FORCES,
FREE BODY DIAGRAMS (FBDs),
AND
STATIC EQUILIBRIUM

Objectives:

- Students will understand what a force is and what forces can do
- Students will be able to correctly draw Free Body Diagrams
- Students will understand what is meant by static equilibrium
- 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 x m)/sec^2

Pound (lb) (1 lb = 4.45 N)

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?

Weight: the size of the force of gravity pulling on an object (downward)
(changes when the strength of gravity changes)

Mass: the amount of stuff in object.
This is what gravity pulls on!
(Always the same)

How to find mass from weight and vice-versa (not a conversion!):

WEIGHT	**=**	**MASS**	**x**	**ACCEL. OF GRAVITY**
Newtons (N)		Kilograms (kg)		$9.8\ m/s^2$ (at earth's surface)
Pounds (lb)		Slugs		$32.2\ ft/s^2$ (")

1 slug = 14.6 kg, 1 lb = 4.45 N

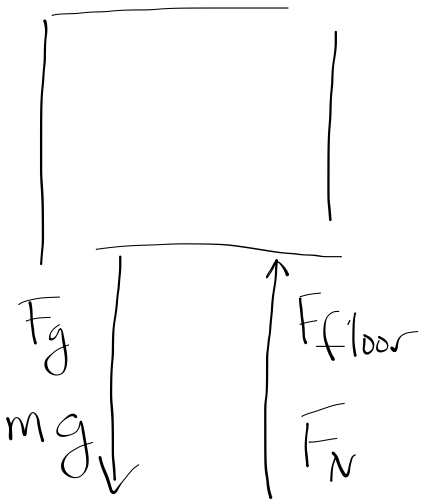
1 kg ---> 2.2 lb, 1 slug ---> 143 N

Free Body Diagrams (FBDs)

FBDs are for one object at a time and:

- -Show all forces acting on that object
- -Do not show forces that object exerts on other objects
- -Show forces as arrows (push = towards, pull = away)
  - -Arrow length implies the size of the force
  - -Arrow points in the direction the force acts
- -All forces are labeled
- -The object is depicted as a simple shape (a box or dot)
- -Are critical for working with forces

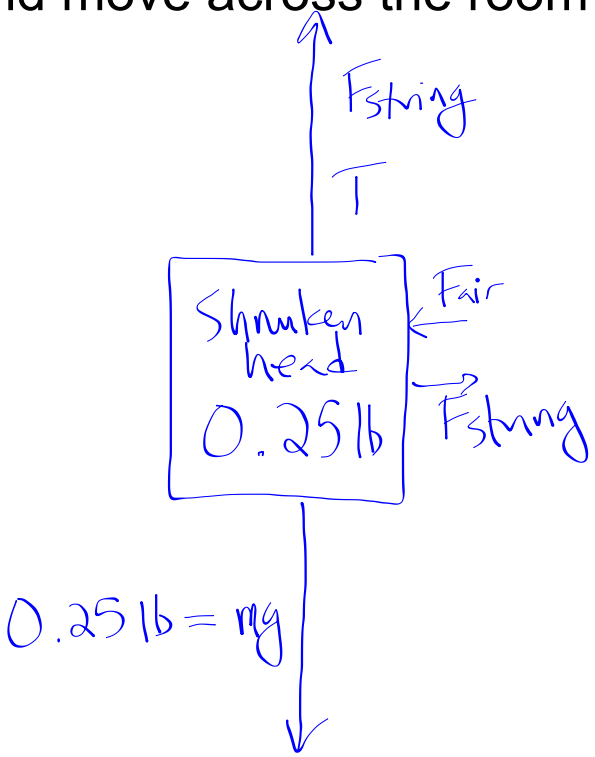
EXAMPLE: Draw an FBD of a chair at rest on the ground.



Weight = mass × accel. gravity

$F_g = m \cdot g$

EXAMPLE: Draw a FBD of an object suspended from a string while you hold the string and move across the room at a constant velocity.



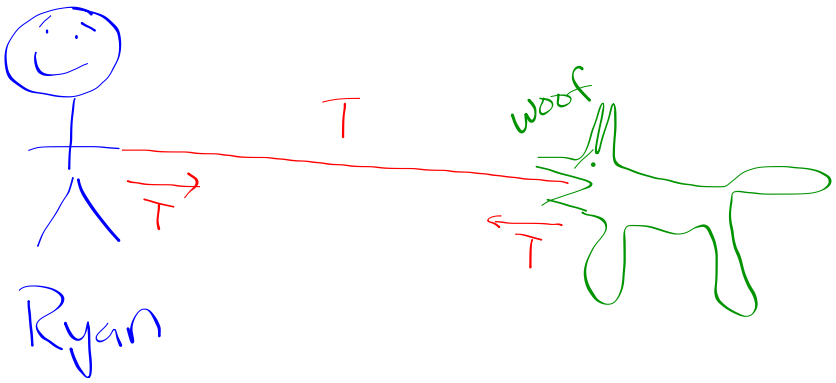
These FBDs showed **static equilibrium**.

Static situations occur when the forces acting on an object 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 is TENSION?

A pulling force transfer through rope, string, chain, cable etc. The tension pulls with the same force, in opposite directions, at each end of the connector.



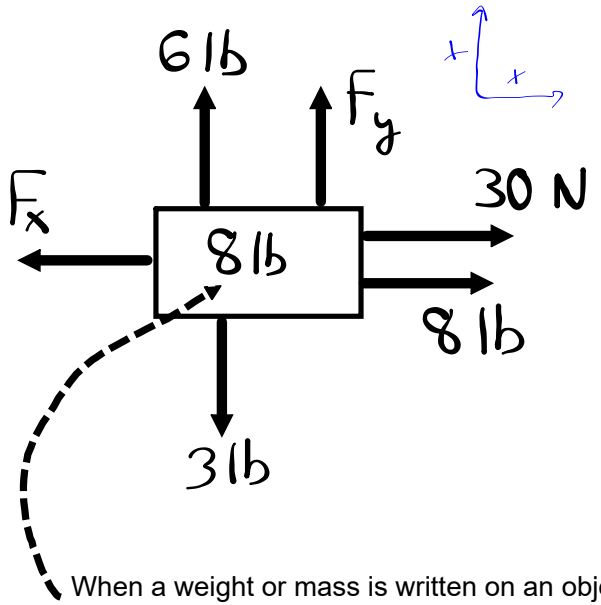
General system for solving Statics Problems:

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

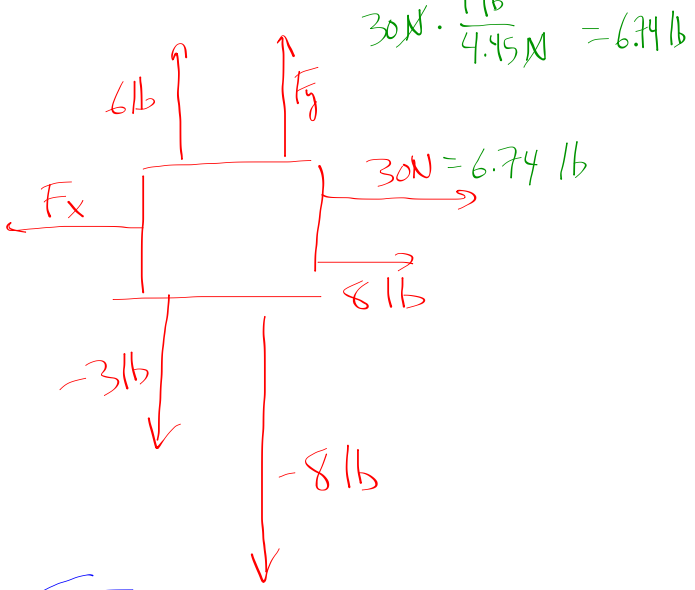
$\Sigma F_x = 0$

$\Sigma F_y = 0$

Solve for the unknown forces F_x and F_y (1 lb = 4.45 N).



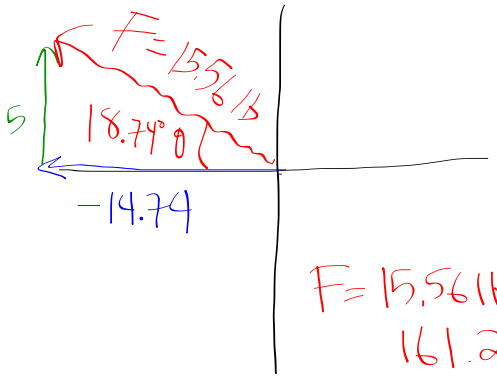
When a weight or mass is written on an object (8 lb in this case), it is the object's weight or mass - and gravity will be pulling down with a force the size of the object's weight!



$\Sigma F_x = 0$

$F_x + 6.74 + 8 = 0$

$F_x = -14.74$ lb



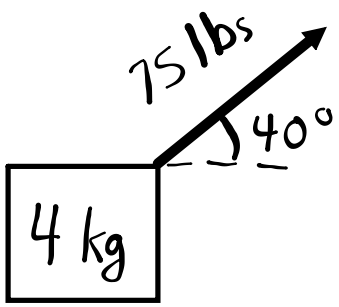
$F = 15.56\,lb @ 161.26°$

$\Sigma F_x = 0$

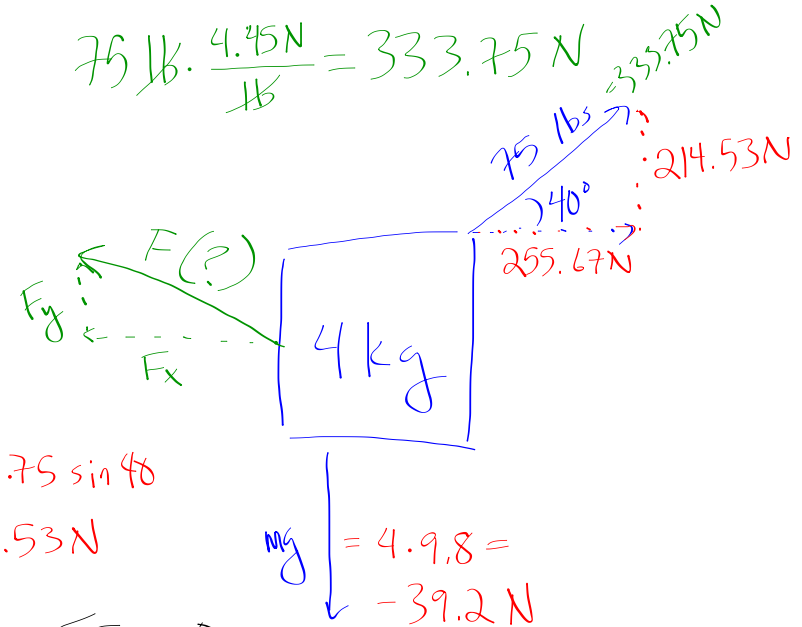
$6 + F_y + -3 + -8 = 0$

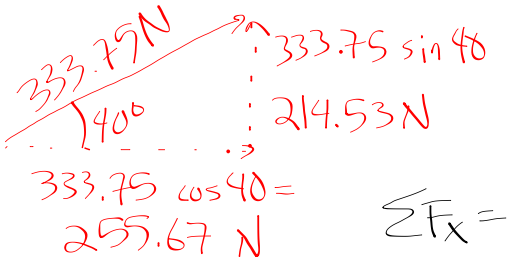
$F_y = 5$ lb

What force must be applied in order to maintain static equilibrium?



$75\ \text{lb} \cdot \frac{4.45\ \text{N}}{1\ \text{lb}} = 333.75\ \text{N}$





$mg = 4 \cdot 9.8 = -39.2\ \text{N}$

$\Sigma F_x = 0$

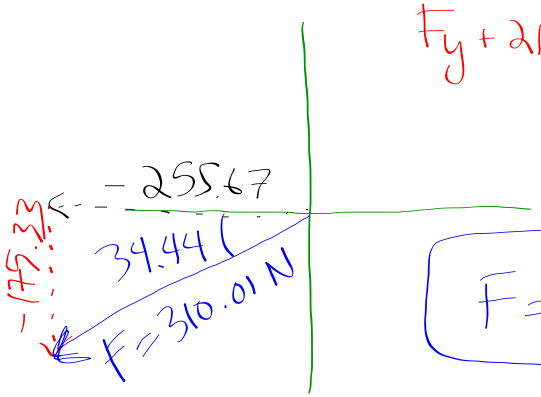
$F_x + 255.67 = 0$

$F_x = -255.67$

$\Sigma F_y = 0$

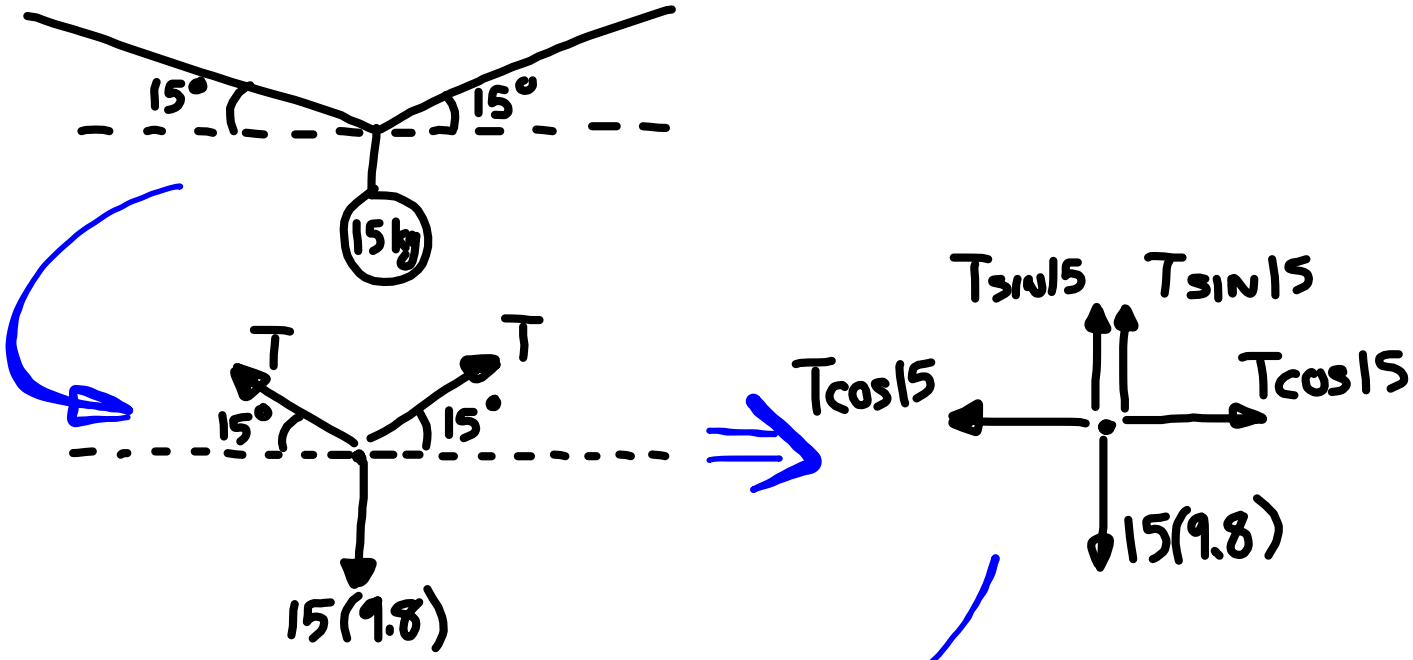
$F_y + 214.53 + -39.2 = 0$

$F_y = -175.33$



$F = 310.01\ \text{N} \measuredangle 214.44°$

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?



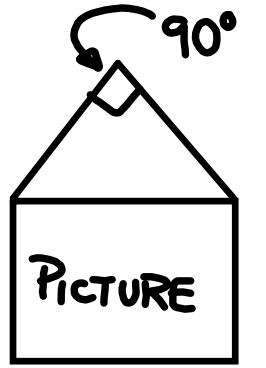
$$\Sigma F_y = 0$$

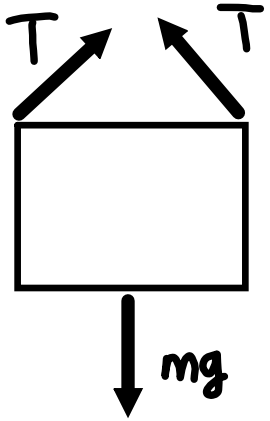
$$T\sin 15 + T\sin 15 - 15(9.8) = 0$$

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

Hints on the homework - Statics Worksheet

1)





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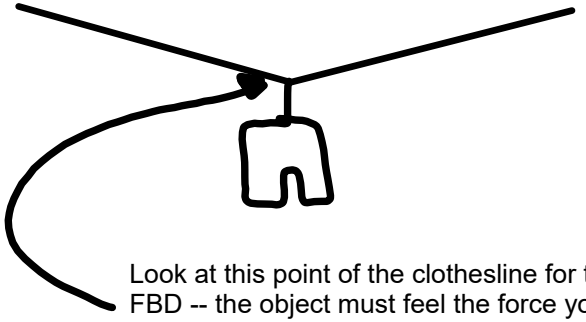

Look at this point of the clothesline for the FBD -- the object must feel the force you are trying to find, and the swimming suit DOES NOT feel the tension in the string.