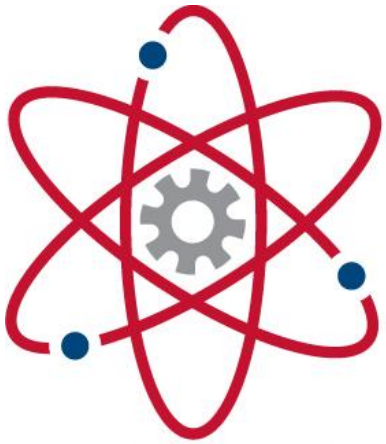


PROJECT LEAD THE WAY

PLTW

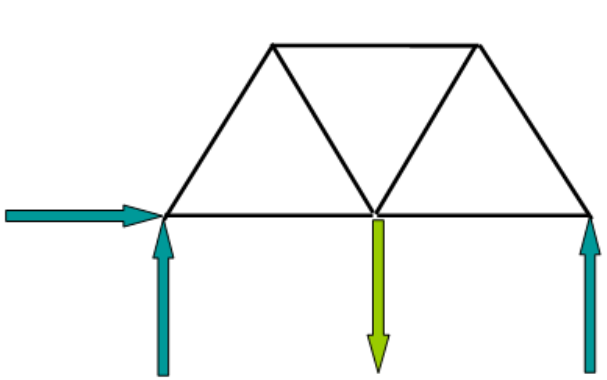
Igniting imagination and innovation through learning.

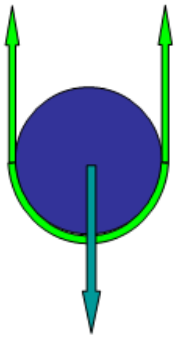
Free Body Diagrams

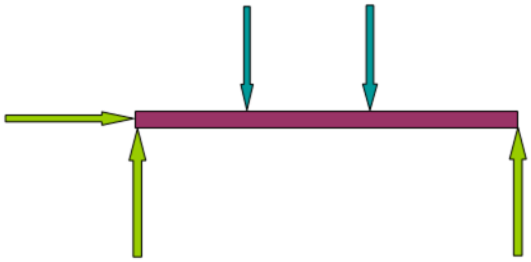
Free Body Diagram

A Free Body Diagram is a **visual** representation of force and object interactions.

Individual objects or members are **isolated** from their environment or system, illustrating all **external** forces acting upon them.





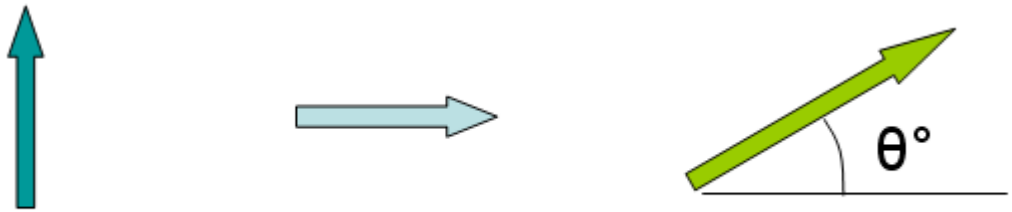


Free Body Diagram Components

Force

A **straight** line **push** or **pull** acting upon an object.

Vector quantities have **direction** and **magnitude**.



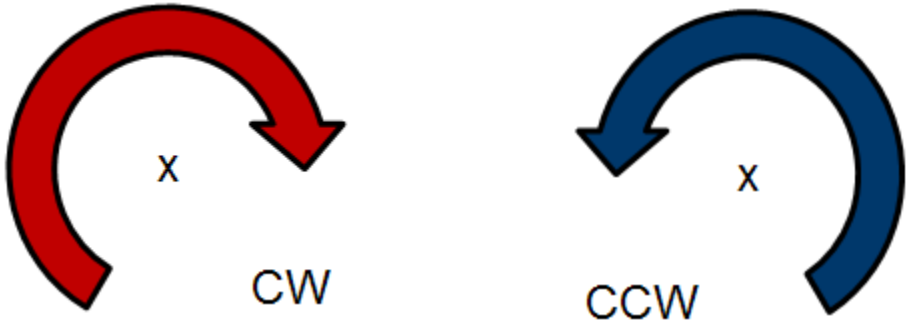
Direction is illustrated by **arrowhead.**

Magnitude is illustrated by **length** of line segment and is the amount of push or pull.

Free Body Diagram Components

Moment

The **twisting** effort (force) about a point or axis when a force is applied at a distance.



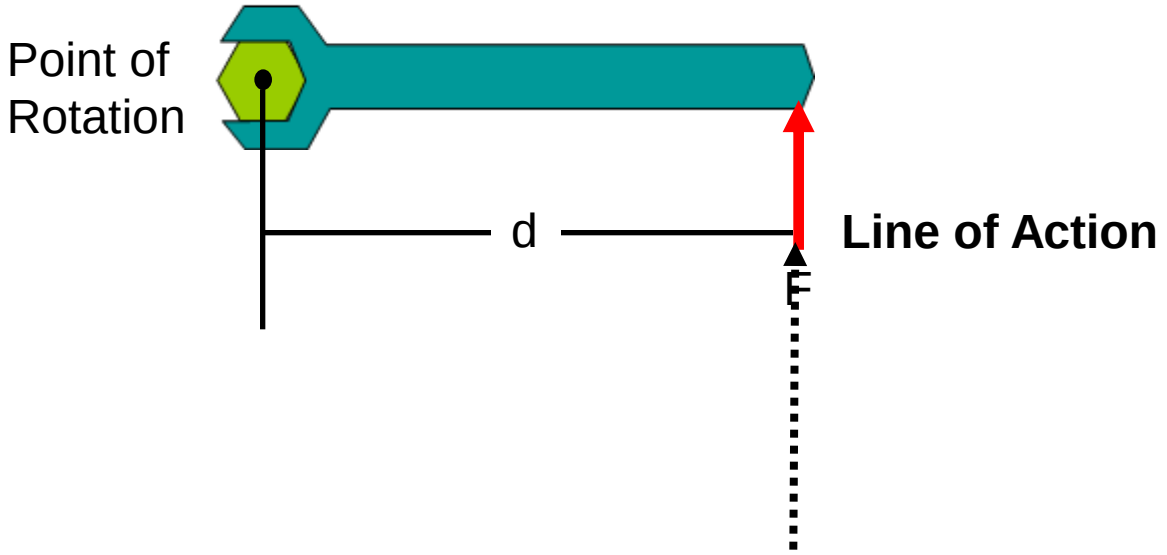
Drawn as an **arc** with an arrowhead acting about a point indicating direction of **CW** or **CCW**.

Moment (Torque) Review

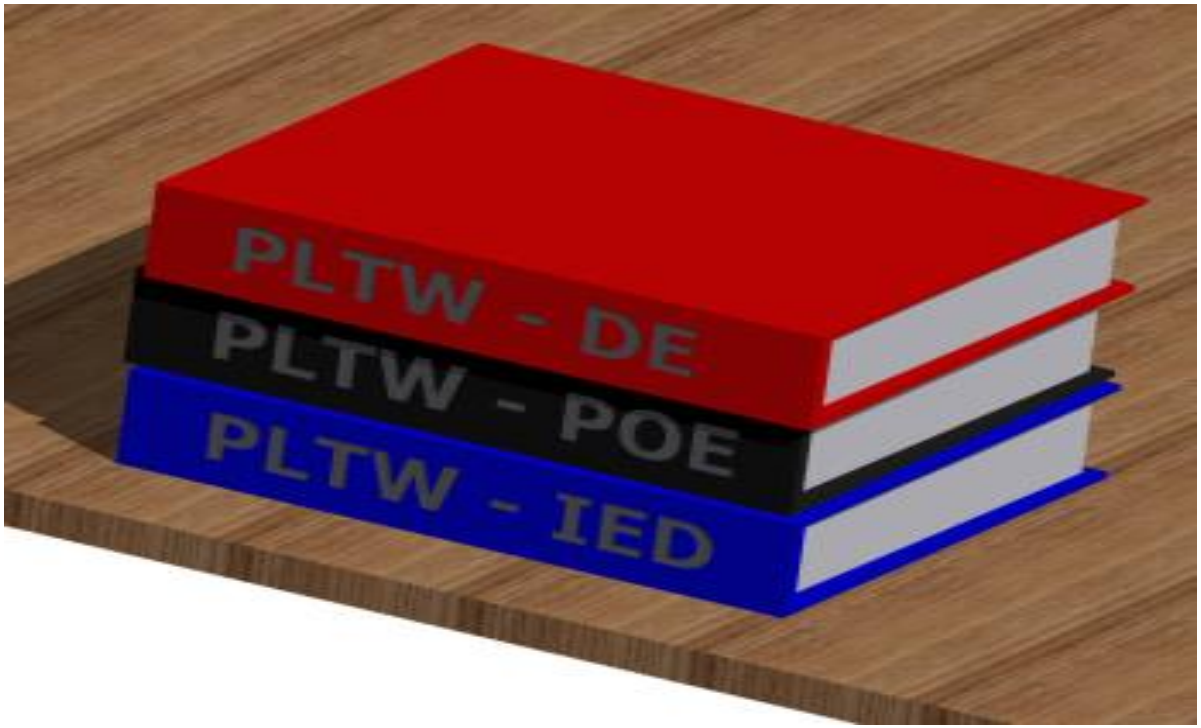
Moment (M) = Force (F) x distance (d)

Distance (d) is called the **moment arm** (or lever arm). It must be measured **perpendicular** to the line of action of the force.

$$M = F\,(d)$$

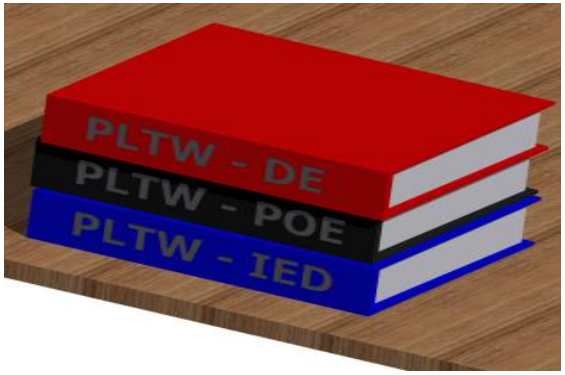


Free Body Diagram Procedure



A stack of three books, each weighing 5 lb, is sitting on top of a table. Draw the Free Body Diagram (FBD) of the ***top*** *book*.

Free Body Diagram Procedure



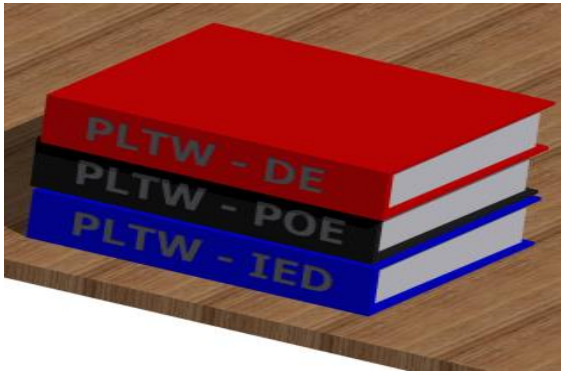
1. **Sketch** the isolated object.

What is the isolated object?

Top Book

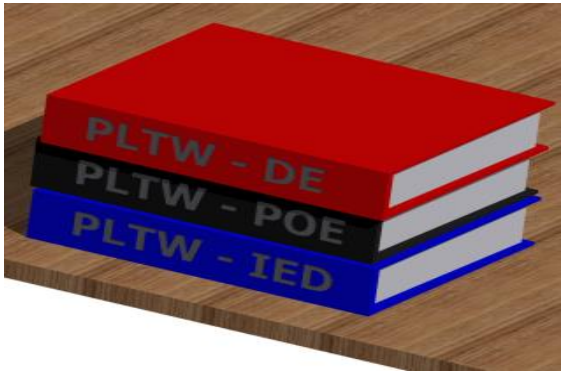
Free Body Diagram Procedure

2. Sketch the **applied** and **normal** forces.



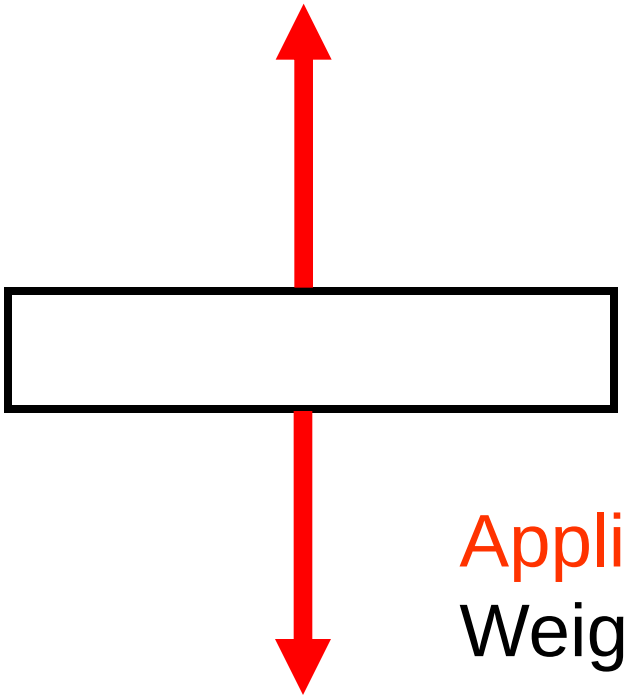
*When an object is in **contact with** and is **supported** by a second object, the second object can be replaced with a normal force which is perpendicular to the surface of the second object.*

Free Body Diagram Procedure



2. Sketch the **applied** and **normal** forces.

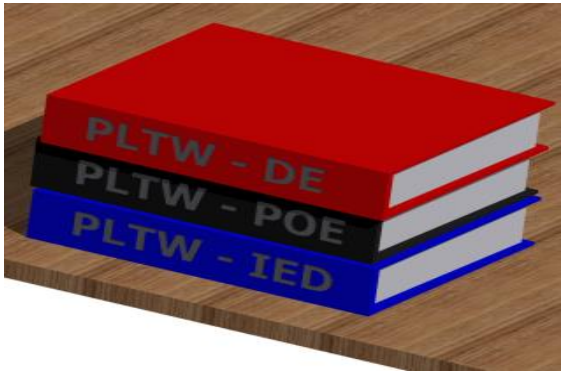
Normal Force:
Reaction force pushing up on the book, causing it not to fall.

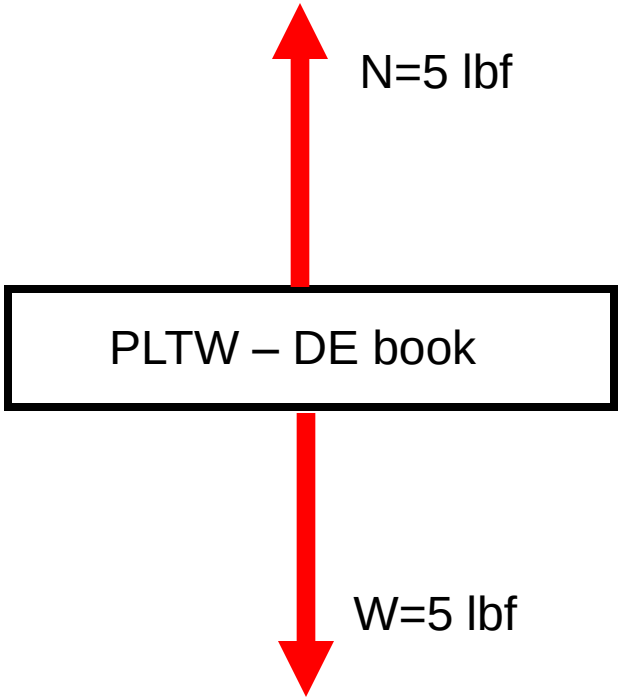


Applied Force:
Weight of top book

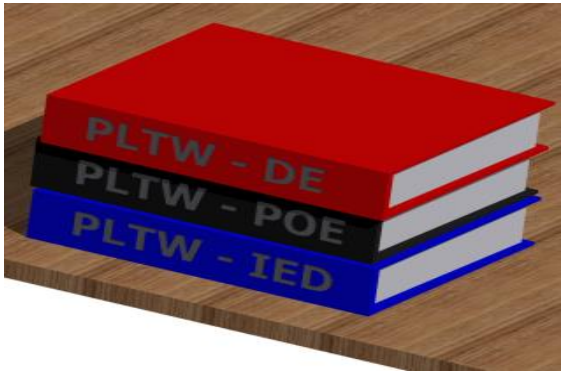
Free Body Diagram Procedure

3. **<u>Label</u>** objects and forces.



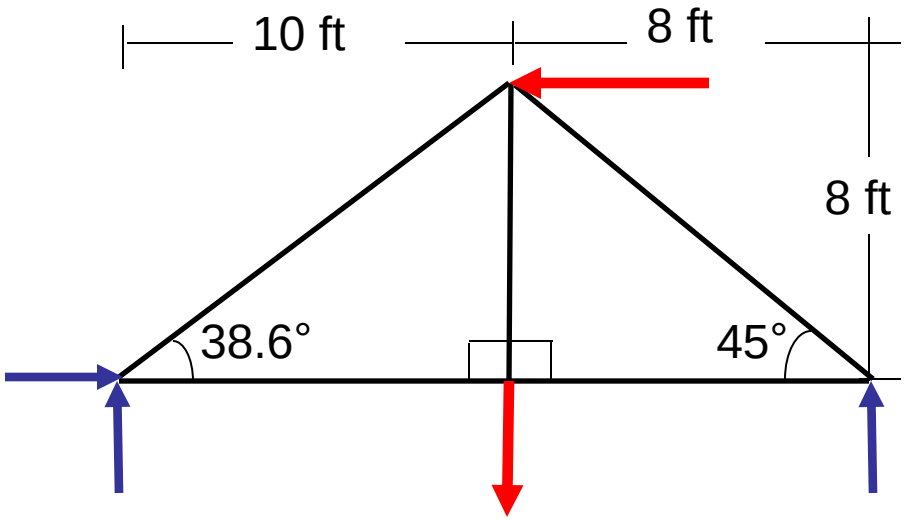


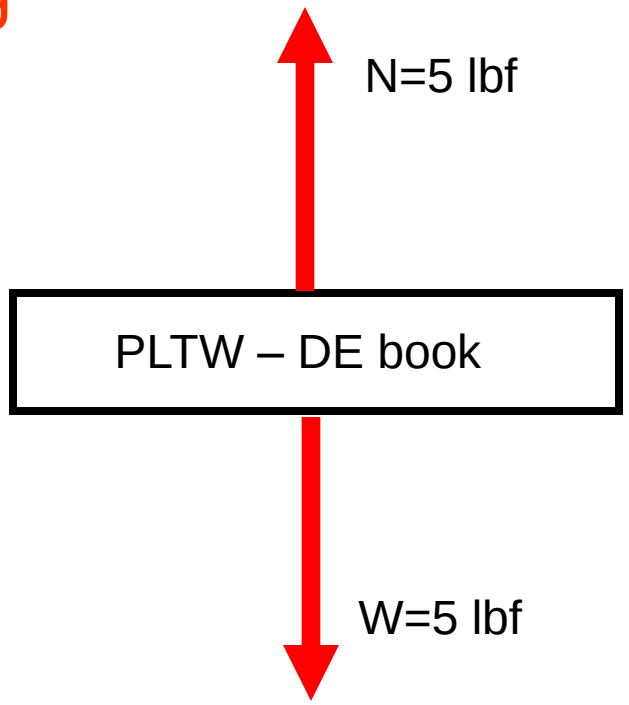
Free Body Diagram Procedure



4. Label **dimensions**.

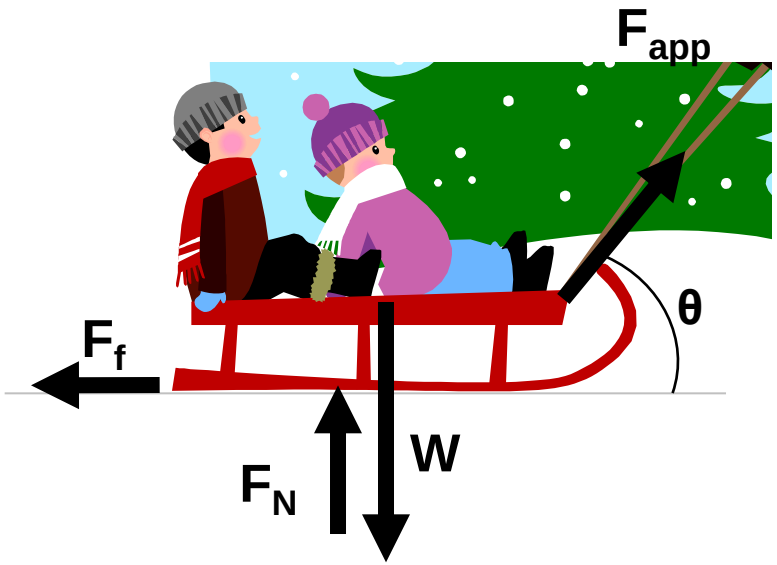
For more complex free body diagrams, proper dimensioning is required, including length, height, and angles.

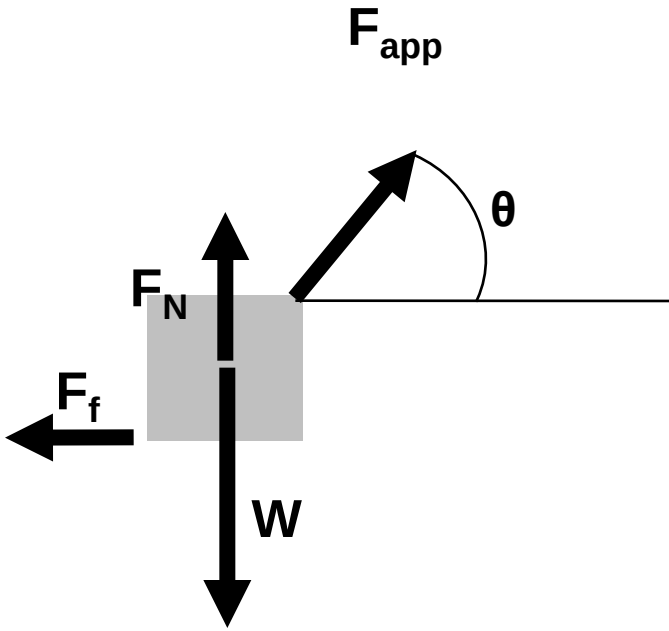




Free Body Diagram Practice

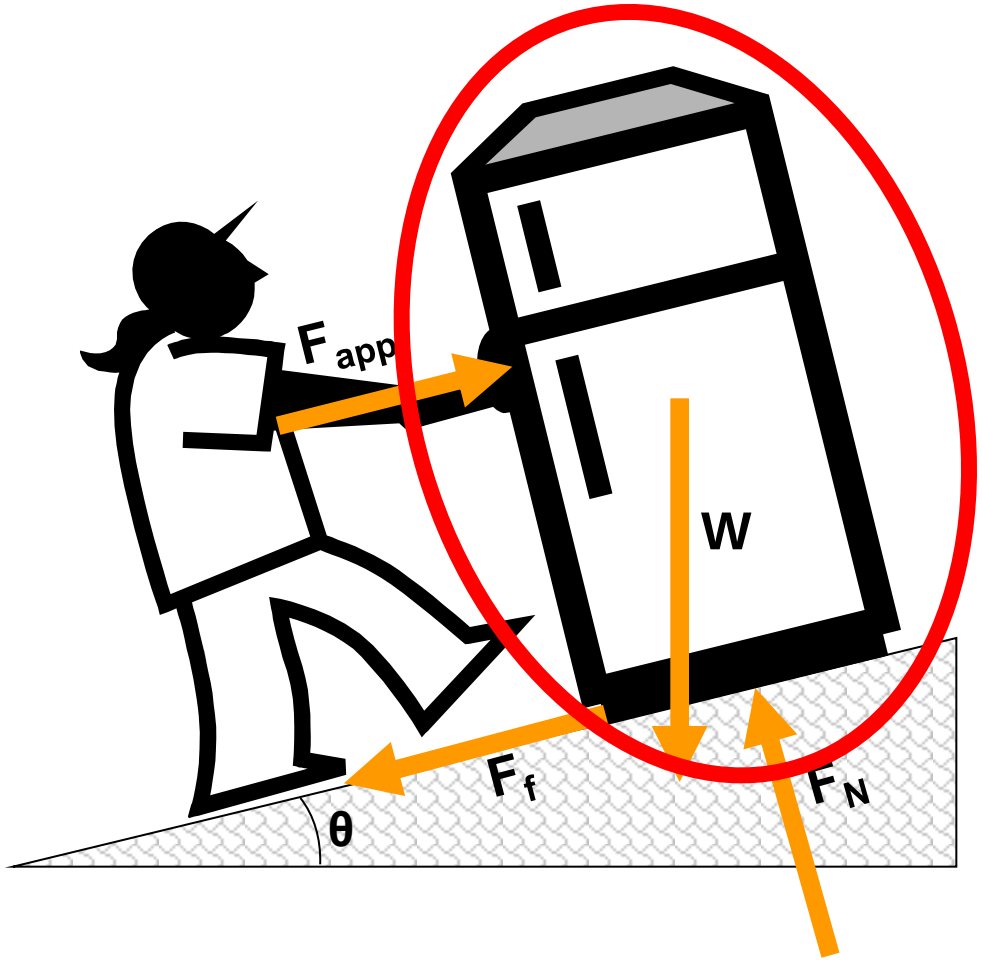
Create a FBD for the sled pictured below.

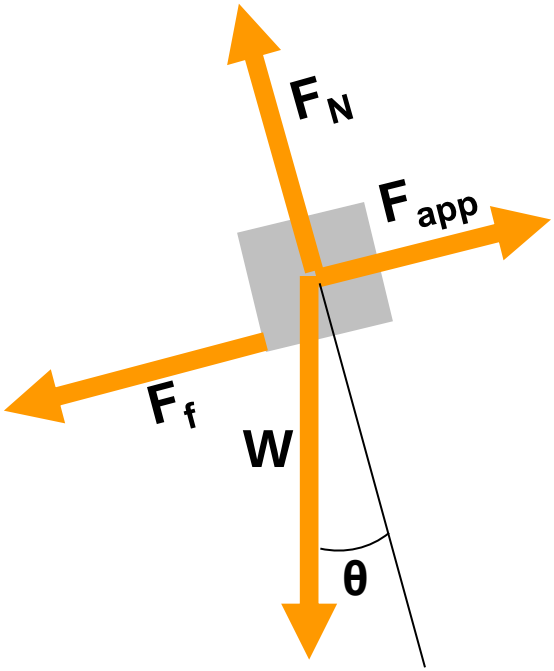




Free Body Diagram Practice

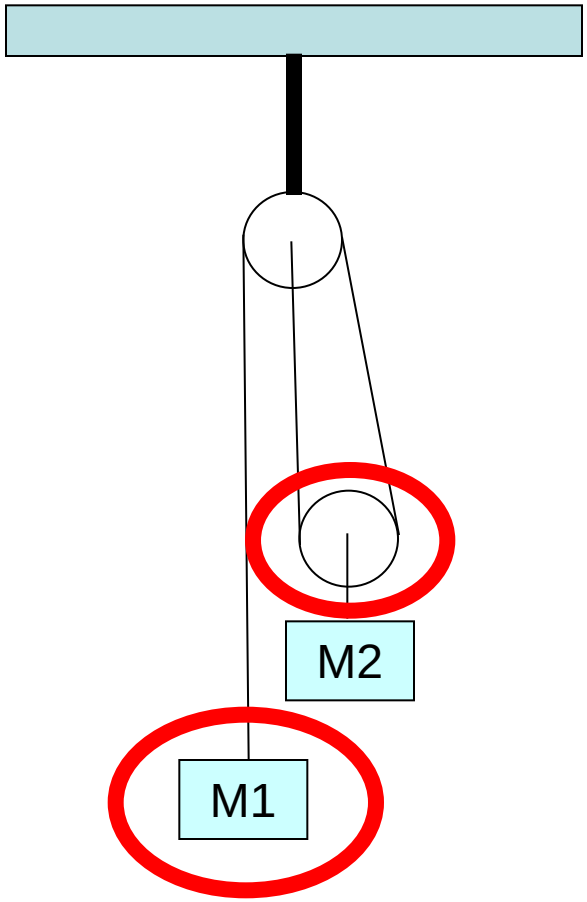
Create a FBD for the refrigerator pictured below.





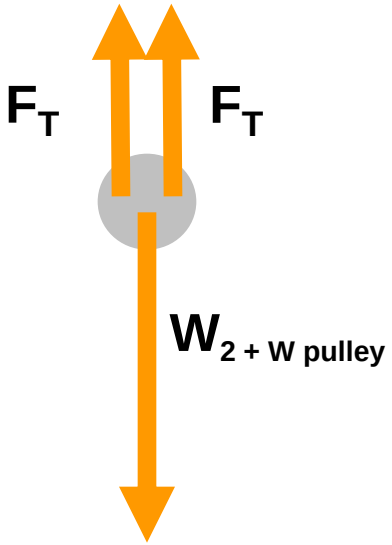
Free Body Diagram Practice

Create a FBD for the pulley system pictured below.



FBD of Mass 1:

FBD of the movable pulley:



Tension Forces (F_T) are equal throughout the system.

Free Body Diagram Reactions

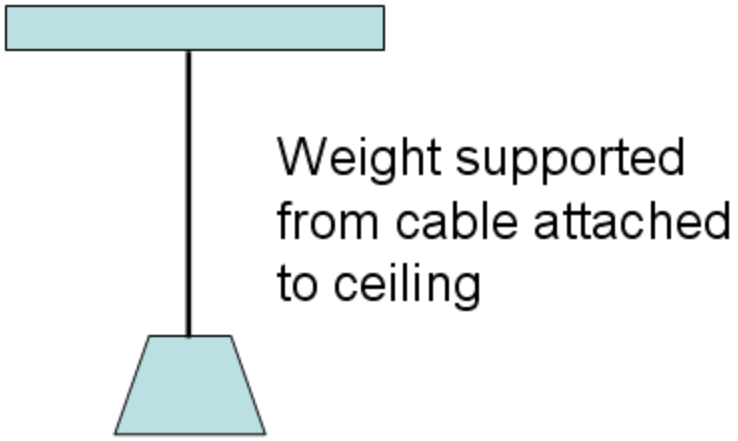
Different types of support reactions:

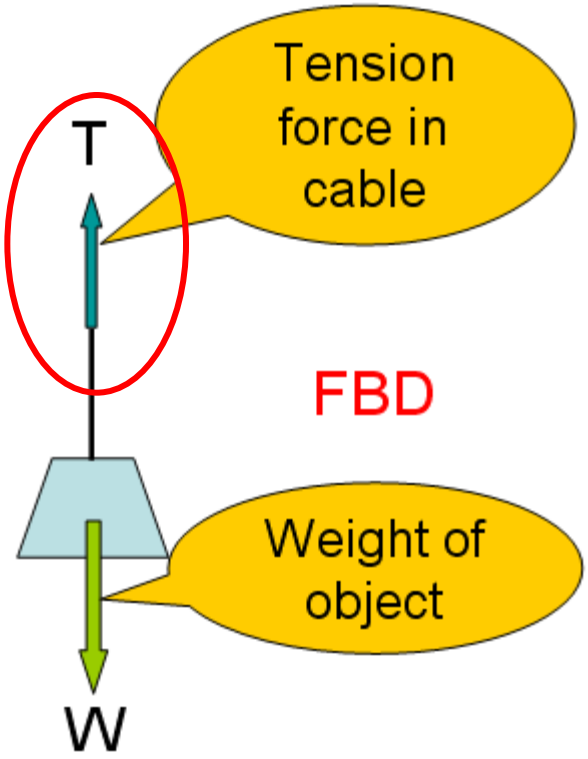
- Cable, rope, or chain
- **Pin**
- **Roller**
- Built-in end – Cantilever

To aid in completing free body diagrams, connections are often identified with letters.

Cable Support

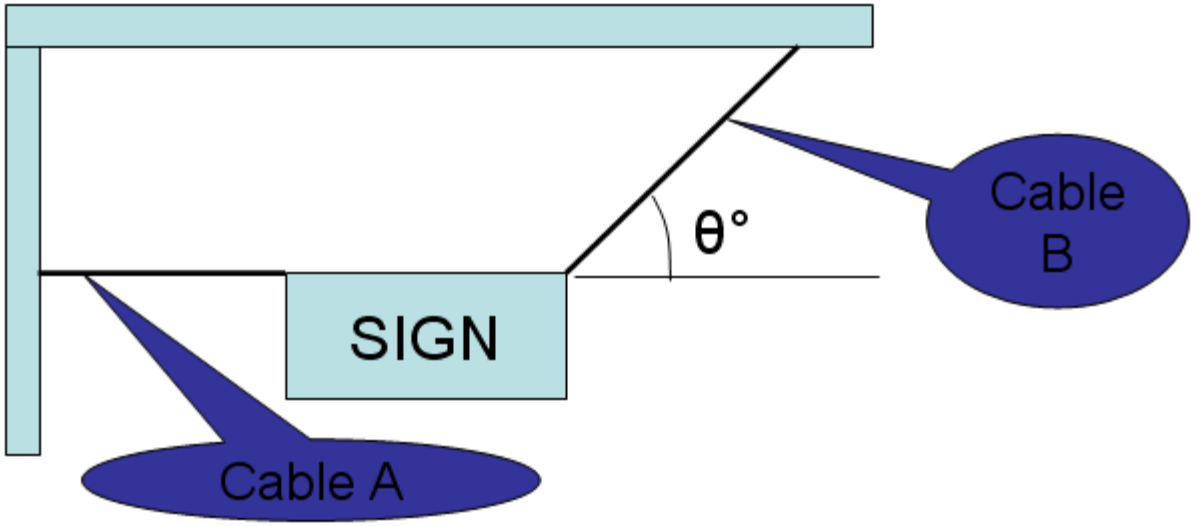
Cable, rope, chain – Replace with a **<u>tension</u>** force only.





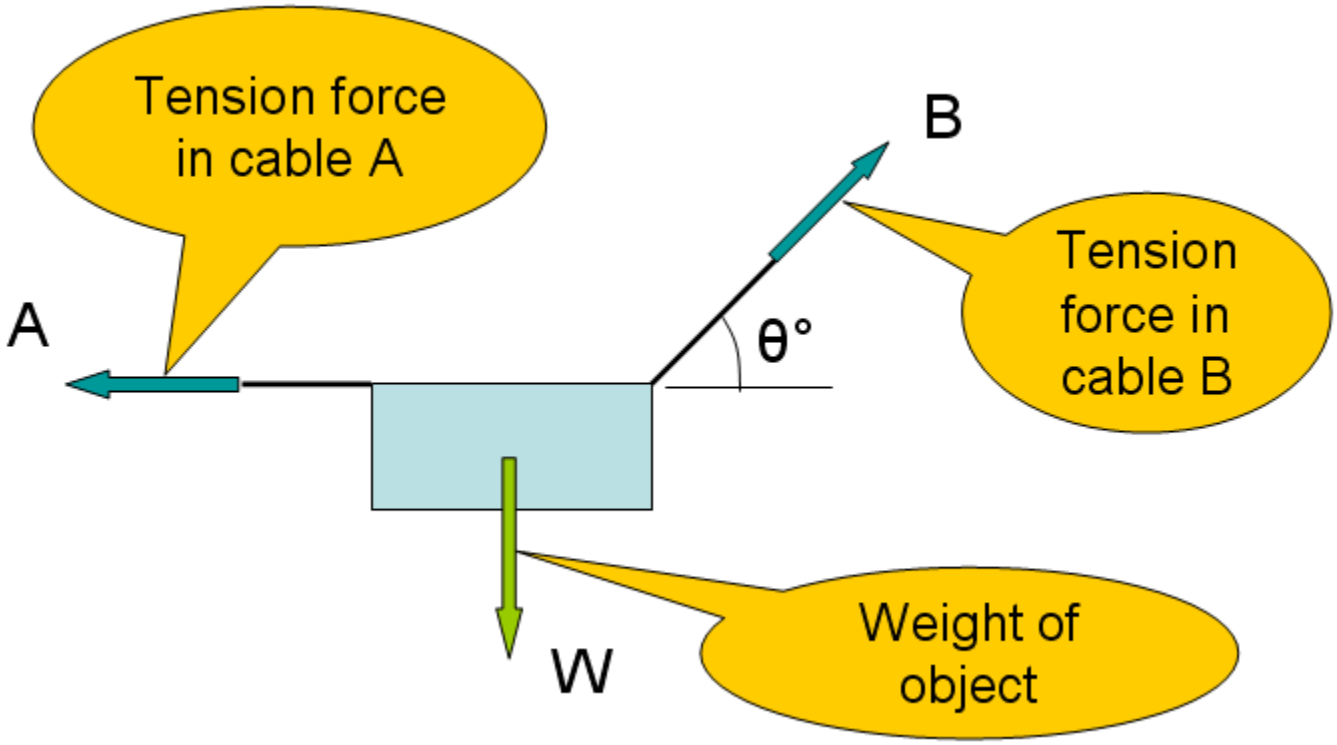
Cable Support

A sign with weight W is hung by two cables as shown. Draw the FBD of the sign and cables.



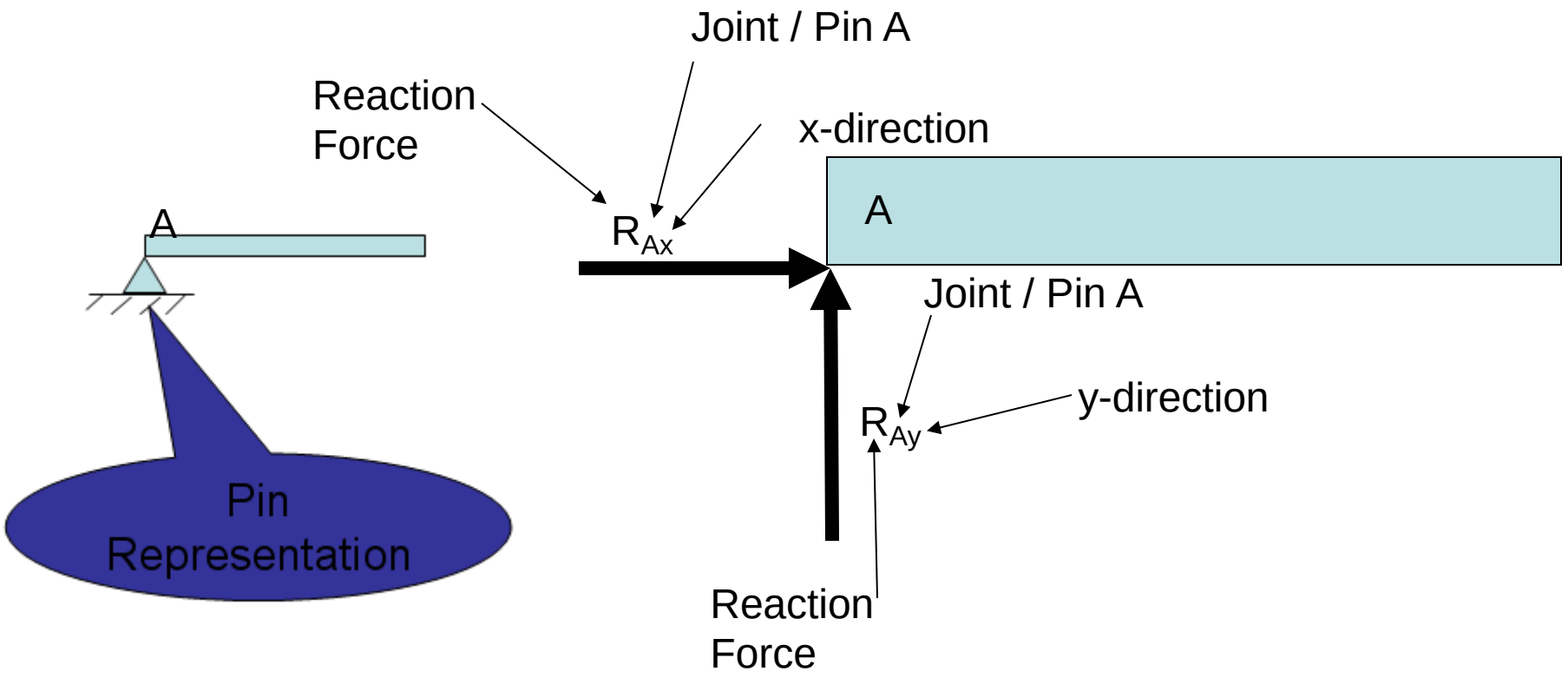
Cable Support

FBD of sign and cables:



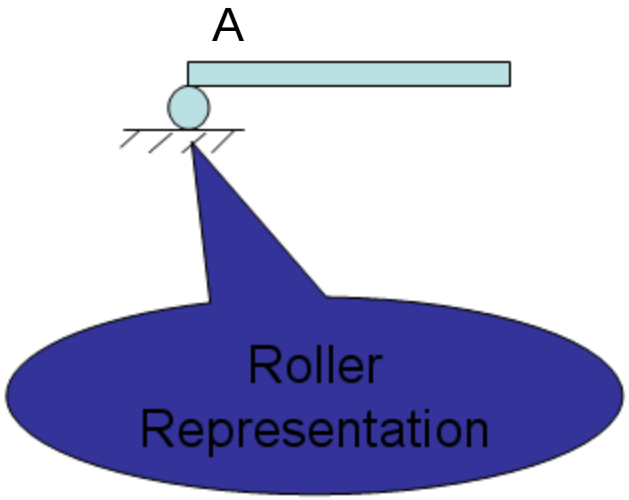
Pin Support

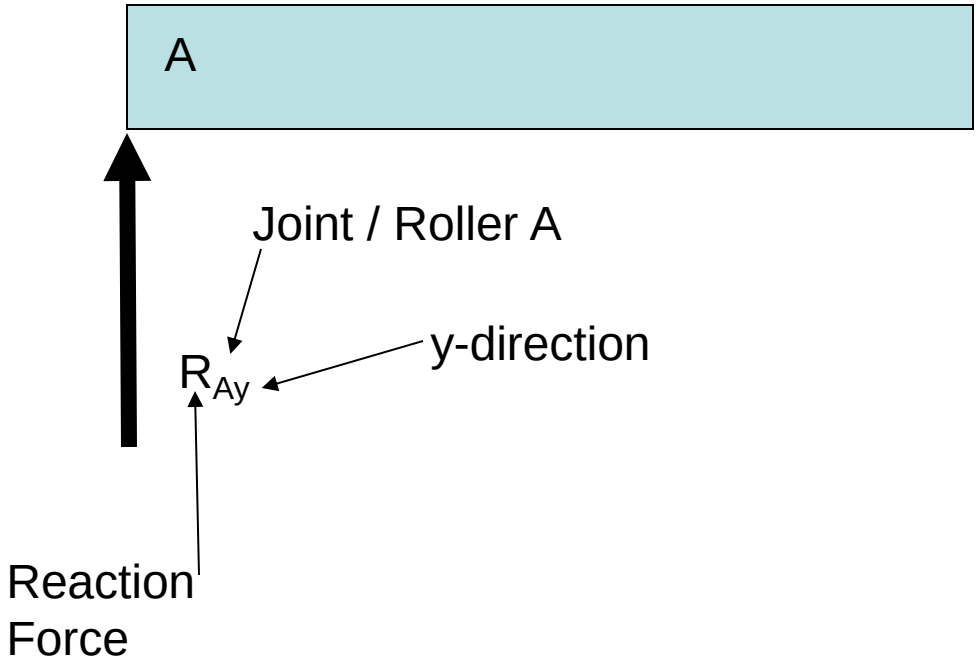
Pin – Replaced with **TWO** reaction forces, one vertical (y) and one horizontal (x).



Roller Support

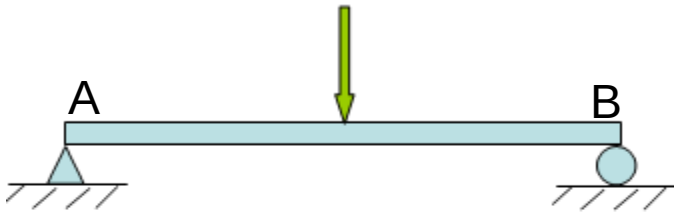
Roller – Replaced with **ONE** reaction force, perpendicular to surface.





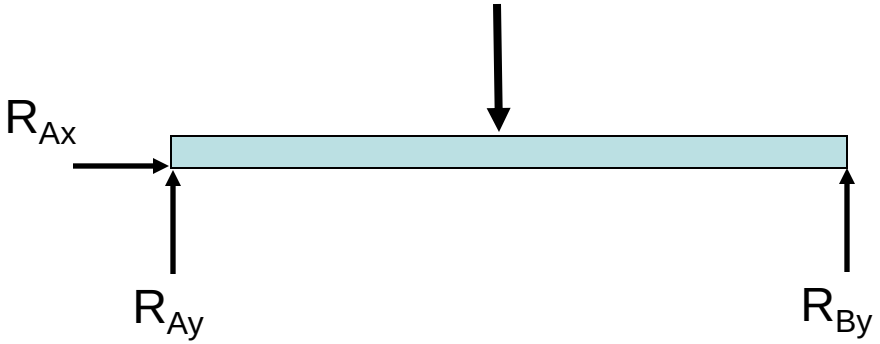
Common Support Reactions

Beams and truss bridges are usually supported with one pin support and one roller support. This is called a **simply supported** object.



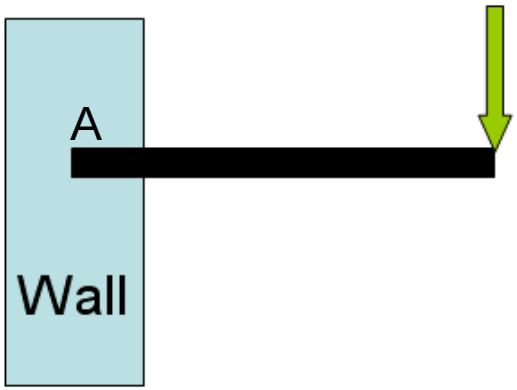
Roller at one end allows expansion/compression of beam or bridge.

Create a FBD for the simply supported beam.



Built-In-End Support

Built-in-end (cantilever) – Replaced with **TWO** forces: one horizontal and one vertical, and ONE moment



Create a FBD for the built-in-end cantilever.

Summary Support Reactions

Contact – Replace with a **normal** force.

Cable, rope, chain – Replace with **tension** force.

Pin – Replace with **two** reaction forces; one vertical and one horizontal.

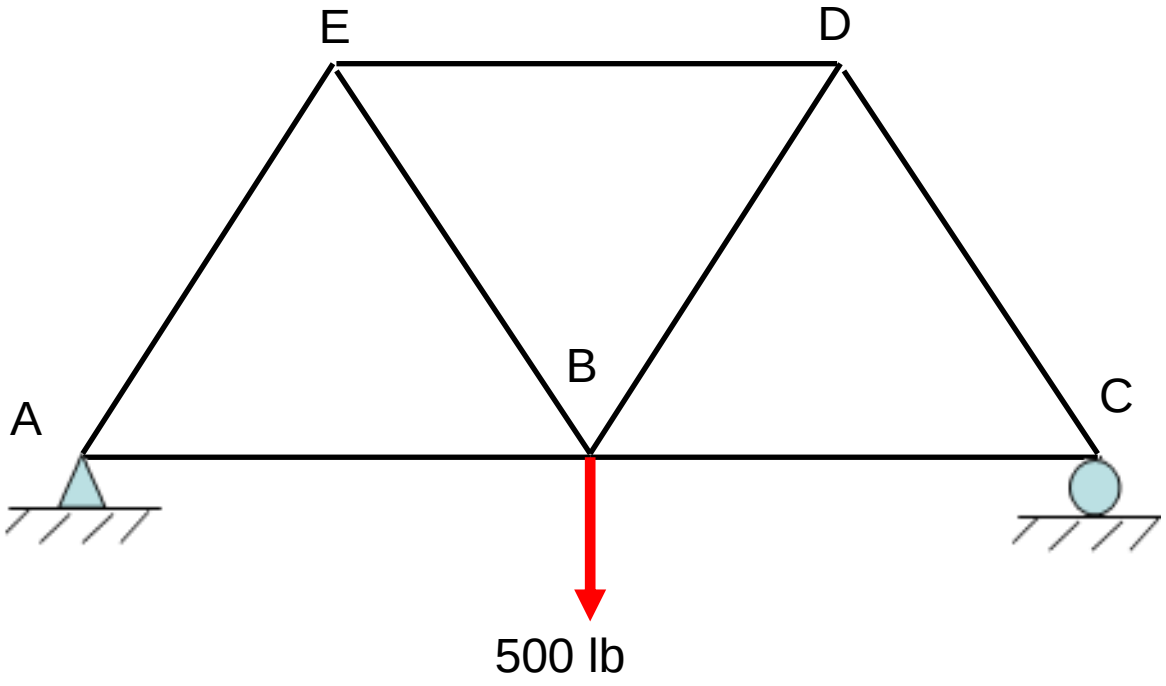
Roller – Replace with **one** reaction force perpendicular to surface.

Built-in-end (cantilever) – Replace with **one** horizontal force, **one** vertical force, and **one** moment.

Truss Bridge FBD

Supported with a **pin** at one end and a **roller** at the other.

Draw the FBD of the entire truss bridge.



Truss Bridge FBD

FBD of the entire truss bridge: