FORCES

FREE BODY DIAGRAMS (FBD)

AND

STATIC EQUILIBRIUM

Objectives:

- Students will understand what a force is and what forces can do
- Students will understand what is meant by static equilibrium
- Students will be able to correctly draw Free Body Diagrams
- Students will be able to use the above concepts to solve problems

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)

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

unbalanced, net

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 = how much matter • is • in an object
(kg, slug)

weight = the force of gravity pulling on an object

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	slugs	$32.2 \, ft/s^2$

1 slug = 14.6 kg

1 lb = 4.45 N

1 kg ---> 2.2 lb

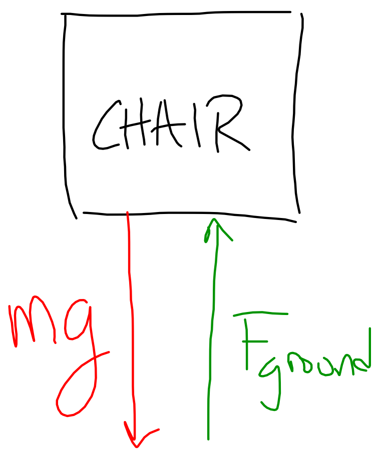
1 slug ---> 143 N

Free Body Diagrams (FBD)

A FBD:

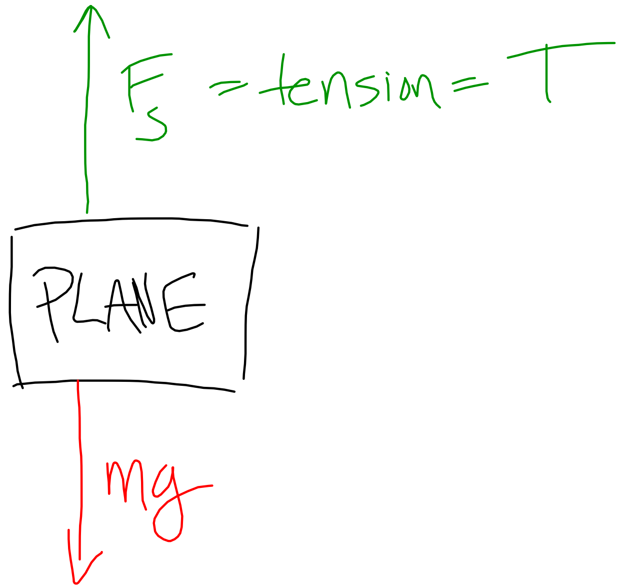
- -Shows all of the forces acting on ONE object
- -Does not show the forces the object exerts on other objects
- -Forces displayed as arrows (push = towards, pull = away)
    - -The length of the arrow corresponds to the size of the force
    - -The arrow points in the direction the force acts
- -All 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.

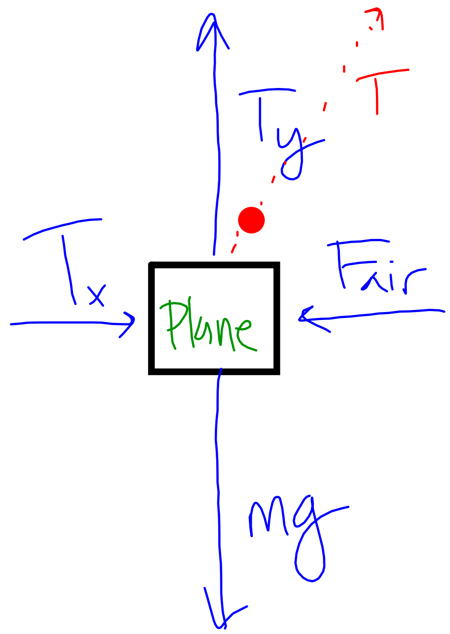


EXAMPLE: Draw a FBD of a toy plane suspended from a string.

(NOT MOVING)



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, all forces balance



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.

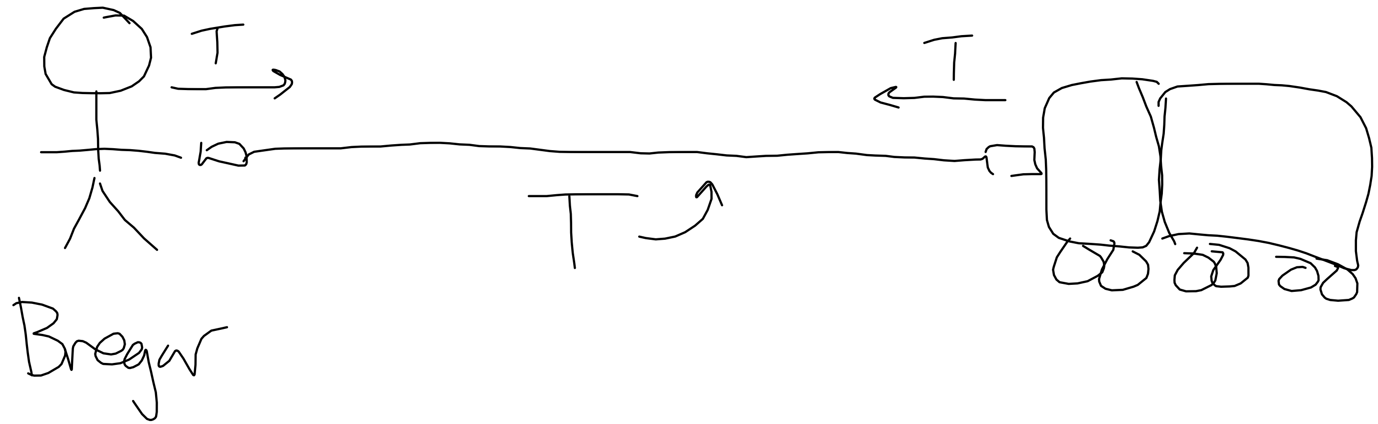
STATIC EQUILIBRIUM • all forces balance (or no force)

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).

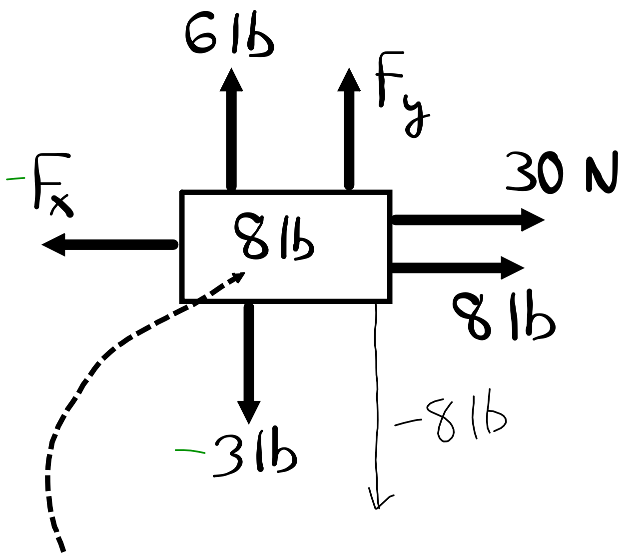
What about TENSION?

A force within an object — pulling force at either end of a rope, chain, string, wire . . .



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).



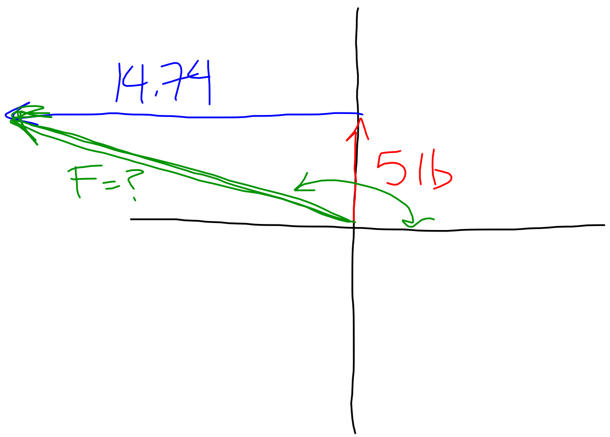
When a weight or mass is placed on an object (8 lb in this case), infer that it is the object's weight or mass.

$$30\text{ N} \cdot \frac{1\text{ lb}}{4.45\text{ N}} = 6.74\text{ lb}$$

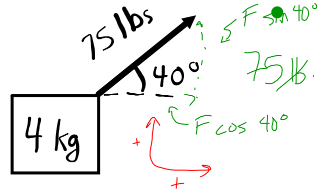
For statics • $\Sigma F = \emptyset$

$$\Sigma F_x = \emptyset$$
$$-F_x + 6.74 + 8 = \emptyset$$
$$F_x = 14.74\text{ lb}$$

$$\Sigma F_y = \emptyset$$
$$F_y + 6 - 3 - 8 = \emptyset$$
$$F_y = 5\text{ lb}$$



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

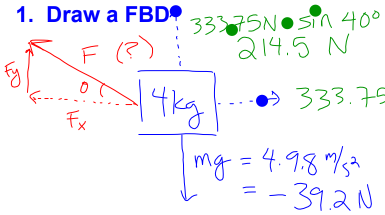


$1\ lb = 4.45\ N$

$75\ \cancel{lb} \cdot \frac{4.45N}{\cancel{lb}} = 333.75\ N$

1. Draw a FBD

2. Resolve forces into x and y components



$333.75N \cdot \sin 40° = 214.5\ N$

$333.75 \cdot \cos 40 = 255.7\ N$

$mg = 4 \cdot 9.8\ m/s^2 = -39.2\ N$

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.

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

$\Sigma F_x = \emptyset$

$F_x + 255.7 = \emptyset$

$F_x = -255.7\ N$

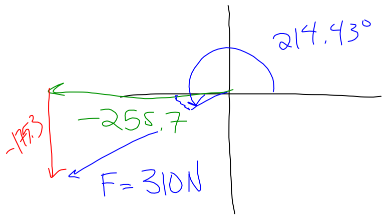
4. Sum your y-forces (they must equal zero)

$\Sigma F_y = \emptyset$

$F_y + 214.5 - 39.2 = \emptyset$

$F_y = -175.3\ N$

5. Calculate the resultant force and angle



$\boxed{F = 310\ N @ 214.43°}$

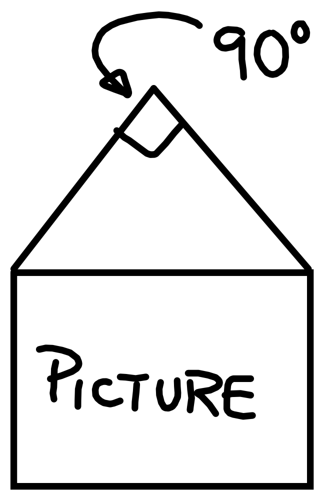
Generalized procedure for solving Statics Problems:

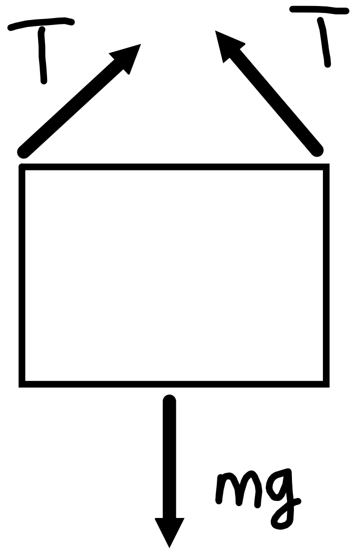
(there is force but no acceleration)

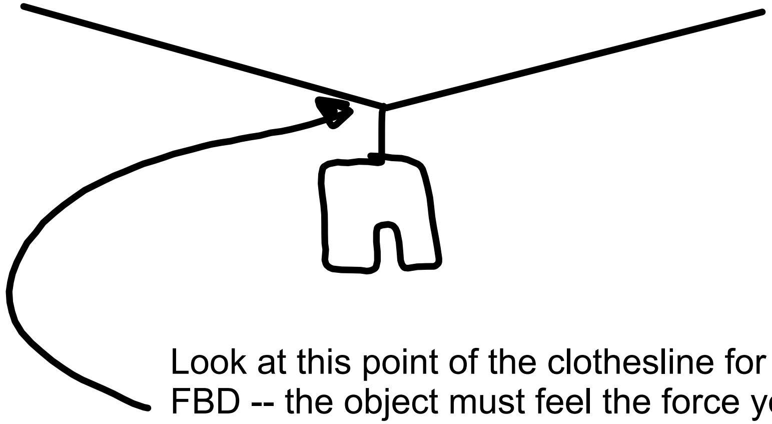
1. Make a drawing.
2. Establish a reference frame. (m, s, m/s, m/s², kg, N)
3. Identify variables & check units (ft, s, ft/s, ft/s², slugs, lbs)
4. **Draw a FBD** (WHY DO YOU THINK THIS ONE IS IN BOLD?)
5. Resolve all forces into X and Y components.
6. Sum all X-components and set the sum equal to zero
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 (if needed)

Clarifications / Hints on the homework -- Statics Worksheet

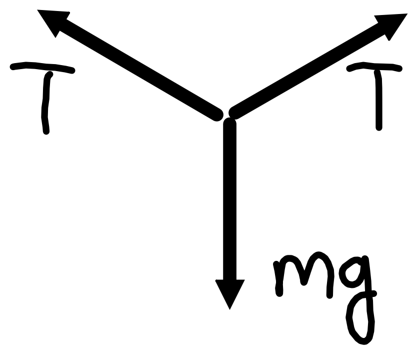
1)



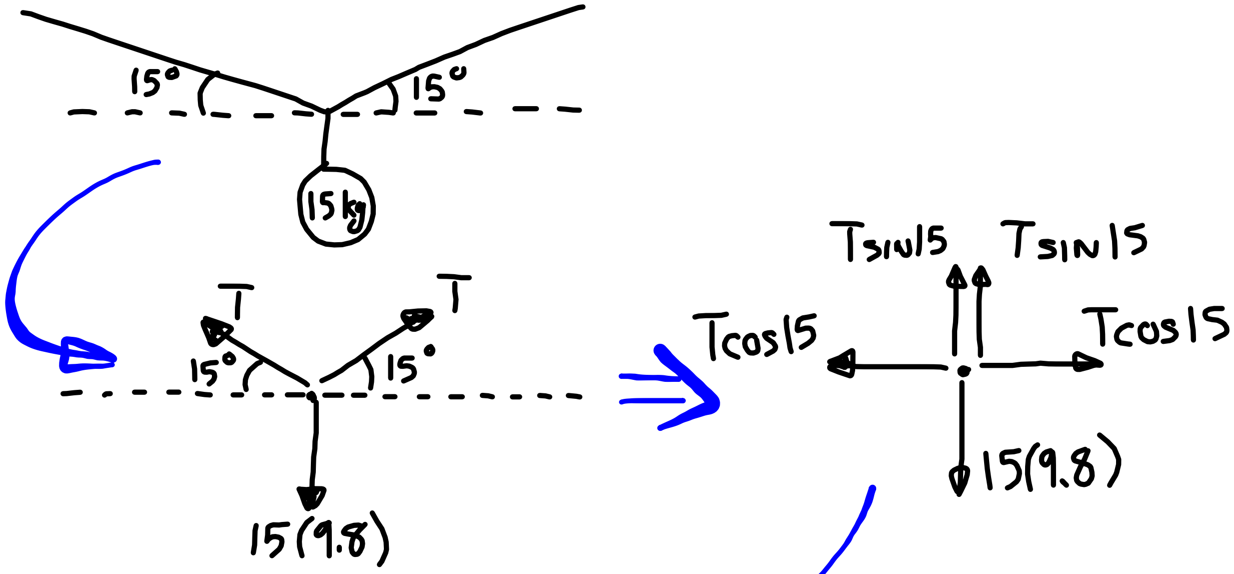




Look at this point of the clothesline for the FBD -- the object must feel the force you are trying to find, and the swimming suit DOES NOT feel the tension in the string.



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° (relative to the horizontal), what tension (in Newtons) is in the line?



$$\Sigma F_y = 0$$

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

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

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.