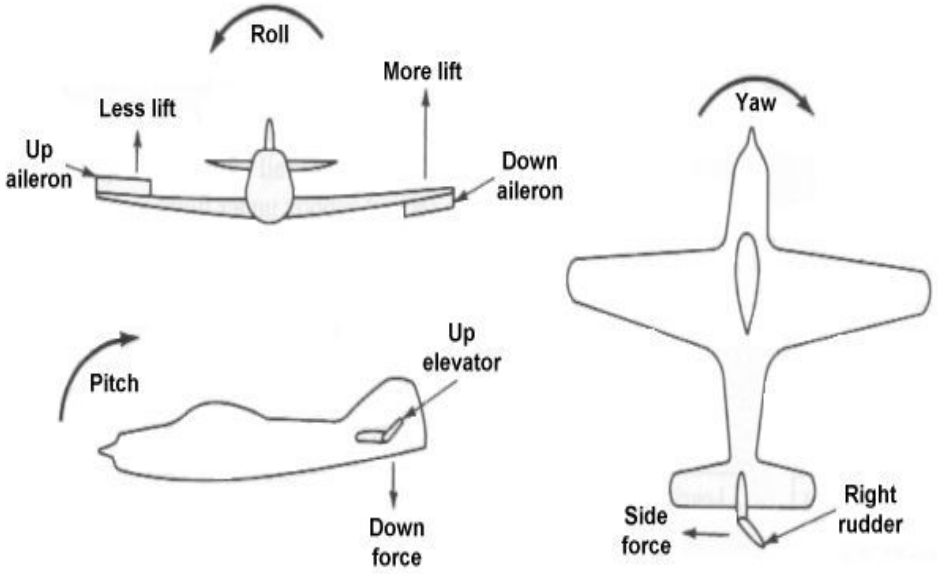
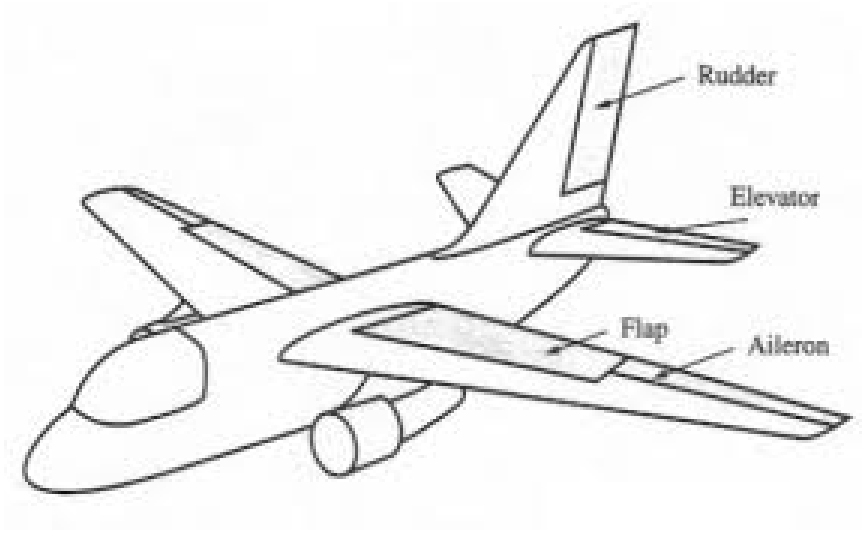
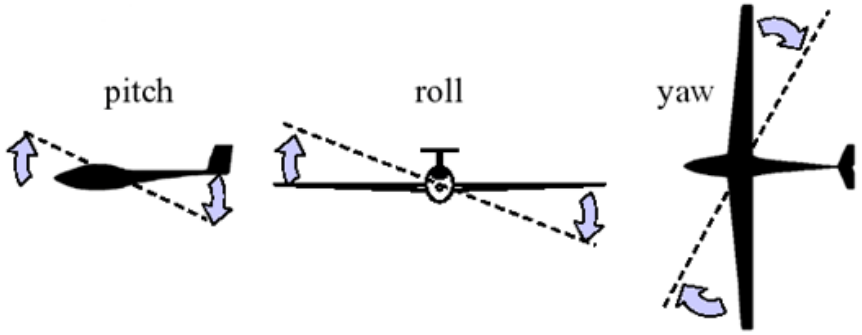
- Flight Controls (Plane, Helicopter, Quadcopter)
- Force and Acceleration of Quadcopter
- Basic Electronics: Ohm's Law
- Hints for HW3

Airplane Dynamics

Fixed wing aircraft use control surfaces to maneuver.

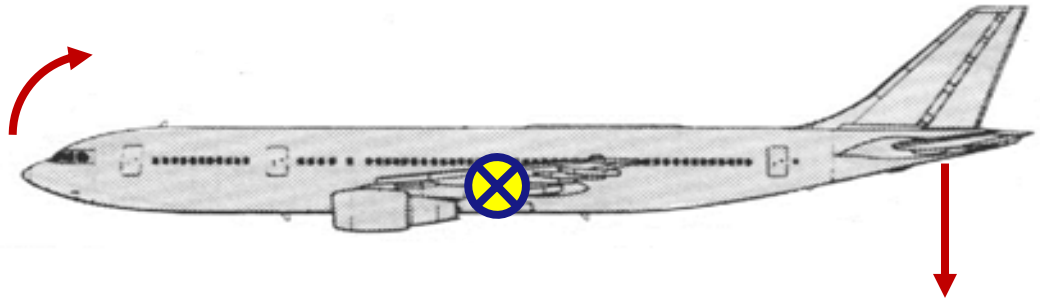


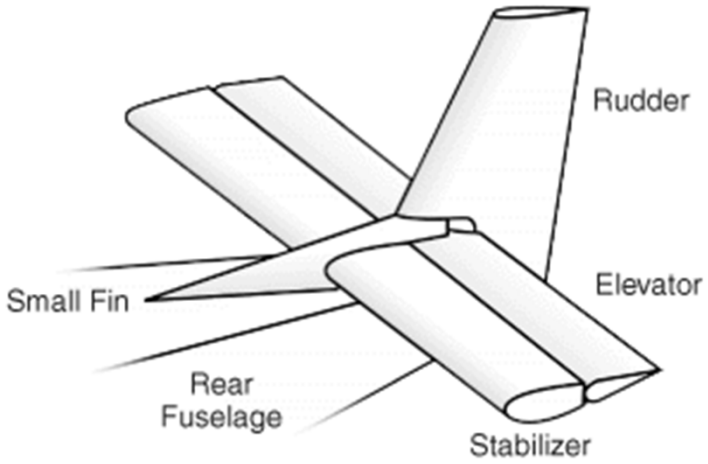


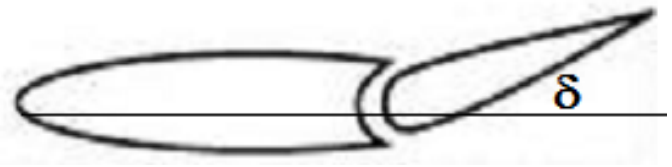


Pitch

Deflect rear flap called **E**LEVATOR to pitch the nose up or down



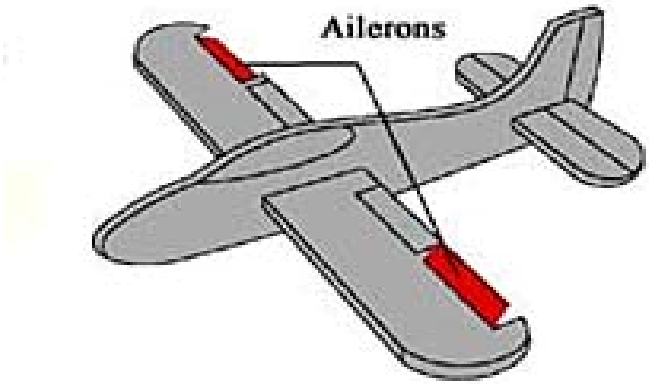


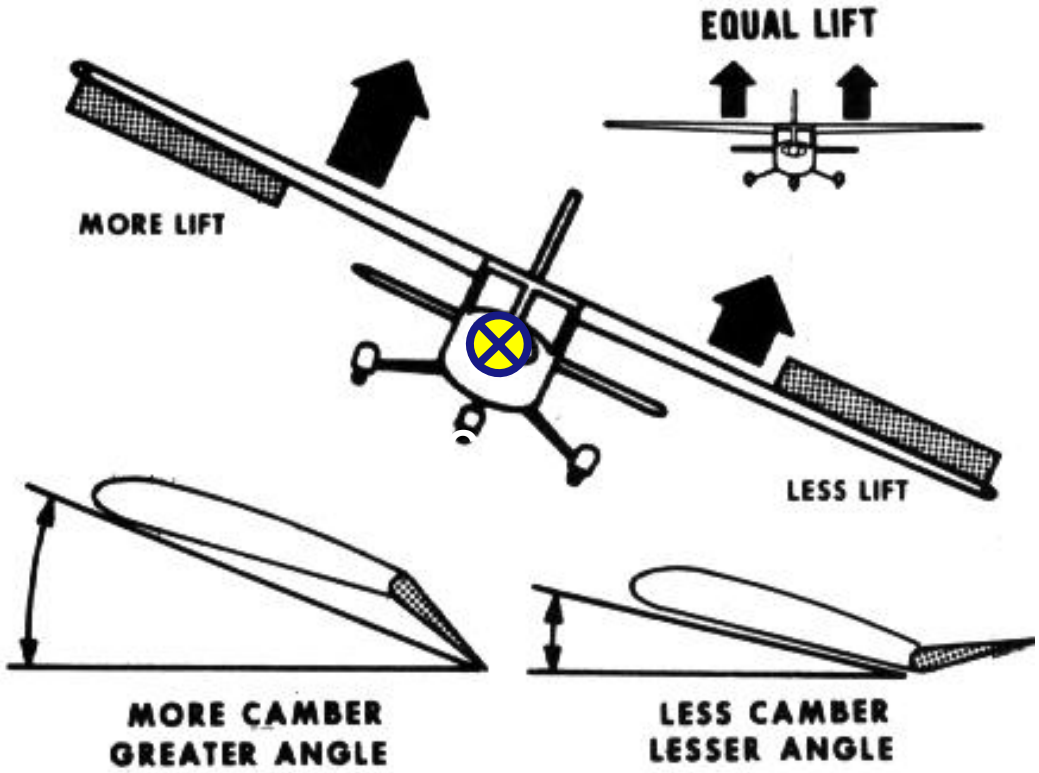


To create pitch UP, the elevator creates a DOWN force on the tail.

Roll

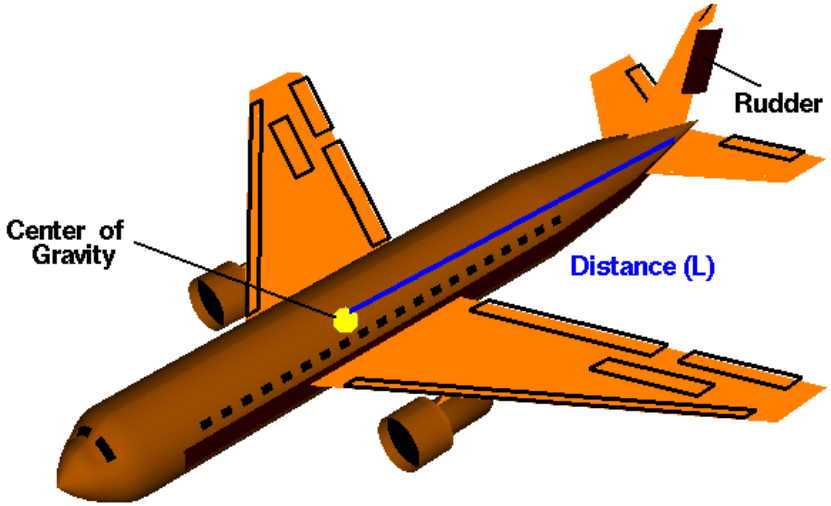
Deflect wing flaps called **A**ILERONS to create more lift on one wing and less on the other

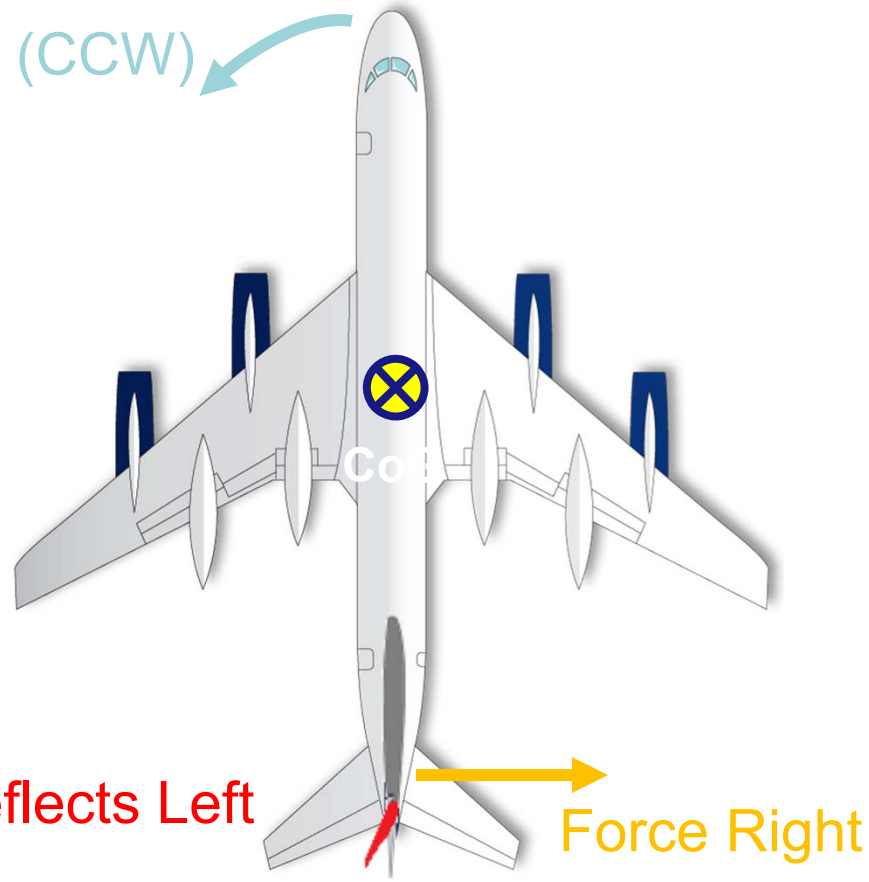




Yaw

Deflect tail **R**UDDER to create right or left force on the tail





https://www.youtube.com/watch?v=bMUdXJPUwm8

Control Surface Summary

- **E**levator → Pitch up or down
- **A**ileron → Roll right or left
- **R**udder → Spin clockwise or counterclockwise

- One more control: **T**hrottle

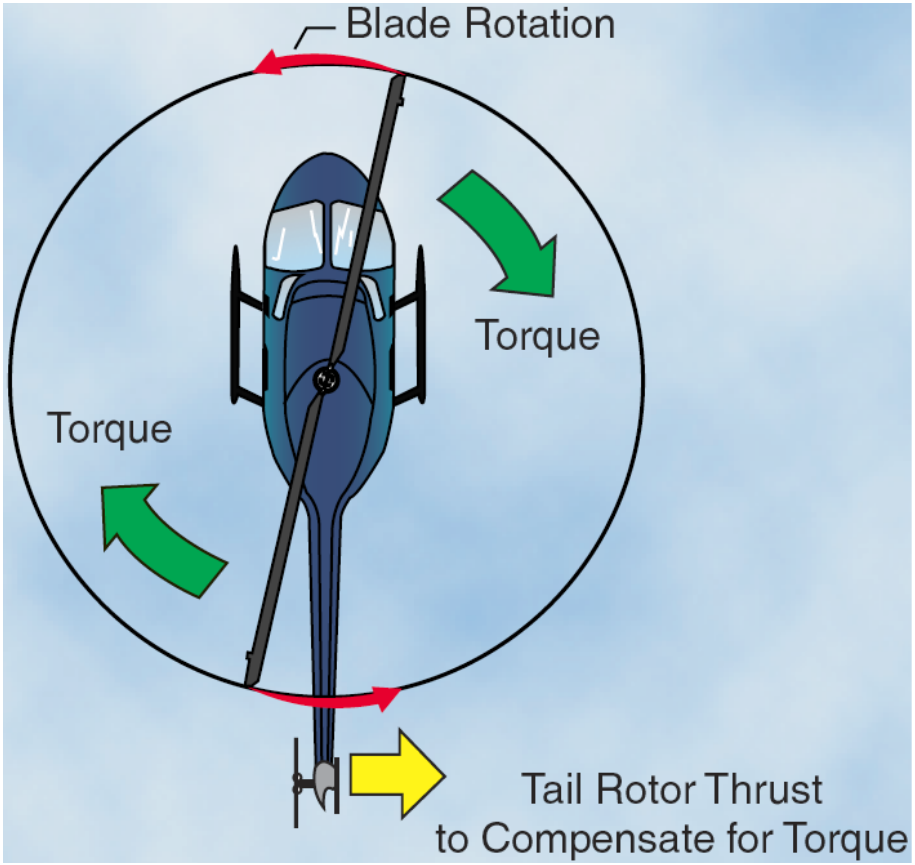
Quadcopter Control

Quadcopter Flight Controller →

Connect to the receiver, which receives commands from the pilot

1. Ailerons (Roll)
2. Elevators (Pitch)
3. Throttle (Altitude)
4. Rudder (Yaw)

Helicopter Dynamics



Main Rotor creates lift using variable pitch blades

→ It can change how much lift is created as the blades spin around

Tail Rotor creates side force to counter yaw of main rotor

https://www.youtube.com/watch?v=hnK9bGCvYtU

Helicopter Dynamics

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Alternate helicopter configuration uses two COUNTER-ROTATING rotors.

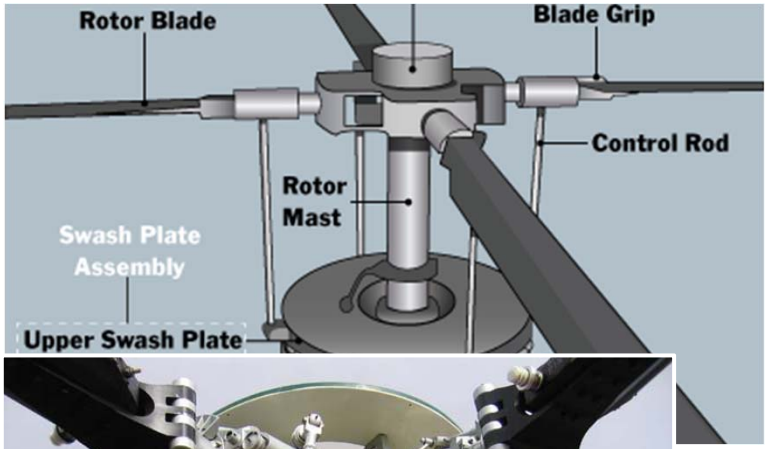
→ The angular momentums cancel out.

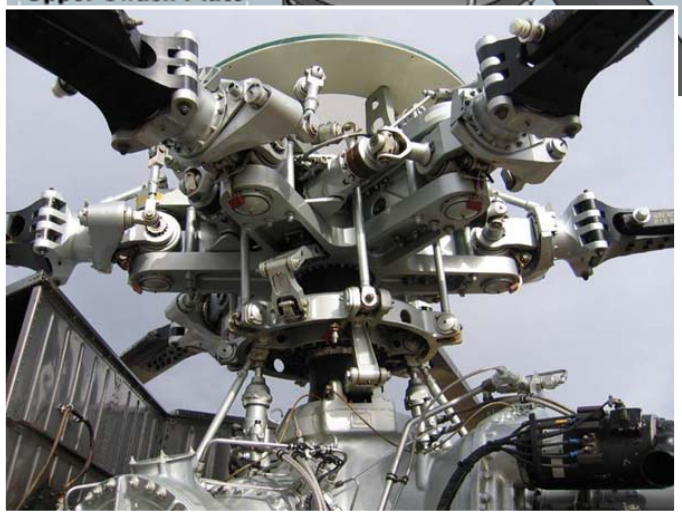
→ More lift.

Helicopter Dynamics

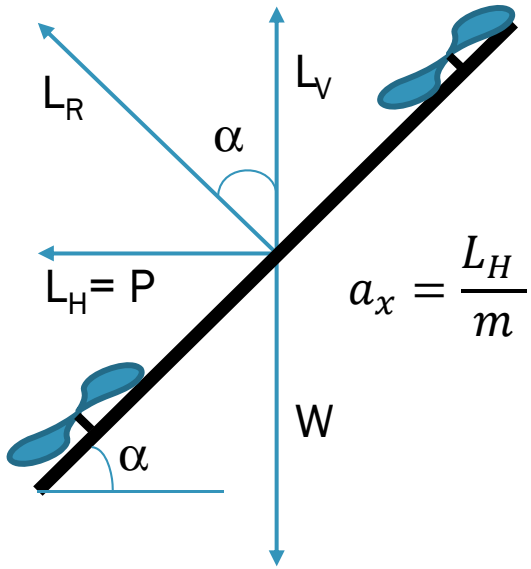
Swash Plate: Controls propeller pitch as blades rotate

→ Roll and Pitch are generated as a result of the swash plate.



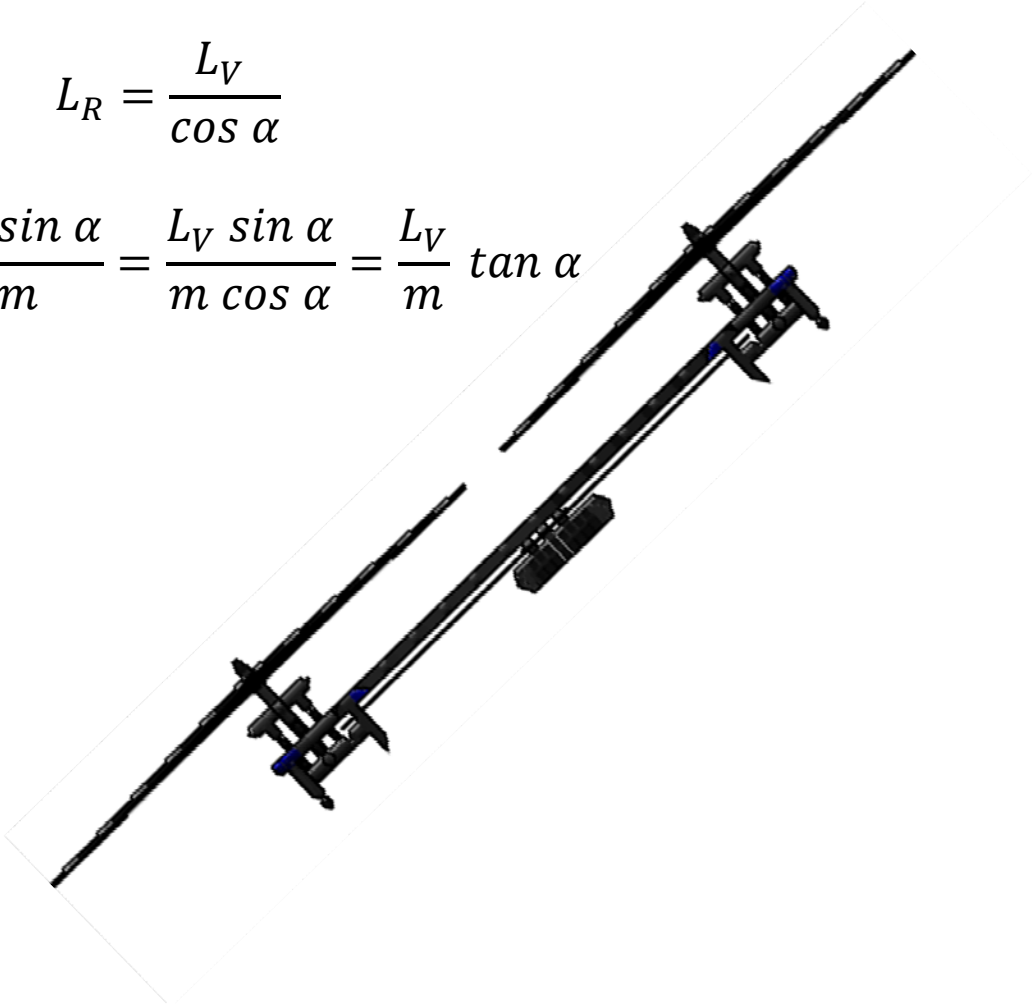


Force Balance



$$L_R = \frac{L_V}{\cos \alpha}$$

$$a_x = \frac{L_H}{m} = \frac{L_R \sin \alpha}{m} = \frac{L_V \sin \alpha}{m \cos \alpha} = \frac{L_V}{m} \tan \alpha$$



Introduction to Electric Circuits

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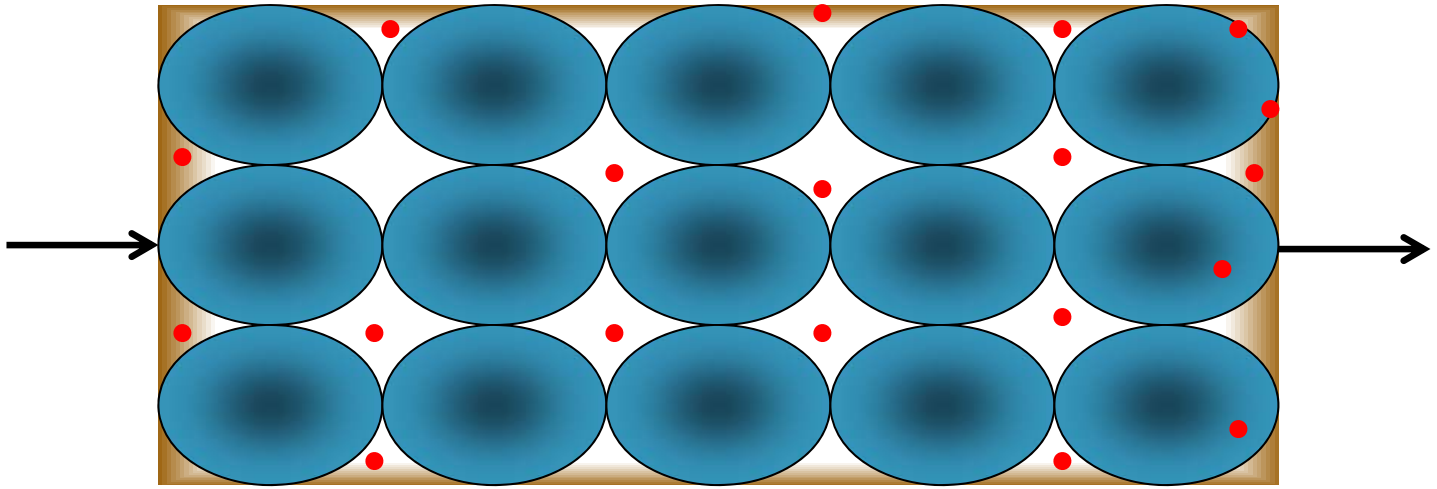
- Learning the language of circuits
- Ohm's Law and Kirchhoff's Law
- Basic circuit analysis (series, parallel)

Basic Concept – Current (I)

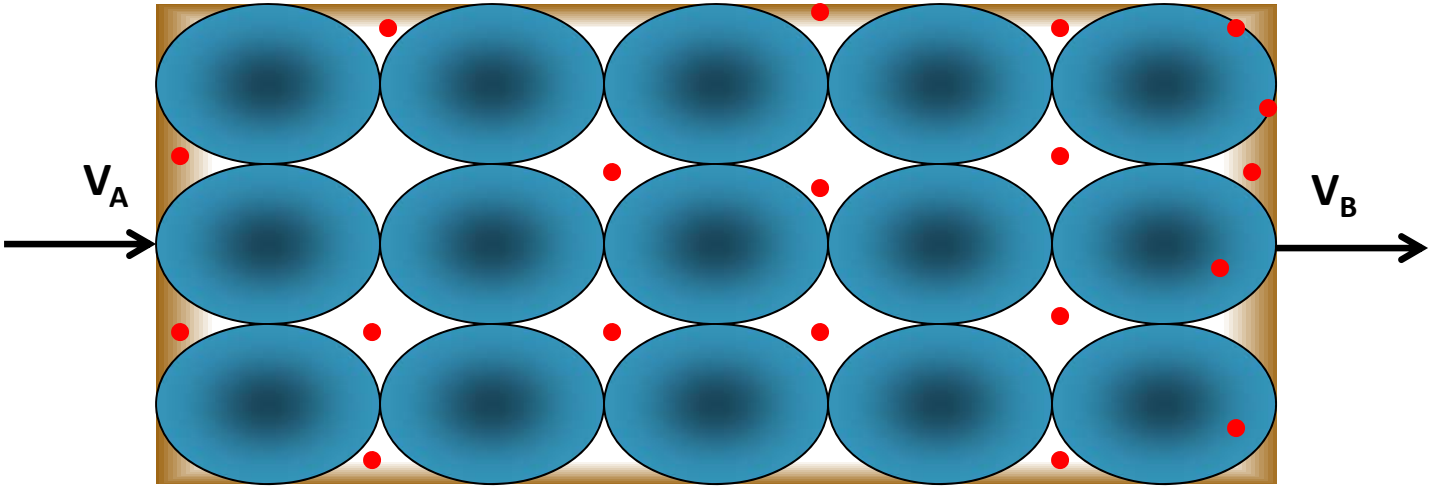
Current is charge in motion. The outer electrons of metal atoms drift, and are free to move. Unit: Ampere, A



Insulators, such as wood and plastic, do not have this 'sea of electrons' which is why they do not conduct electricity

Basic Concept – Voltage (V)

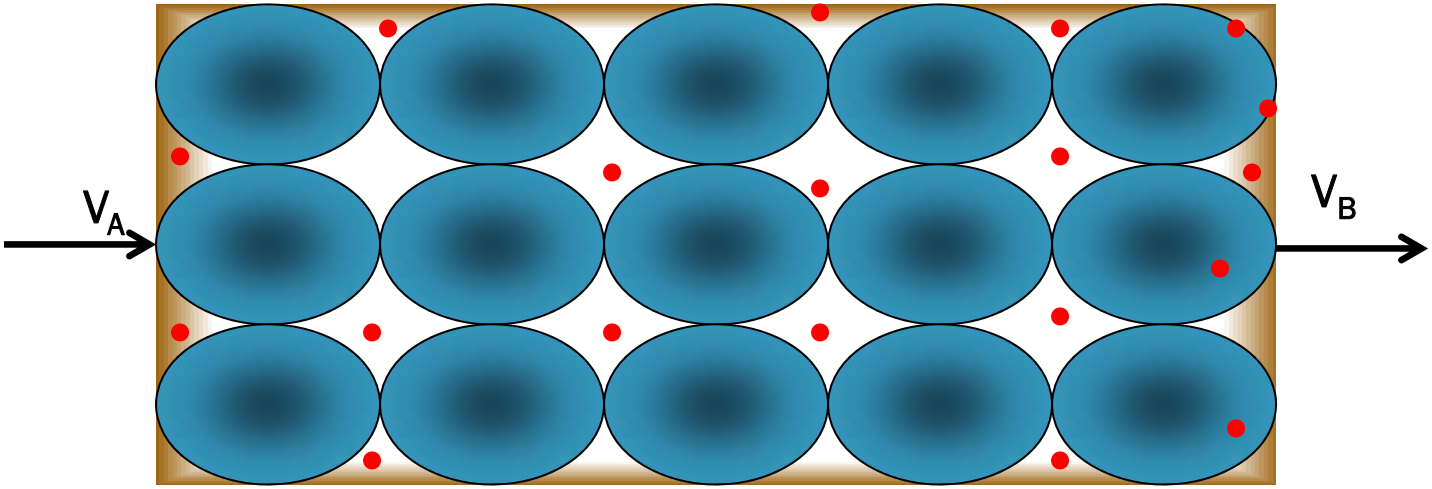
Electrical pressure or potential that causes electrons to flow. A voltage source creates pressure to push charges through a circuit. Unit: Volt, V



A single volt is defined as the *difference in electric potential* across a wire when an electric current of one ampere dissipates one watt of power

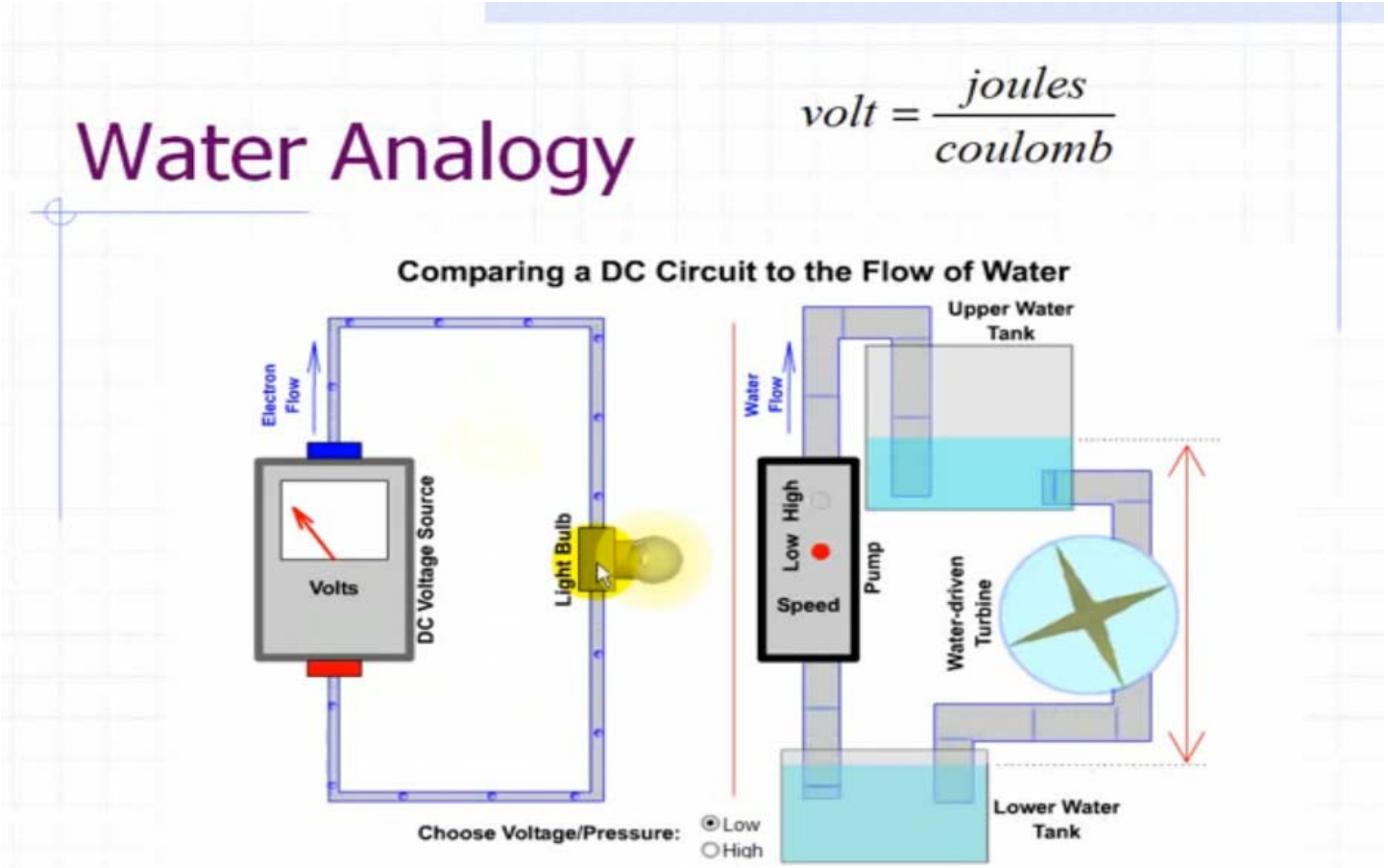
Basic Concept – Power (P)

Power describes the rate the electric energy flows in a circuit. Electric energy describes the potential of a circuit or component to do work. Unit: Watt, W



Power = Voltage x Current

Analogy to Water Flow



http://www.youtube.com/watch?v=j8TyygWl9nQ

Circuit Variables

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Voltage, V

- Units: Volts (V)
- Measures the electric potential energy between any two points in the circuit.

Current, I = dq/dt

- Units: Amperes (A, or C/s)
- The rate at which charge is flowing

Power, P

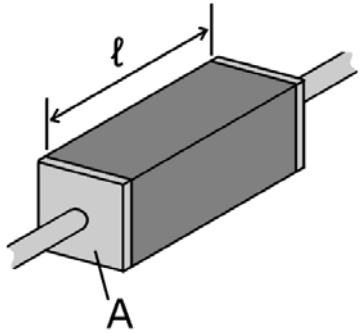
- Units: Watts (W) = Joule/second
- Rate at which energy is consumed (or supplied).

Basic Concepts- Resistance (R)

- Resistance: measures the difficulty of pushing current from one place to another. Unit: Ohms, Ω

- Resistivity, ρ:

  -- a material property, how strongly a given material opposes the flow of electric current, independent of size and shape.



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

current flow path length

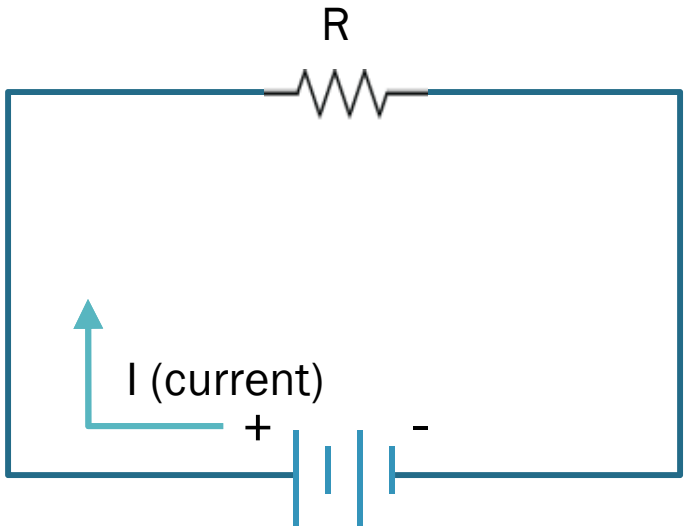
surface area of current flow

- Conductivity, σ

$$\sigma = \frac{1}{\rho}$$

Ohm's Law

- *The current flowing in a conductor is directly proportional to the applied voltage V and inversely proportional to its resistance R*



Conventional: Current Flow from Positive to Negative

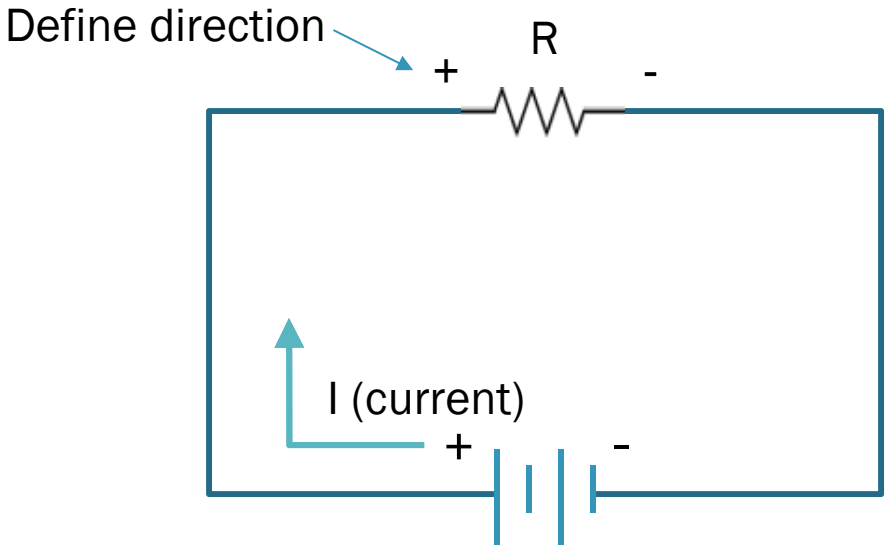
$$V = IR$$

$$I = V/R$$

$$R = V/I$$

Ohm's Law

- *The current flowing in a conductor is directly proportional to the applied voltage V and inversely proportional to its resistance R*



Battery, V = 16V
Resistor, R = 8 Ω

What is the current?
I = V/R = 2 A

Power

- Power: rate at which energy is consumed (or supplied).

$$P = IV$$

$$P = I(IR) = I^2R$$

$$P = (V/R)V = V^2/R$$

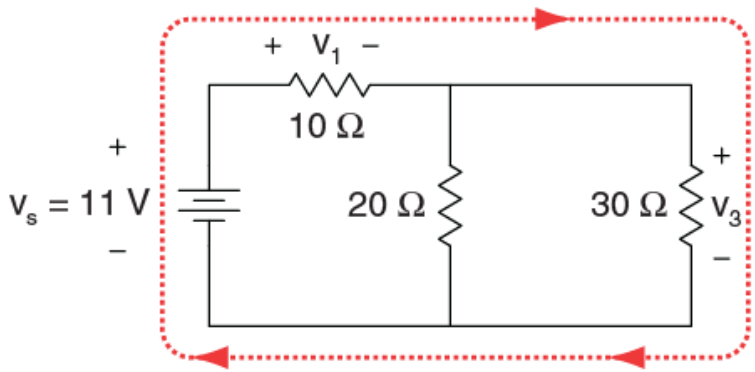
  - I = current through element
  - V = voltage across the same element
  - R = Resistance of the element
  - Don't get confused with pressure (also denoted P)
  - Measured in Watts (W)

    1 Watt = 1 Volt Amp = 1 Joule/second

Kirchhoff's Voltage Law

- Conversation of Energy

KVL: $v_1 + v_3 - v_s = 0$

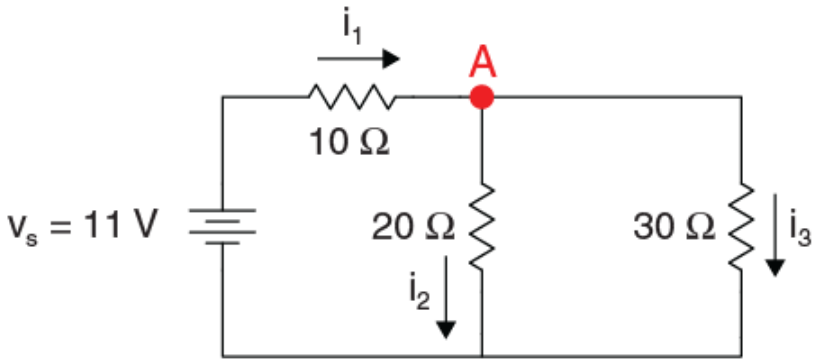


- Voltages sum to zero around any closed path
- Can be applied to any closed loop in circuit
- Pay attention to signs and polarity!

Kirchhoff's Current Law

- Conversation of charge

KCL A: $i_2 + i_3 - i_1 = 0$



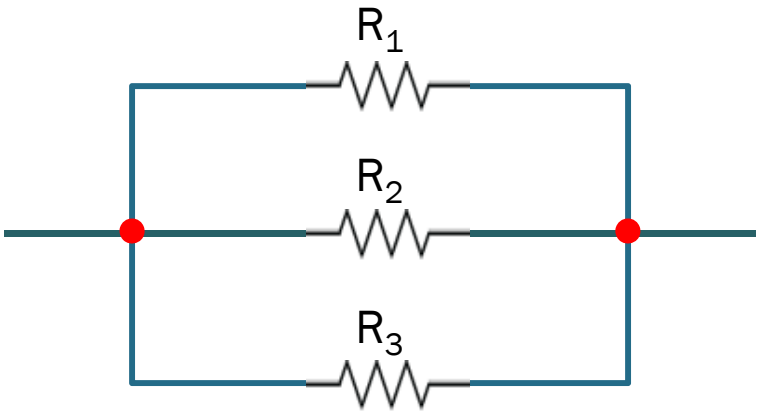
- Currents coming out of any part of circuit must sum to zero
  - Can be applied at any point (node) in circuit
    - Pay attention to signs and polarity!

Resistors in Series and Parallel

- Series

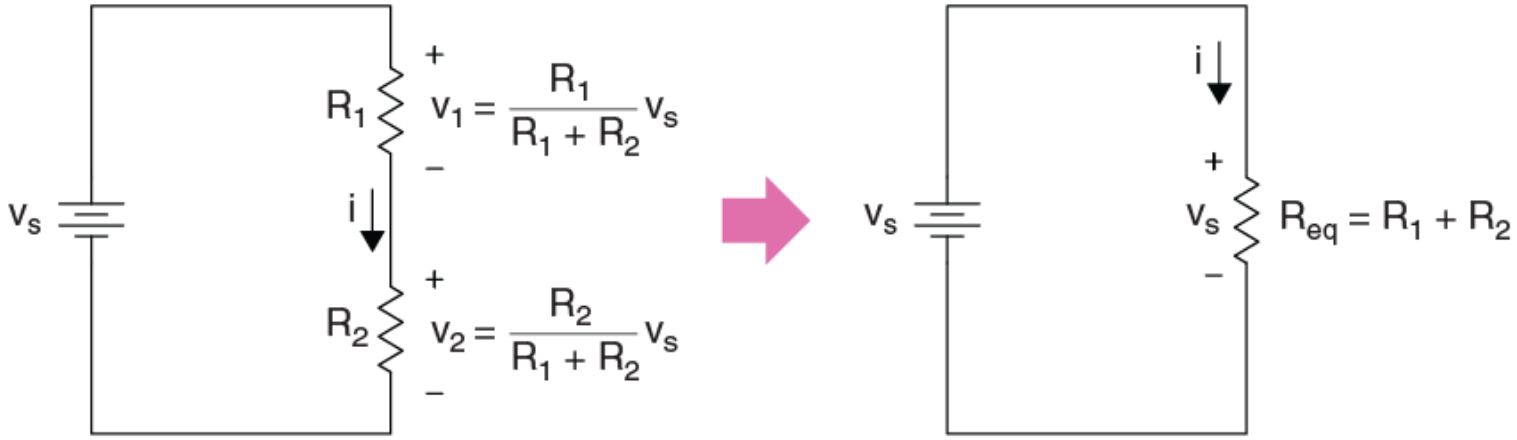
$$R_{eq} = R_1 + R_2 + R_3$$

- Parallel



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

Series (Voltage Divider)



KCL: $i_1 = i_2 \ (= i)$

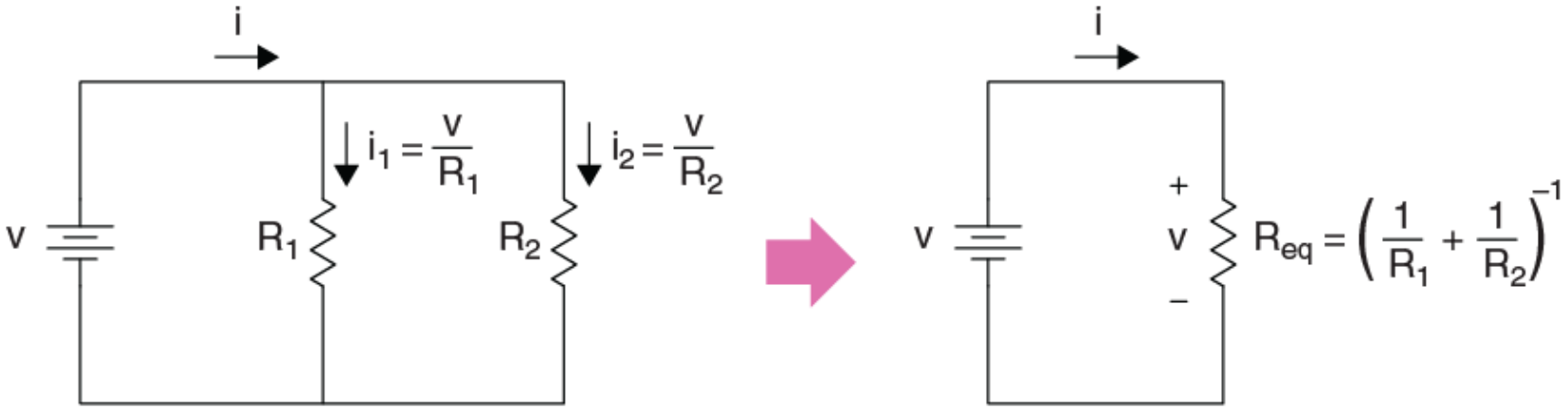
KVL: $v_s = v_1 + v_2$

$= i(R_1 + R_2)$

WHEN RESISTORS ARE CONNECTED IN SERIES:

- Equivalent resistance: $R_{eq} = R_1 + R_2$
- Currents are the same in R_1, R_2 and R_{eq}
- Voltage divides in proportion to R

Parallel (Current Divider)



KVL: $v_1 = v_2 = v$

KCL: $i = i_1 + i_2$

$$= \left(\frac{1}{R_1} + \frac{1}{R_2}\right) v$$

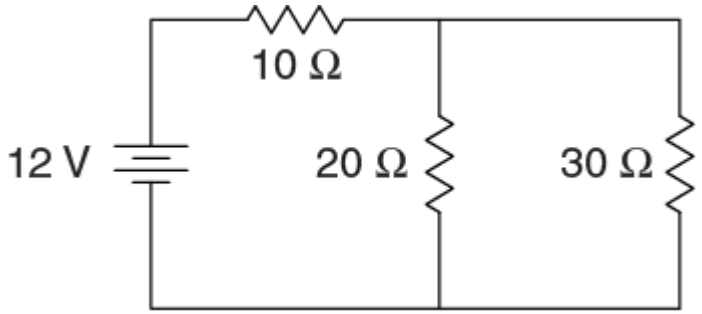
$$i_1 = \frac{\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2}} i \qquad i_2 = \frac{\frac{1}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2}} i$$

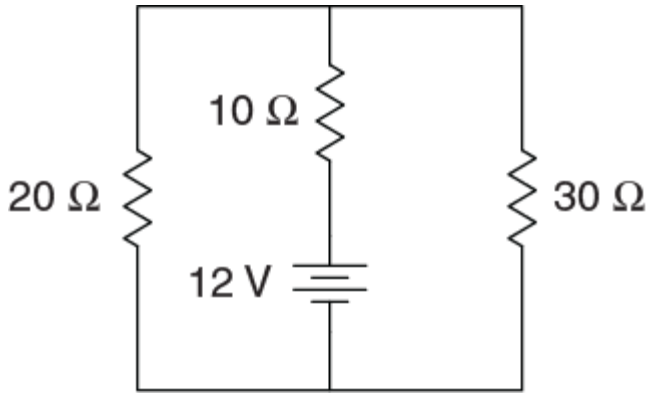
WHEN RESISTORS ARE CONNECTED IN PARALLEL:

- Equivalent resistance: $1/R_{eq} = 1/R_1 + 1/R_2$
- Voltages are the same in R_1, R_2 and R_{eq}
- Current divides in proportion to 1/R

Circuit Schematics

- Show how things are connected

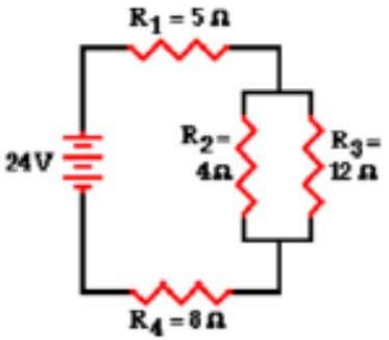




  - Many equivalent ways to draw the same circuit
  - Length of wire (line) has no meaning in schematic diagram
  - Circuit schematic does not show:
    - Where the components are physically placed on circuit board
    - Relative orientation of elements
    - Location of solder joints or connections

Hints for HW3

1. (a) Analyze the following circuit to find the variables listed. Show your calculations.



R_{tot} = _____ I_{tot} = _____

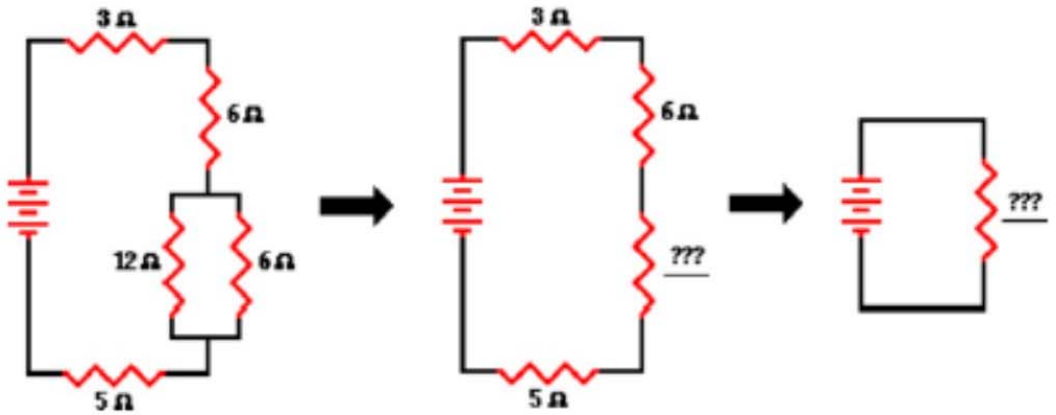
I_1 = _____ ΔV_1 = _____

I_2 = _____ ΔV_2 = _____

I_3 = _____ ΔV_3 = _____

I_4 = _____ ΔV_4 = _____

(b) Given the following circuit diagram use the concept of equivalent resistance to determine the resistances marked unknown. Show your calculations.



Hints for HW3

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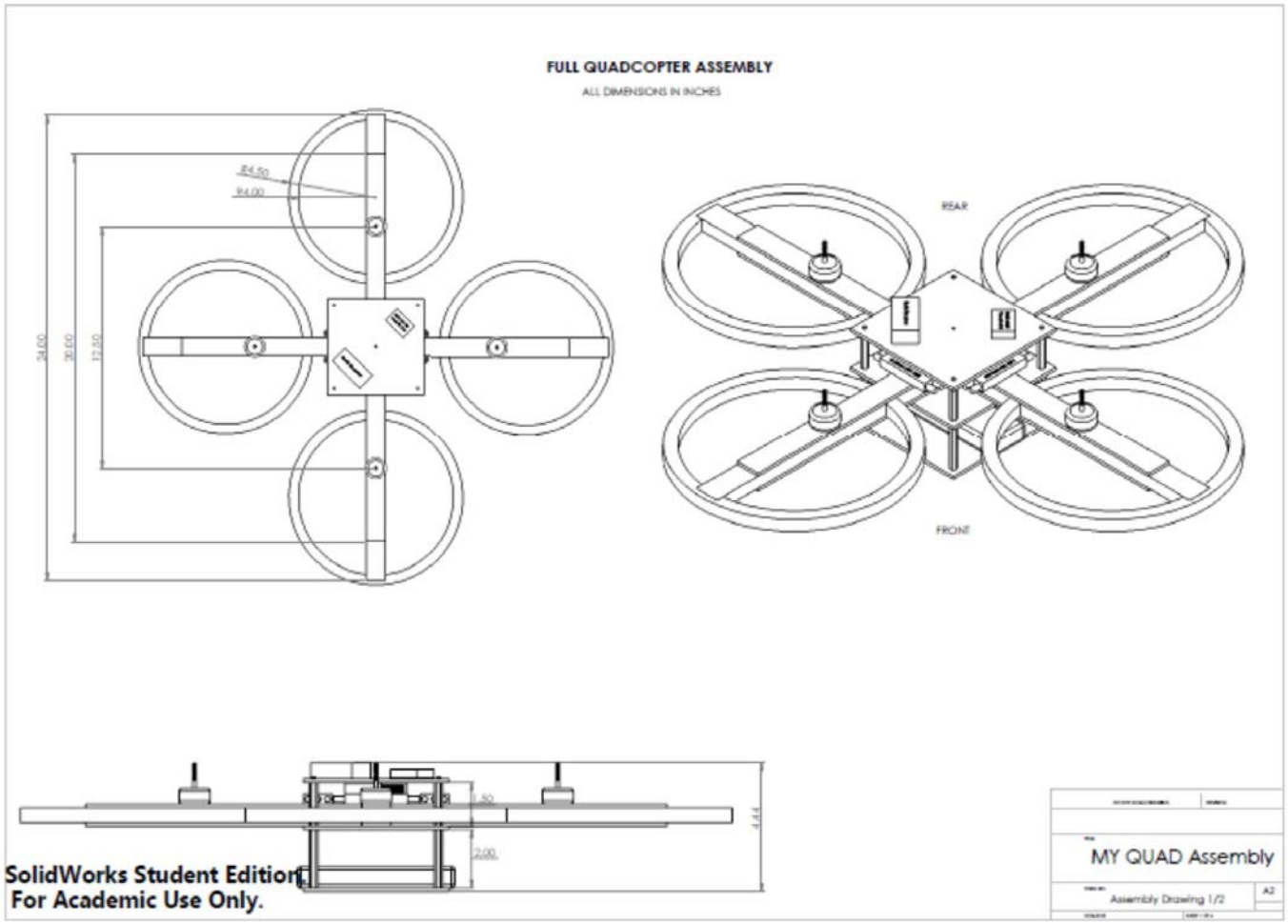
2. Match the appropriate flight controller input with the corresponding quadcopter motion:

Roll	
Pitch	
Yaw	
Increase in elevation	

3. Complete problem 3.4 from the textbook (Book 11, 4th Edition): If the total lift force of 2.86 lbs (i.e. the same as 2.86 lbs ·32.2 ft/s=92.09 lbs·ft/s) is generated by the four motors, determine the angle of tilt α (with respect to horizontal plane) required to produce horizontal acceleration $a_x = 0.75\ ^{ft}/_{s^2}$. The quadcopter weights 2.42 lbs. Hint: see section 3.4.1 of the textbook.

Announcements

- SDW Quadcopter Design is due 11/2/2018 **before midnight**
- See the Sample Drawing on Canvas



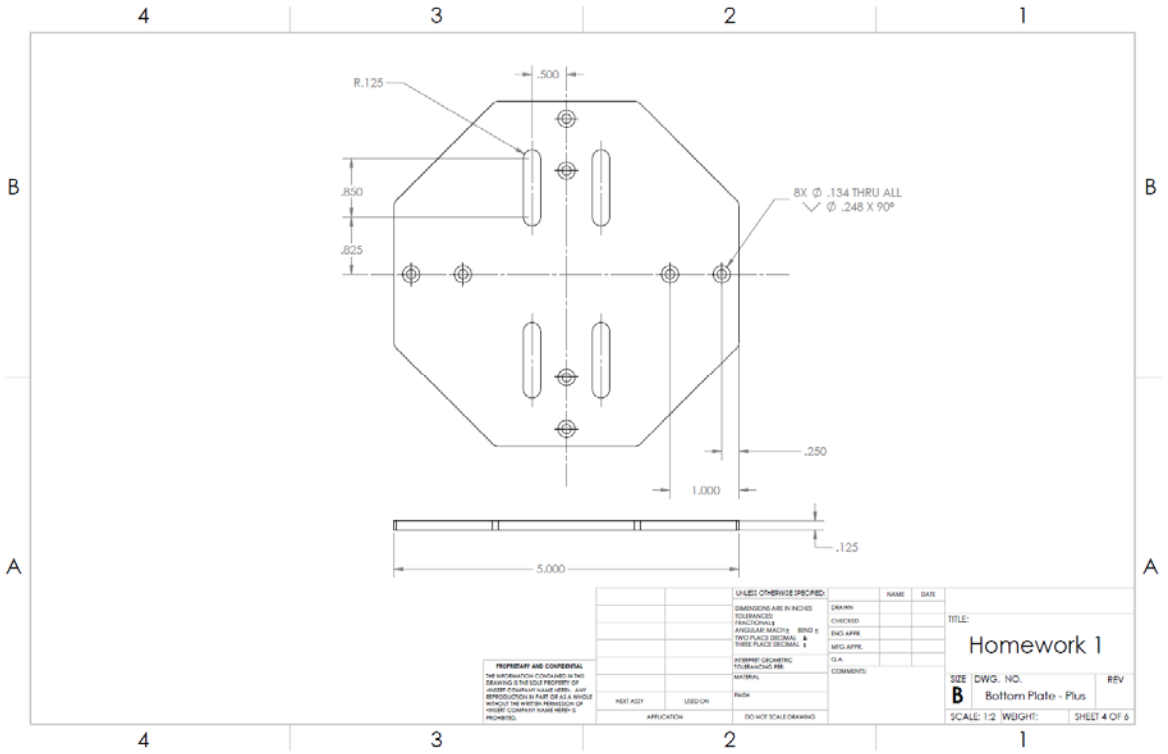
Quadcopter Design Drawings

Full Design Drawings Due: Friday of Week 5

One drawing page for each part to be manufactured in lab

- Center frame(s)
- Landing gear
- Propeller guard
- Frame arm
- Etc.

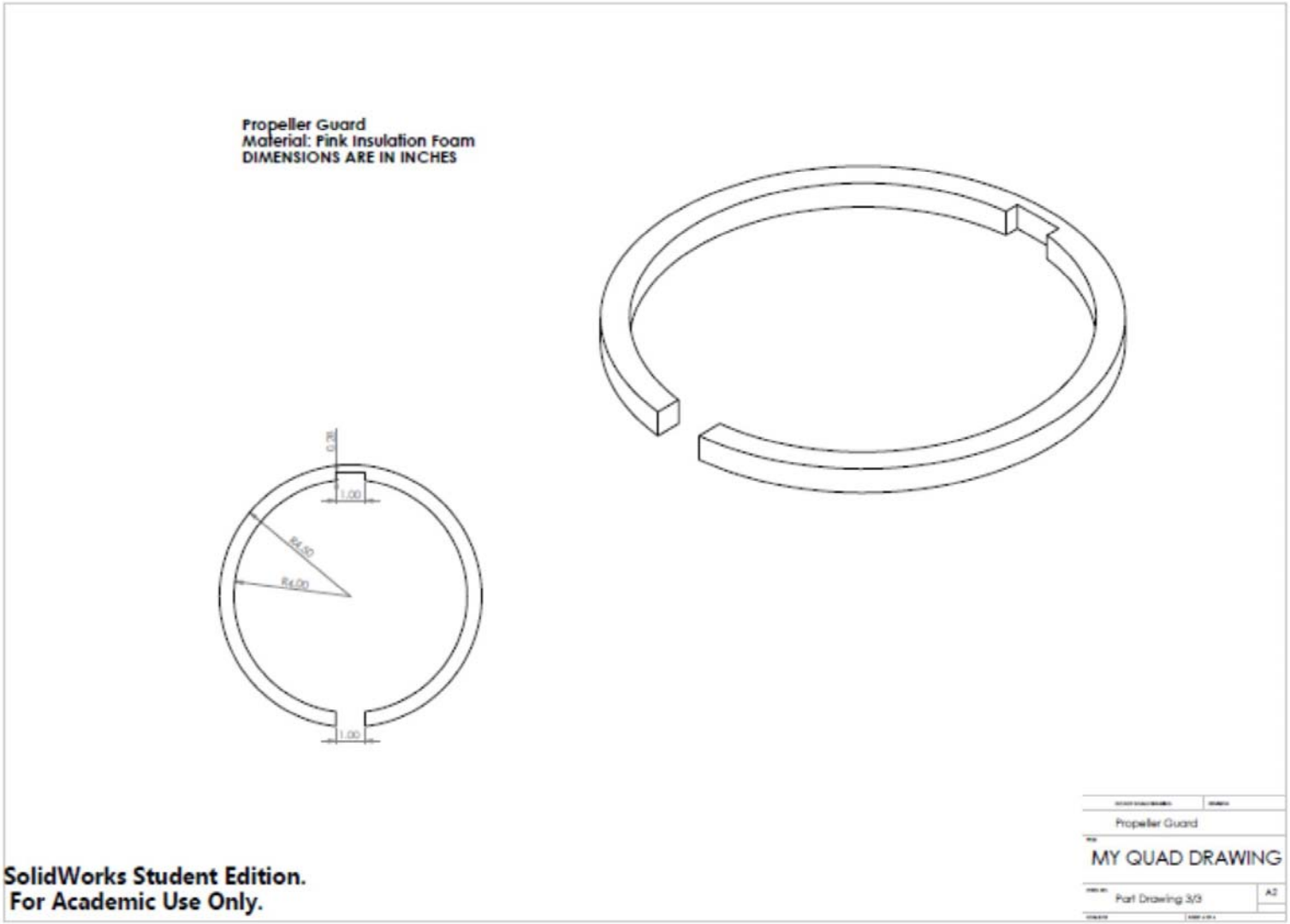
See Solidworks Tutorial 3: Drawings



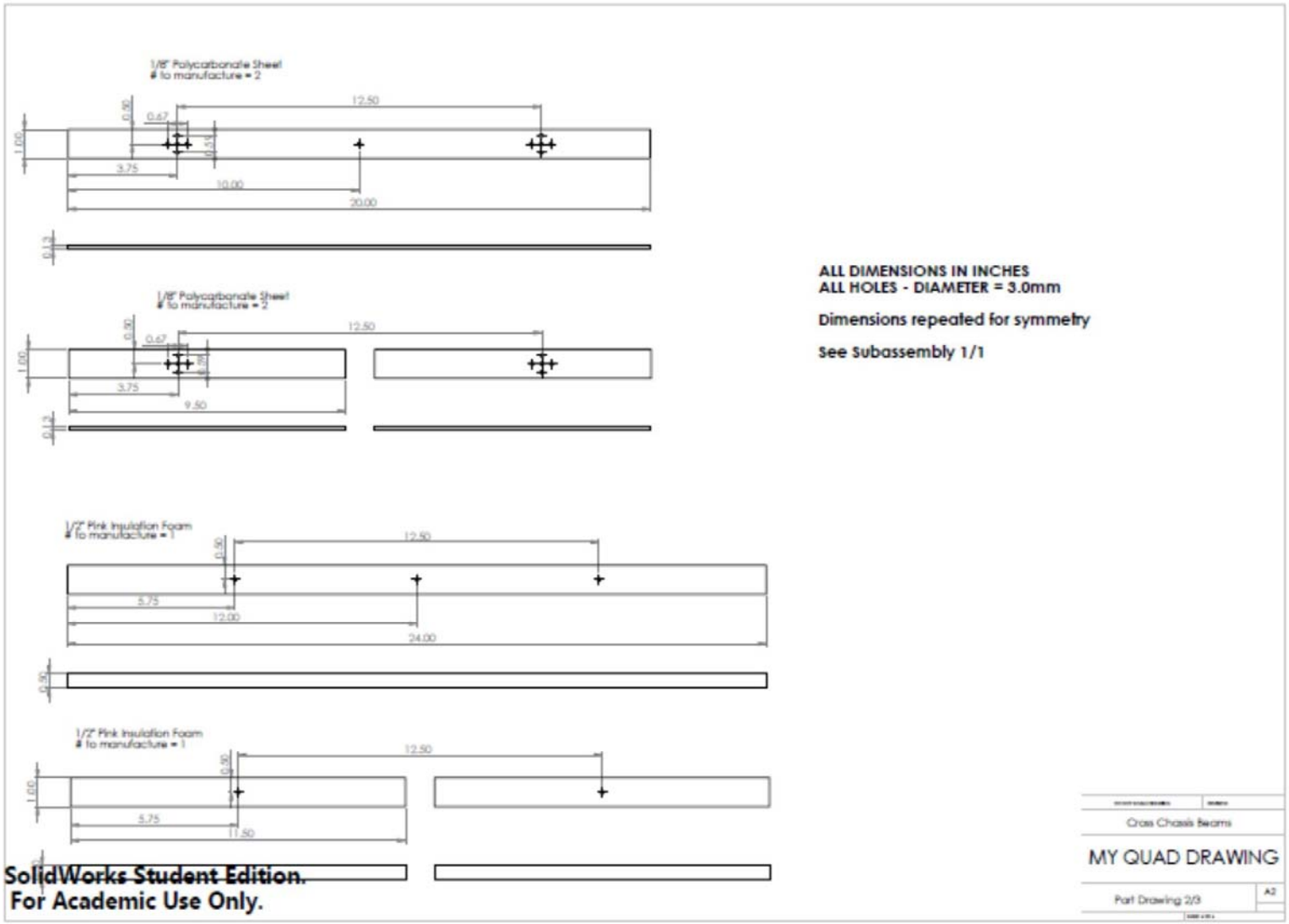
Include: Size Dimensions, Hole Locations

Tip: Make dimensions useful for fabrication

Announcements



Announcements



Announcements

- The sooner you submit SDW Quadcopter Design the sooner you can start fabrication of the quadcopter frame
- The Structure of Quadcopter is due 11/16/2018 at 5 pm
- The PO for quadcopter parts (motor, controller, electrical parts) is due 11/9/2017 **before midnight**
- The sooner you submit the PO, the more chances you will have parts that you want as there is a limited supply of parts
- Please, only do the following pairing of motors/propellers:
  - 2450kv SunnySky motors should be paired with 5” or 6”propellers
  - 1400kv SunnySky motors should be paired with 8” propellers only

Open Labs

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- Starting from Week 6 you will have open lab sessions (optional) in addition to mandatory weekly labs
- The signup sheet is posted on the corkboard in front of ET408 the Monday (around noon) of the previous week (i.e. Monday of week 5 for week 6 open labs)
- Each team can have up to TWO slots. No more than 3 people from team can attend the same open lab slot.
- There can be maximum of 6 teams per open lab session.
- Lab sessions will run from Week 6 through Week 10. During Week 7 there will be no open Labs on Monday due to Veterans' Day, but we'll have more slots open during other days of week 7.

List of Open Labs

- Open Lab 1A: Mon 1-3 pm (ET 421)
- Open Lab 1B: Mon 1-3 pm (ET 409)
- Open Lab 2A: Mon 3-5 pm (ET 421)
- Open Lab 2B: Mon 3-5 pm (ET 409)
- Open Lab 3: Tu 12-2 pm (ET 421)
- Open Lab 4: Wed 11 am - 1 pm (ET 421)
- Open Lab 5: Wed 1-3 pm (ET 409)
- Open Lab 6: Wed 3-5 pm (ET 409)
- Open Lab 7: Th 11am - 1 pm (ET 409)
- Open Lab 8: Thursday 1-3 pm (ET 421)
- Open Lab 9A: Thursday 3-5 pm (ET 421)
- Open Lab 9B: Thursday 3-5 pm (ET 409)
- Open Lab 10: Friday 8-10 am (ET 409)
- Open Lab 11: Friday 11am -1 pm (ET 421)
- Open Lab 12: Friday 1-3 pm (ET 409)
- Open Lab 13A: Friday 3-5 pm (ET 421)
- Open Lab 13B: Friday 3-5 pm (ET 409)

Reading Assignment for Week 5

"Introduction to Engineering Design" Book 11

Engineering Skills and Quadcopter Missions 4th Edition 2017

Chapter 3 "Flight Dynamics" Sections 3.1-3.5

Chapter 5 "Basic Electric Circuits"