NEWTON'S LAWS

Newton's First Law – The Law of *Inertia*

INERTIA – a quantity of matter, tendency to resist changes in motion.

- *Proportional to mass.* Unit for MASS = kilogram.
- Is it harder to stop a bike or a train? Why?

Newton's First Law

An object's motion is unchanged, UNLESS acted upon by an unbalanced force.

- If an object has a net force ≠ 0, then its motion will change.

There are TWO conditions here and one constraint.

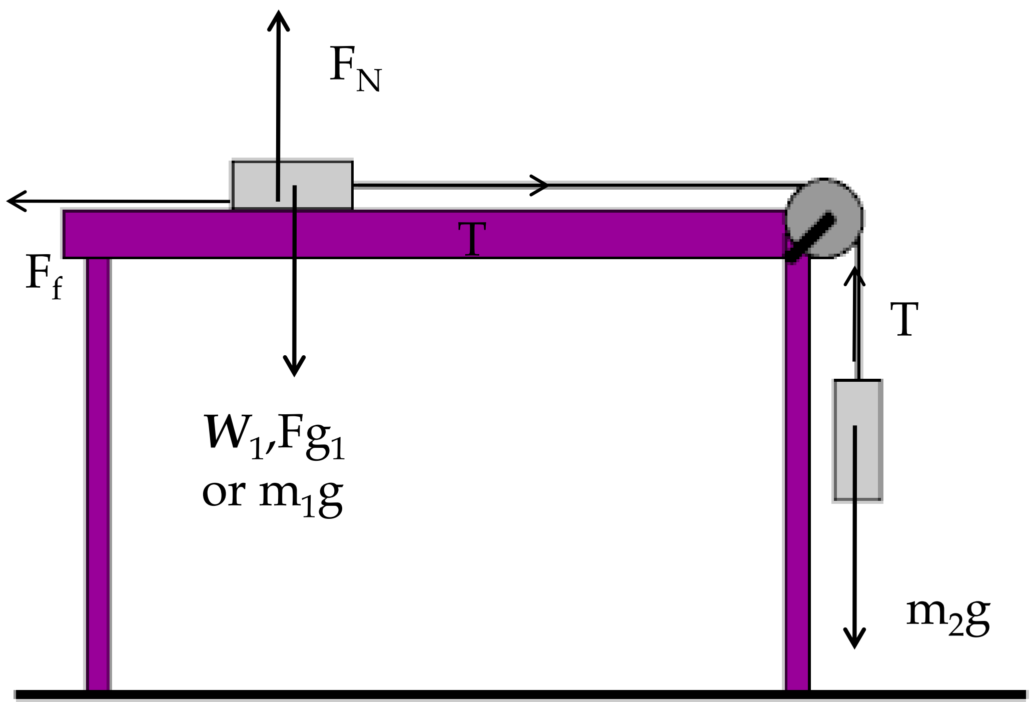
Condition #1 – The object CAN move but must be at a CONSTANT SPEED
Condition #2 – The object is at REST
Constraint – As long as the forces are BALANCED!!!!! And if all the forces are balanced the SUM of all the forces is ZERO.

The bottom line: There is NO ACCELERATION in this case AND the object must be at EQUILIBRIUM (All the forces cancel out)

$$acc = 0 \rightarrow \sum F = 0$$

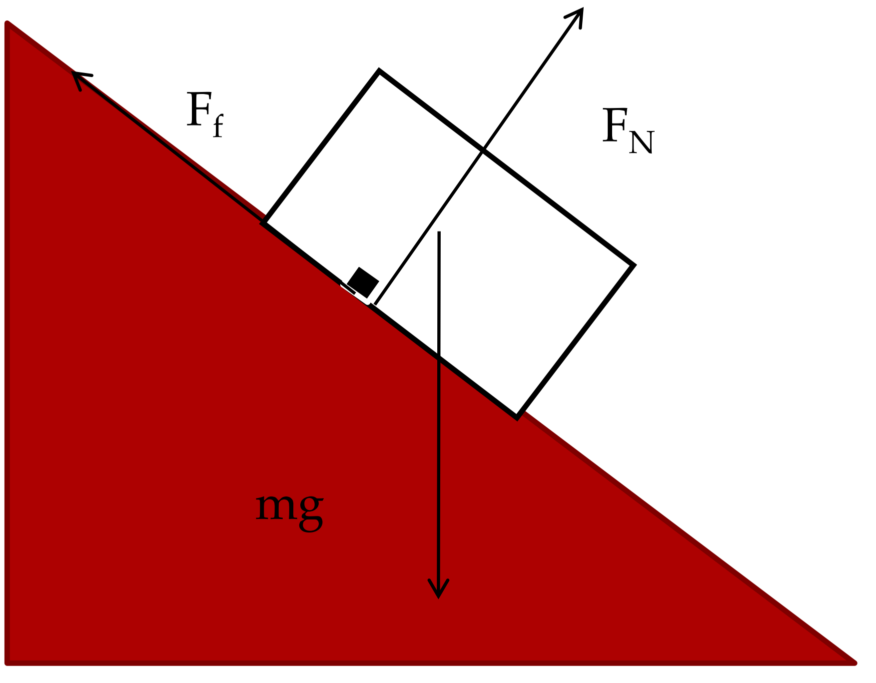
Free Body Diagrams

A pictorial representation of forces complete with labels.



- **Weight(mg)** – Always drawn from the center, straight down
- **Force Normal(F_N)** – A surface force always drawn perpendicular to a surface.
- **Tension(T or F_T)** – force in ropes and always drawn AWAY from object.
- **Friction(Ff)-** Always drawn opposing the motion.

Free Body Diagrams



N.F.L and Equilibrium

If the F_{net} = 0, a system moving at a constant speed or at rest MUST be at **EQUILIBRIUM.**

TIPS for solving problems

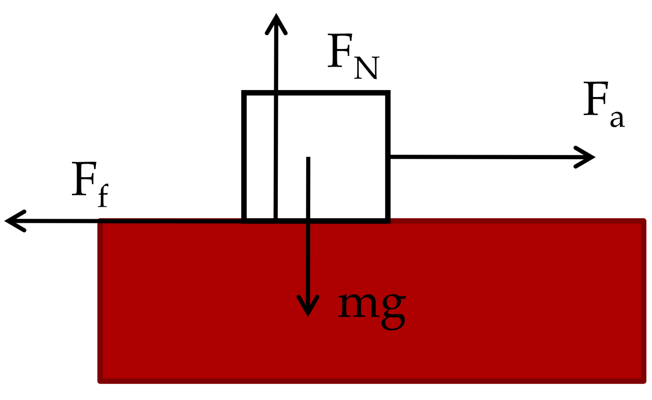
- Draw a FBD
- Resolve anything into COMPONENTS
- Write equations of equilibrium for horizontal and vertical forces.
- Solve for unknowns

Example

A 10-kg box is being pulled across the table to the right at a constant speed with a force of 50N.

a) Calculate the Force of Friction

b) Calculate the Force Normal

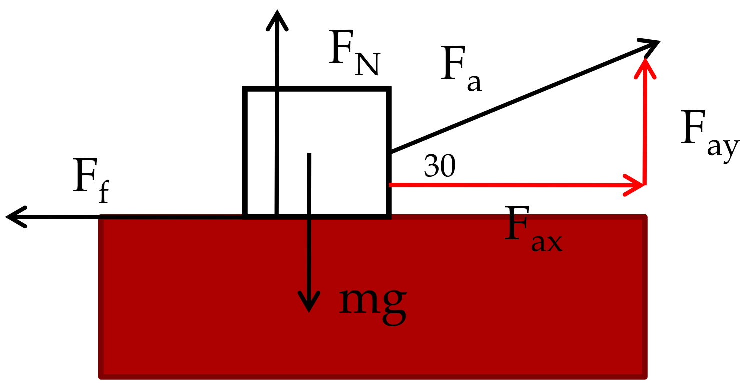


Example

Suppose the same box is now pulled at an angle of 30 degrees above the horizontal.

a) Calculate the Force of Friction

b) Calculate the Force Normal



What if it is NOT at Equilibrium?

If an object is NOT at rest or moving at a constant speed, that means the FORCES are UNBALANCED. One force(s) in a certain direction over power the others.

THE OBJECT WILL THEN ACCELERATE.

Newton's Second Law

The acceleration of an object is directly proportional to the NET FORCE and inversely proportional to the mass.

$$F_{NET} = \sum F$$

$$a \,\alpha\, F_{NET} \qquad a \,\alpha\, \frac{1}{m}$$

$$a = \frac{F_{NET}}{m} \rightarrow \boxed{F_{NET} = ma}$$

Tips:

•Draw an FBD

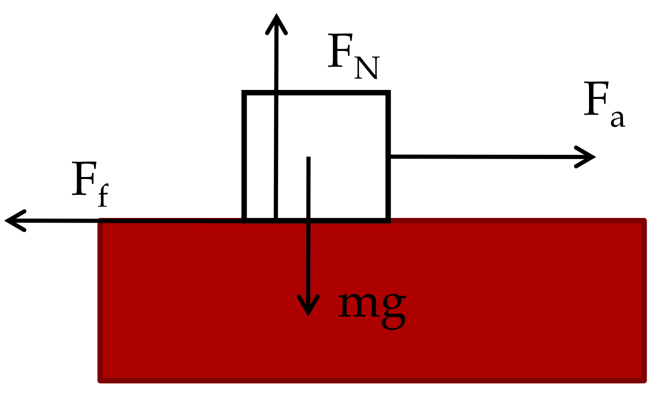
•Resolve vectors into components

•Write equations of motion by adding and subtracting vectors to find the NET FORCE. Always write larger force – smaller force.

•Solve for any unknowns

N.S.L

A 10-kg box is being pulled across the table to the right by a rope with an applied force of 50N. Calculate the acceleration of the box if a 12 N frictional force acts upon it.



In which direction, is this object accelerating?

The X direction!

So N.S.L. is worked out using the forces in the "x" direction only

$$F_{Net} = ma$$

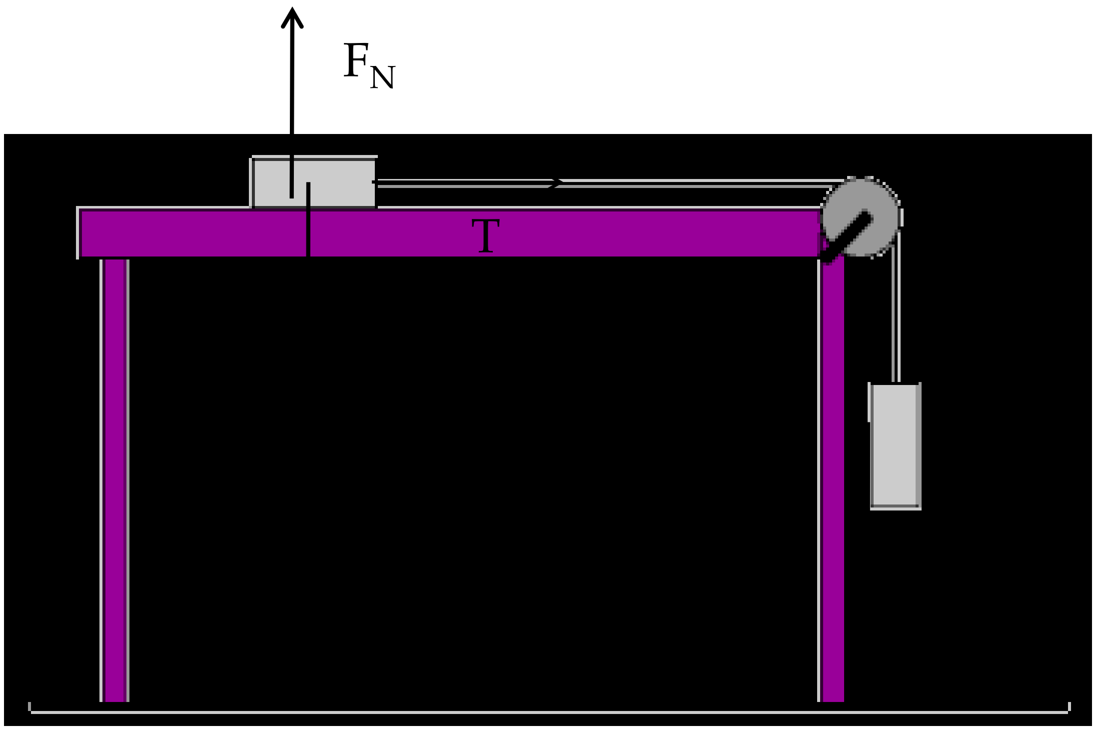
$$F_a - F_f = ma$$

$$50 - 12 = 10a$$

$$a = 3.8\, m/s^2$$

Example

A mass, m_1 = 3.00kg, is resting on a frictionless horizontal table is connected to a cable that passes over a pulley and then is fastened to a hanging mass, m_2 = 11.0 kg as shown below. Find the acceleration of each mass and the tension in the cable.



$$F_{Net} = ma$$

$$m_2 g - T = m_2 a$$

$$T = m_1 a$$

$$m_2 g - m_1 a = m_2 a$$

$$m_2 g = m_2 a + m_1 a$$

$$m_2 g = a(m_2 + m_1)$$

$$a = \frac{m_2 g}{m_1 + m_2} \rightarrow \frac{(11)(9.8)}{14} = 7.7\ m/s^2$$

Example

$$F_{Net} = ma$$

$$m_2 g - T = m_2 a$$

$$T = m_1 a$$

$$T = (3)(7.7) = 23.1N$$

$$F_{Net} = ma \rightarrow \frac{F_{NET}}{a} = m$$

$$Slope = \frac{Rise}{Run}$$