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

$\frac{kg \cdot m}{s^2}$

Pound (lb)

(1 lb = 4.45 N)

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

mass: the quantity (amount) of matter in a substance

weight: the force (downward) that an object creates due to gravity.

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

WEIGHT =	**MASS** x	**ACCEL. OF GRAVITY**
N (Newtons)	Kg (Kilograms)	9.8 m/s^2
lb (pounds)	slug	32.2 ft/s^2

1 slug = 14.6 kg

1 kg ---> 2.2 lb

1 slug ---> 143 N

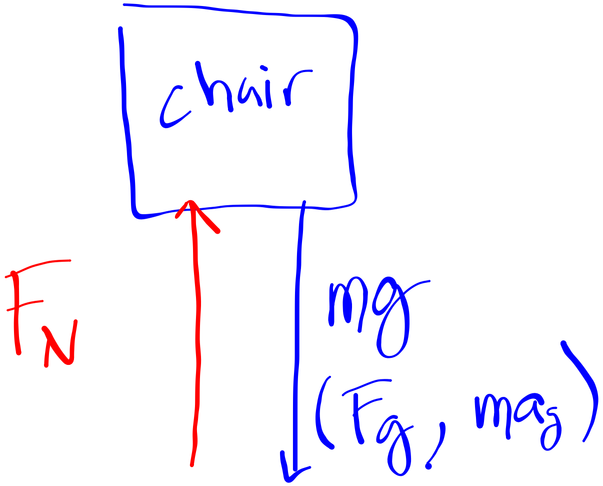
not conversion factors (not equivalent units)

Free Body Diagrams (FBD)

A FBD:

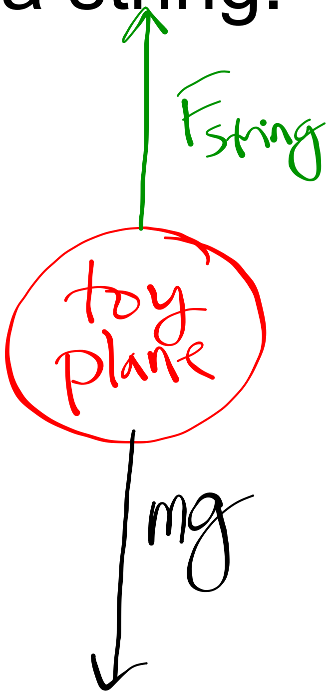
- -Shows all of the forces acting on ONE object
- -Does not show the forces the object exerts on other objects
- -Forces displayed as arrows (push = towards, pull = away)
  - -The length of the arrow corresponds to the size of the force
  - -The arrow points in the direction the force acts
- -All forces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

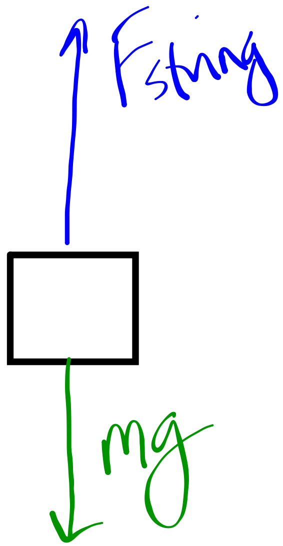


F_N = normal force - force that supports objects against gravity

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.



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.

↳ there may be forces → but they balance
so there is no acceleration

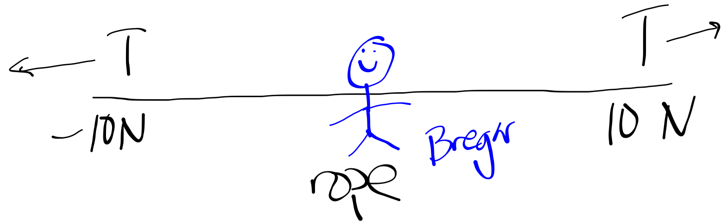
Static situations occur when the forces acting on an object(s) are all balanced and the object is either stationary or moving at constant velocity (per Newton's 1st Law of Motion).

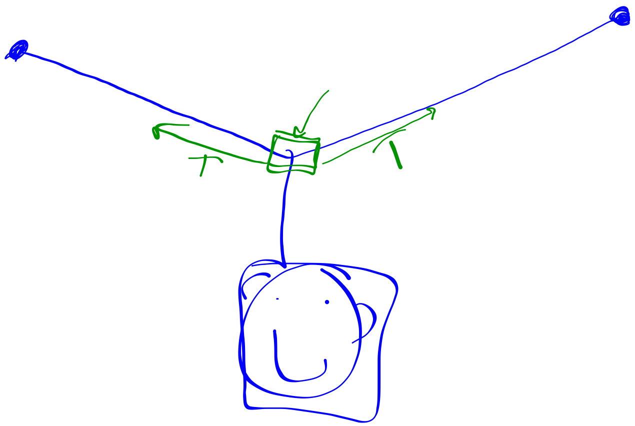
Newton's 1st Law of Motion: An object at rest or moving at a constant velocity stays at rest or continues moving at the same velocity UNLESS acted upon by an unbalanced force (net force).

What about TENSION?

the force that holds something together that is being pulled apart

* typically → ropes, strings, chains

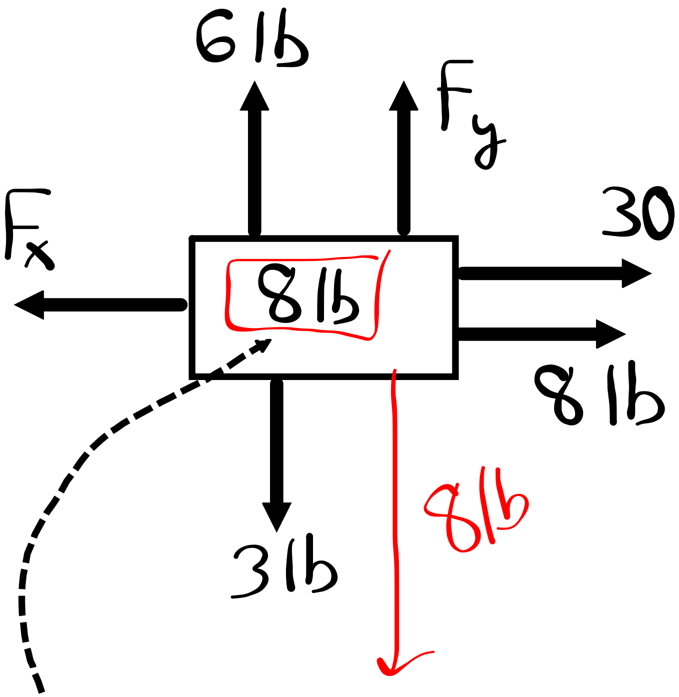




Now, lets start using the idea of forces, static equilibrium, and balanced forces to solve problems.

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

$a = 0$



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.

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

$$\sum F_x = 0$$

$$F_x + 6.74\ lb + 8\ lb = 0$$

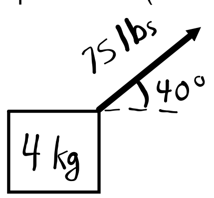
$$F_x = -14.74\ lb$$

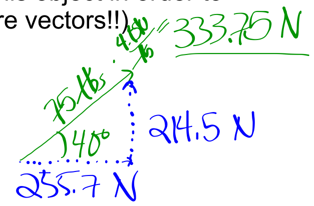
$$\sum F_y = 0$$

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

$$F_y = 5\ lb$$

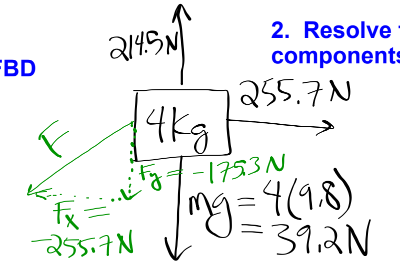
EXAMPLE: What force must be applied to this object in order to maintain equilibrium? (Remember, forces are vectors!!)





1. Draw a FBD

2. Resolve forces into x and y components



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)

$$\Sigma F_x = 0$$
$$255.7N + F_x = 0$$
$$F_x = -255.7N$$

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

$$\Sigma F_y = 0$$
$$214.5 + {}^-39.2 + F_y = 0$$
$$F_y = -175.3N$$

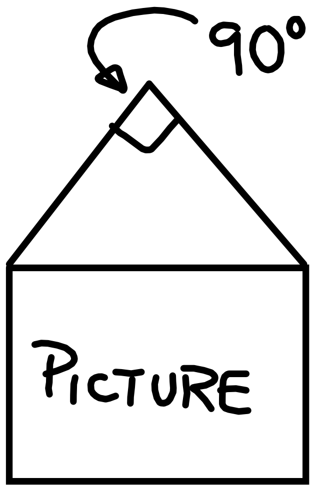
5. Calculate the resultant force and angle

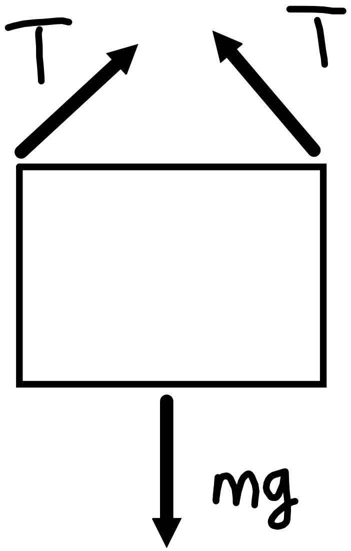
Generalized procedure for solving Statics Problems:

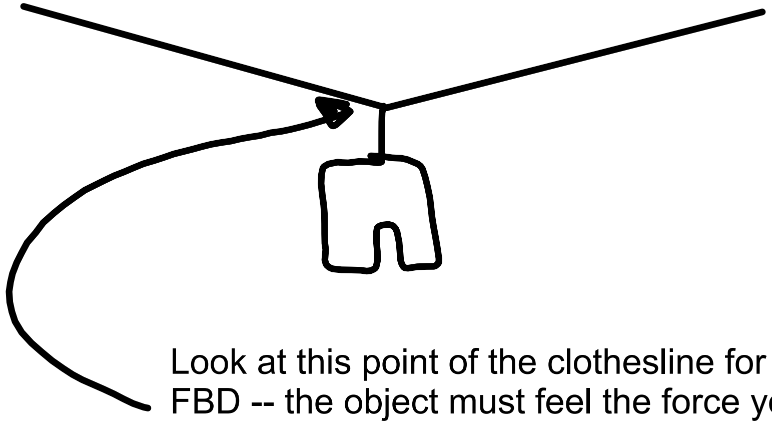
1. Make a drawing.
2. Establish a reference frame.
3. Identify variables & check units
4. **Draw a FBD** (WHY DO YOU THINK THIS ONE IS IN BOLD?)
5. Resolve all forces into X and Y components.
6. Sum all X-components and set the sum equal to zero
7. Sum all Y-components and set the sum equal to zero
8.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

Clarifications / Hints on the homework -- Statics Worksheet

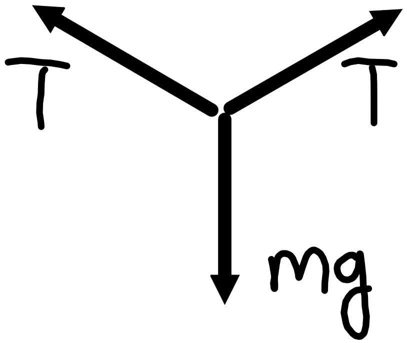
1)



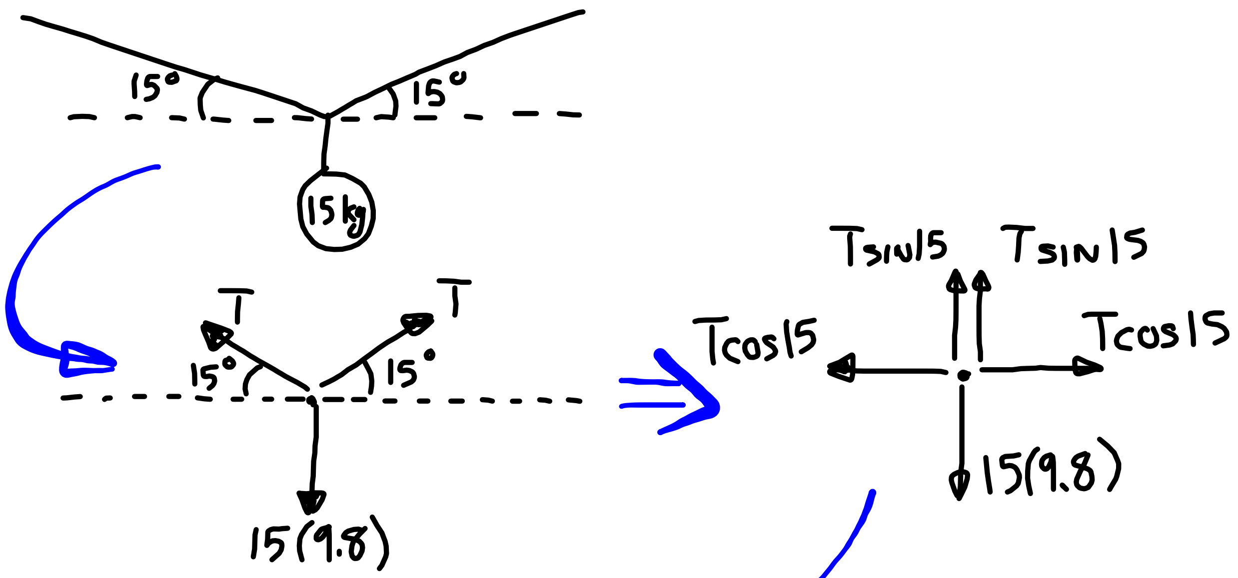




Look at this point of the clothesline for the FBD -- the object must feel the force you are trying to find, and the swimming suit DOES NOT feel the tension in the string.



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?



$$\Sigma F_y = 0$$

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

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

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.