FORCES

FREE BODY DIAGRAMS (FBD)

AND

STATIC EQUILIBRIUM

Key Points:

A force can be thought of as a PUSH or a PULL.

The units used with forces:

Newtons (N) $1\ N = 1\ (kg \times m)/sec^2$

Pound (lb)

(1 lb = 4.45 N)

$1\ N = 1\ \frac{kg \cdot m}{s^2}$

Forces CAN cause acceleration (overall forces lead to acceleration; balanced forces don't)

What is the difference between the mass of an object and the weight of an object?

mass: the amount of matter in an object

(same no matter where an object is)

weight: the force with which gravity pulls on an object

(depends on location)

Sometimes you will need an object's mass, sometimes its weight. How to go from one to the other?

WEIGHT =	MASS x	ACCEL. OF GRAVITY
Newtons	kg	9.8 m/s^2
Pounds (lb)	slug	32.2 ft/s^2

ON EARTH'S SURFACE!

1 slug = 14.6 kg

1 lb = 4.45 N

1 kg ---> 2.2 lb
weighs

1 slug ---> 143 N
weighs

Free Body Diagrams (FBD)

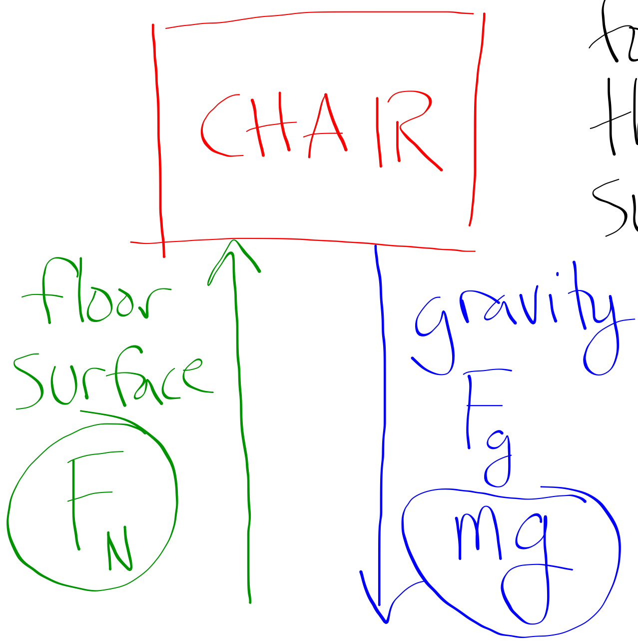
A FBD:

- -Shows all of the forces acting on ONE object
- -Does not show the forces the object exerts on other objects
- -Forces displayed as arrows (push = towards, pull = away)
    - -The length of the arrow corresponds to the size of the force
    - -The arrow points in the direction the force acts
- -All forces are labeled
- -The object is usually depicted as either a simple shape, or even just as a dot
- -Is essential if one hopes to work with forces properly.

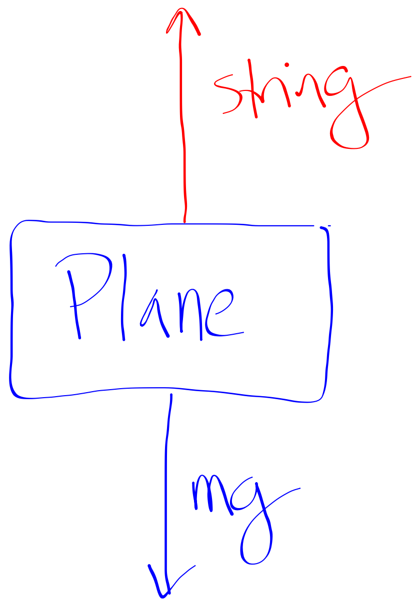
EXAMPLE: Draw a free-body diagram of a chair at rest on the ground.

F_N = "normal force"

The perpendicular force from a surface that is (partially) supporting an object.

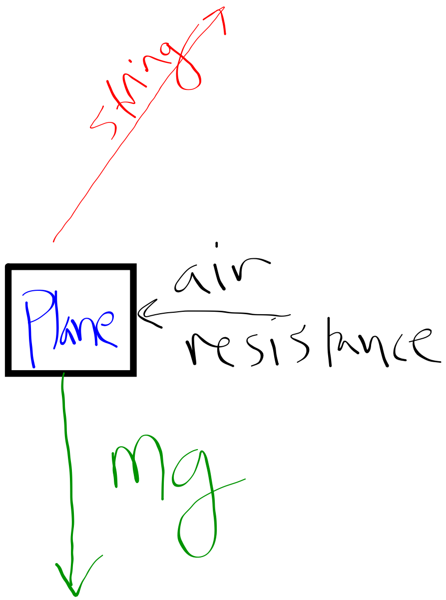


EXAMPLE: Draw a FBD of a toy plane suspended from a string.



EXAMPLE: Draw a FBD of the toy plane if it is suspended from a string while you hold the string and move across the room at a constant velocity.

no acceleration
Static equilibrium
all forces balanced



Note: If plane moves at a CONSTANT SPEED, then the two horizontal forces, if drawn, must be equal and opposite. Otherwise the plane would accelerate horizontally. Likely, these forces are so small they could be neglected altogether.

Each of the previous examples are examples of static equilibrium.

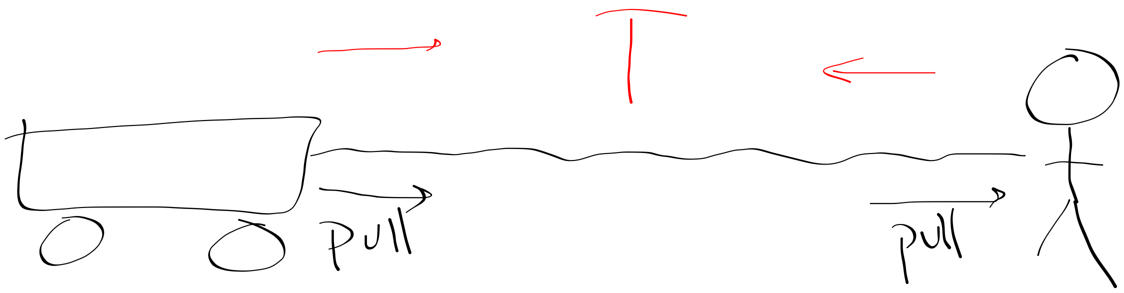
Static situations occur when the forces acting on an object(s) are all balanced and the object is either stationary or moving at constant velocity (per Newton's 1st Law of Motion).

Newton's 1st Law of Motion: An object at rest or moving at a constant velocity stays at rest or continues moving at the same velocity UNLESS acted upon by an unbalanced force (net force).

What about TENSION?

An internal pulling force within an object being pulled in two directions

Tension transmits forces:

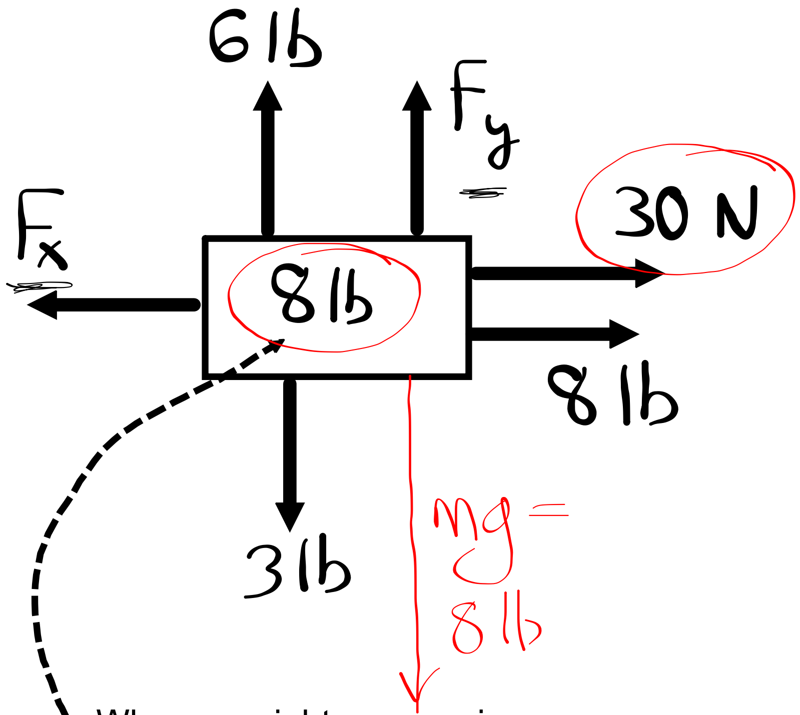


Now, lets start using the idea of forces, static equilibrium, and balanced forces to solve problems.

EXAMPLE: Solve for the unknown forces F_x and F_y (express answers in lbs - 1 lb = 4.45 N).

(Incomplete FBD)

- Static equilibrium -



When a weight or mass is placed on an object (8 lb in this case), infer that it is the object's weight or mass.

$$\frac{1 \text{ lb}}{4.45 \text{ N}} = 6.74 \text{ lb}$$

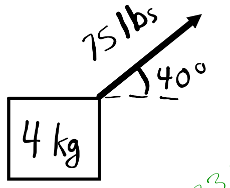
$$F_x = 8 \text{ lb} + 6.74 \text{ lb}$$

$$\boxed{F_x = 14.74 \text{ lb}}$$

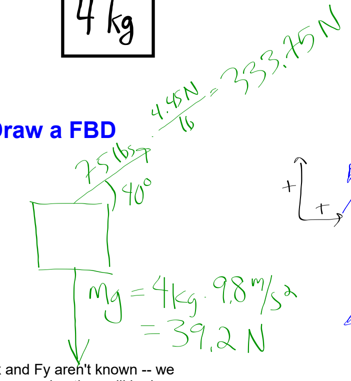
$$F_y + 6 \text{ lb} = 3 \text{ lb} + 8 \text{ lb}$$

$$\boxed{F_y = 5 \text{ lb}}$$

EXAMPLE: What force must be applied to this object in order to maintain equilibrium? (Remember, forces are vectors!!)

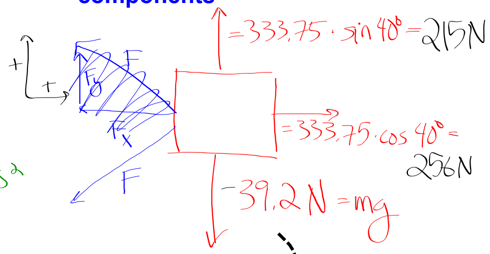


1. Draw a FBD



Fx and Fy aren't known -- we are guessing they will be in these directions. The sign of our answers will tell us the actual directions.

2. Resolve forces into x and y components



3. Sum your x-forces (they must equal zero)

$F_x + 256\ N = 0$

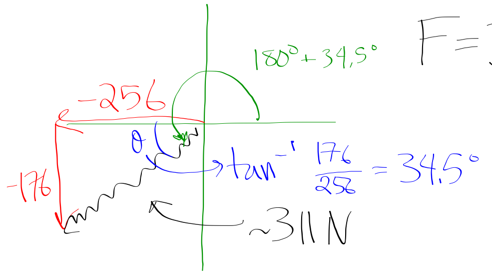
$F_x = -256\ N$

4. Sum your y-forces (they must equal zero)

$F_y + 215N + {}^-39.2 = 0$

$F_y = {}^-176\ N$

5. Calculate the resultant force and angle



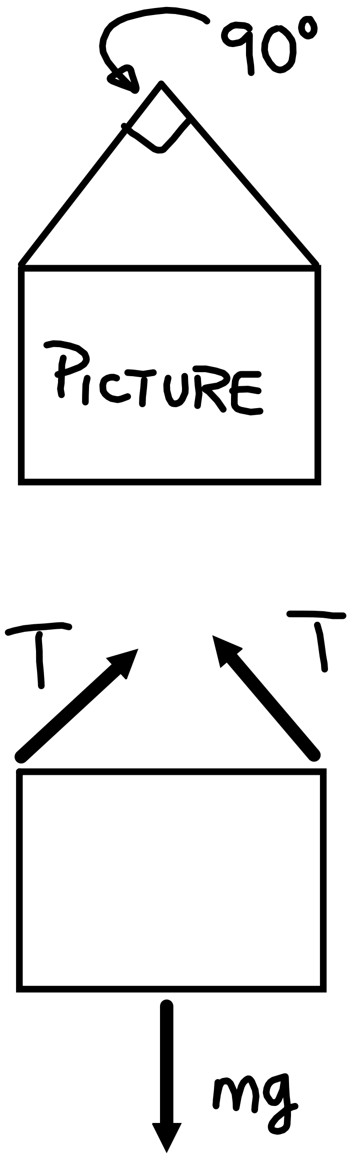
$F = 311\ N$ @ $214.5°$

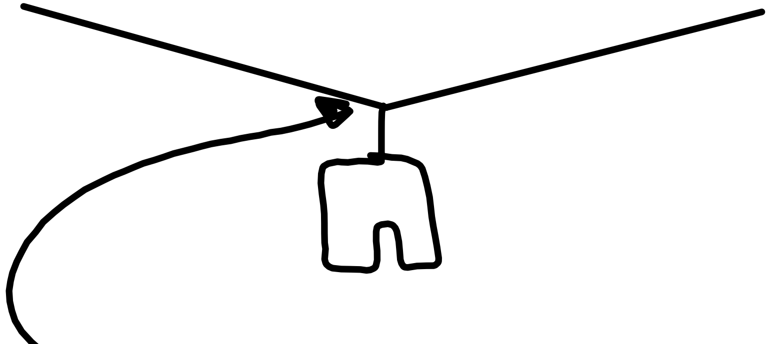
Generalized procedure for solving Statics Problems:

1. Make a drawing.
2. Establish a reference frame.
3. Identify variables & check units
4. **Draw a FBD** (WHY DO YOU THINK THIS ONE IS IN BOLD?)
5. Resolve all forces into X and Y components.
6. Sum all X-components and set the sum equal to zero
7. Sum all Y-components and set the sum equal to zero
8. Solve for your unknown(s)
9. Calculate the resultant force vector and angle

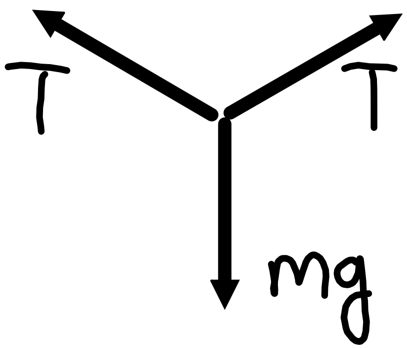
Clarifications / Hints on the homework -- Statics Worksheet

1)



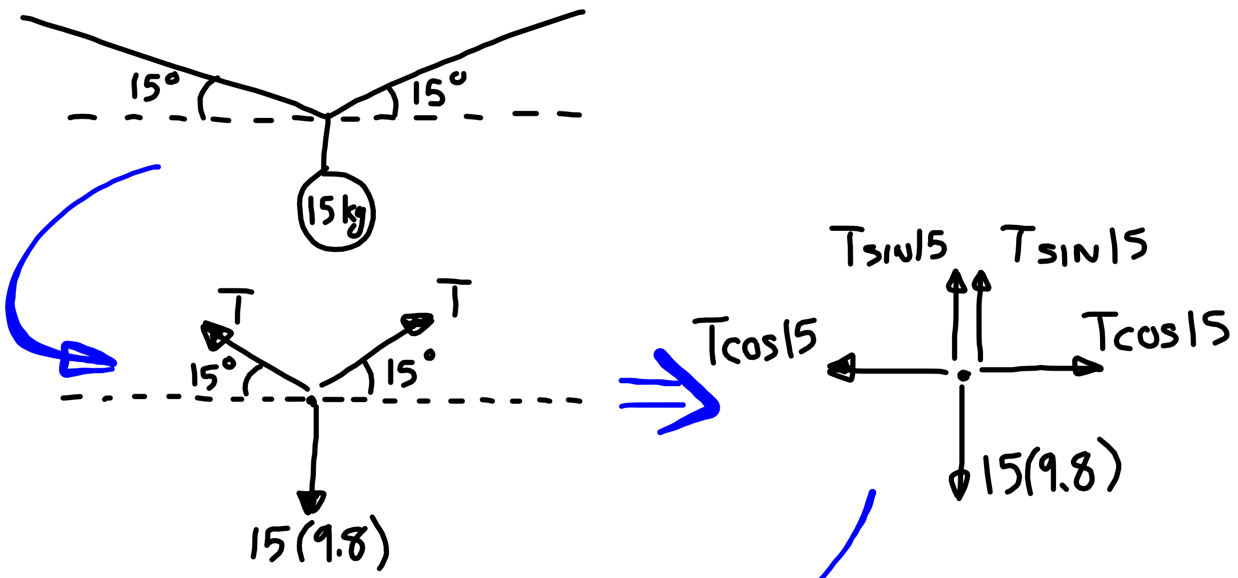


Look at this point of the clothesline for the FBD -- the object must feel the force you are trying to find, and the swimming suit DOES NOT feel the tension in the string.



EXAMPLE: A 15 kg bag of bananas hands from a taunt line strung between two trees. If the line sags in the middle by 15^o (relative to the horizontal), what tension (in Newtons) is in the line?

EXAMPLE: A 15 kg bag of bananas hands from a taunt line strung between two trees. If the line sags in the middle by 15° (relative to the horizontal), what tension (in Newtons) is in the line?



$$\Sigma F_y = 0$$

$$T\sin 15 + T\sin 15 - 15(9.8) = 0$$

$$T = \boxed{283.98\ N}$$

In this problem, we did not need to sum forces in the X-direction. Why? Well, we only needed one equation to find our single unknown.