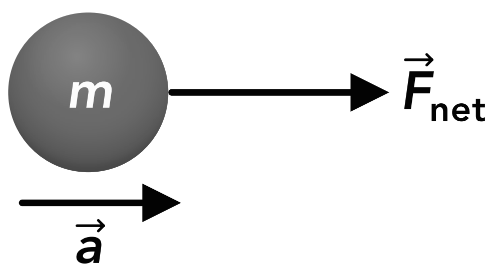
STUDY GUIDE

NEWTON'S 2ND LAW OF MOTION

Newton's 2nd Law of Motion

- **Newton's 2nd law of motion:** A net force F_{net} (the vector sum of all forces) acting on an object of mass m will cause it to accelerate at a rate of a in the same direction as the net force, and the net force is equal to the mass multiplied by the acceleration: $F_{net} = ma$
- It's important to remember that the forces acting on an object are related to its **acceleration**, not its velocity.
- In a way, Newton's 2nd law also covers Newton's 1st law. Acceleration is the change in an object's velocity. If the net force acting on an object is zero, the acceleration is zero and the velocity will remain the same. If the object is at rest (has zero velocity) it will remain at rest. If the object is moving (has a velocity) it will maintain that velocity.
- The relationship $F = ma$ is the source of the base SI units used in the unit of force, the Newton (N).



Newton's 2nd law of motion

$\vec{F}_{net} = m\vec{a}$ or $\sum \vec{F} = m\vec{a}$

$\sum$: the sum of __

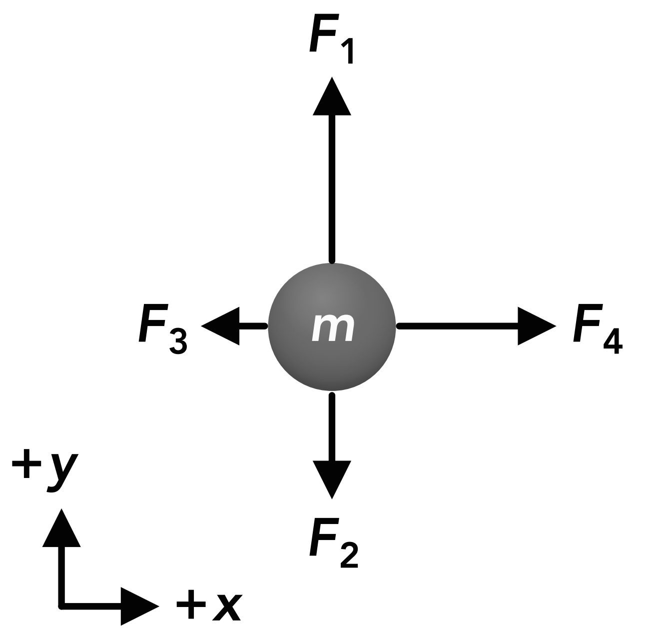
Units:

$$\mathrm{N} = \mathrm{kg}\,\frac{\mathrm{m}}{\mathrm{s}^2}$$

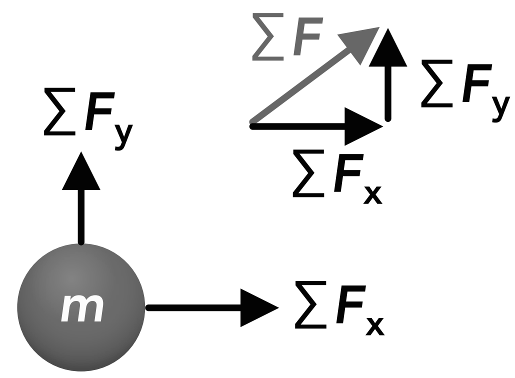
- This may be the first time we're discussing ***mass***. All objects have mass, and there are several ways to define or think about mass:
- As a simple starting point, you can think of an object's mass as the "weight" of the object. Heavier objects have more mass and lighter objects have less mass. It's important to know that mass and weight are two separate things, which will be covered later, but in the presence of gravity an object's weight is proportional to its mass.
- Mass is the amount of matter contained in an object.
- Mass is related to the inertia of an object (for now it's fair to say they are the same thing). An object with more mass has more inertia and will resist a change to its current state (at rest or in motion) more than an object with less mass. This is essentially Newton's 2nd law: the amount an object changes its motion (the acceleration) due to a net force is proportional to its mass ($F_{net} = ma$, $m = F_{net}/a$, $a = F_{net}/m$).
- The SI unit of mass is the **kilogram (kg)**.

- An important part of Newton's 1st and 2nd laws is that only a **net force** causes an acceleration, and the forces and the acceleration are **vectors**.
- Free body diagrams are used in combination with Newton's 2nd law to determine the net force vector acting on an object and the acceleration vector.
- In almost every scenario we're going to **analyze the components of the net force and the acceleration in the *x* and *y* directions separately**, just like in kinematics, because the *x* and *y* directions are independent.
- If a force is not parallel to the *x* or *y* axis then we need to find the *x* and *y* components of that force.
- We will end up with two equations (one for each direction) that describe the relationship between the forces and the acceleration. Then we can plug in all of the known values to solve for an unknown value.

Free body diagram of the forces acting on an object



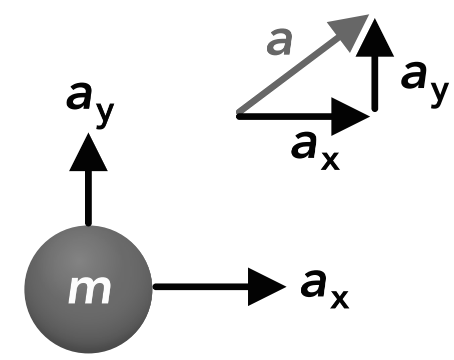
The net force acting on an object is the vector sum of all the forces



$\sum F_x = (F_4) + (-F_3)$

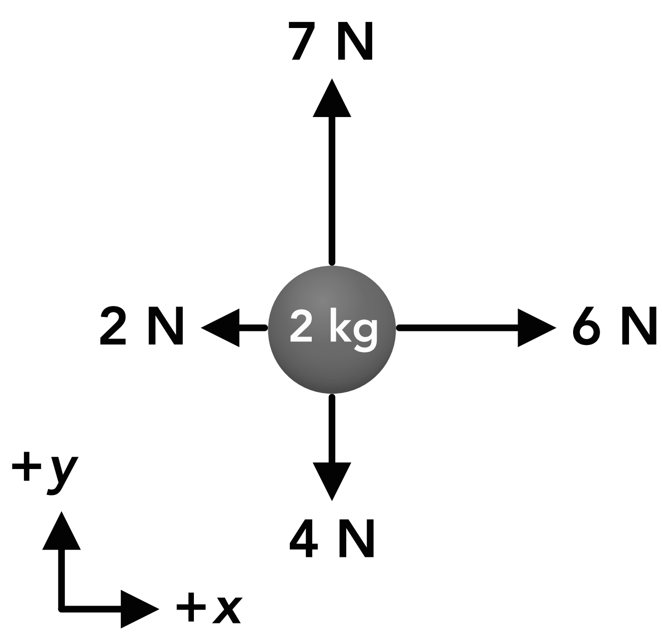
$\sum F_y = (F_1) + (-F_2)$

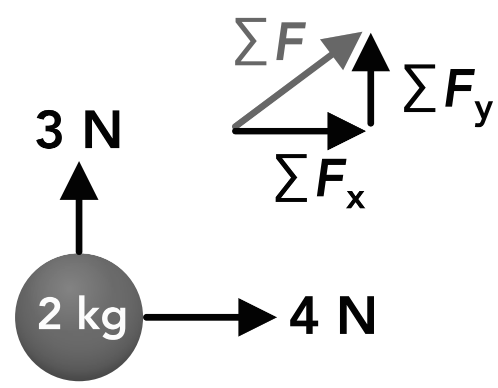
Newton's 2nd law applies to each direction



$\sum F_x = ma_x$

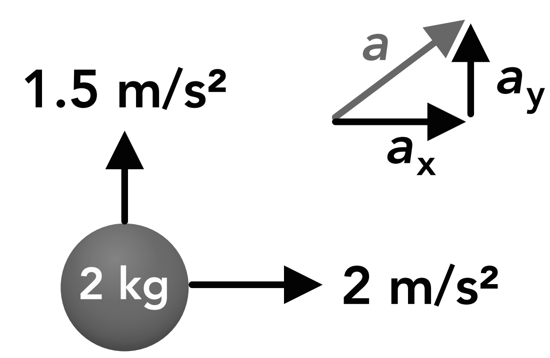
$\sum F_y = ma_y$





$\sum F_x = (6\text{ N}) + (-2\text{ N}) = 4\text{ N}$

$\sum F_y = (7\text{ N}) + (-4\text{ N}) = 3\text{ N}$

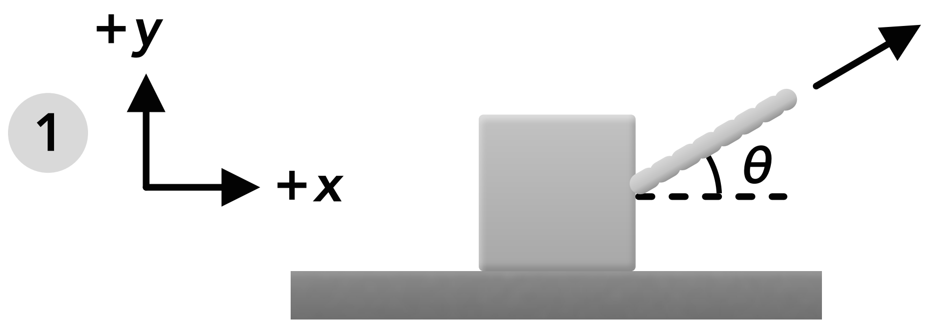


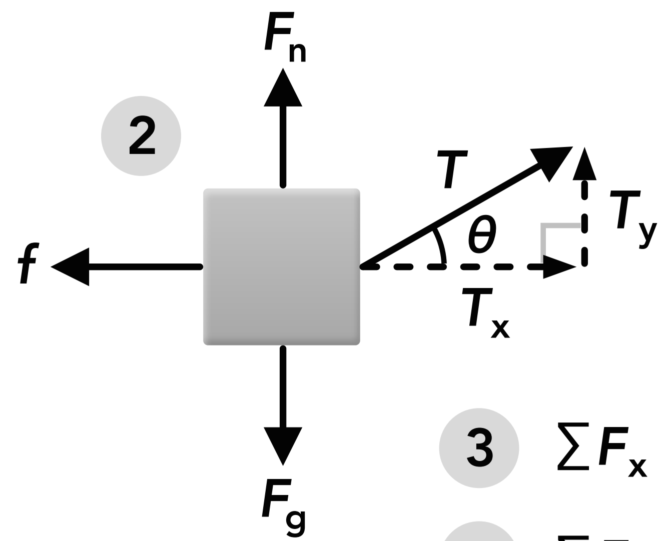
$4\text{ N} = (2\text{ kg})a_x \quad a_x = 2\text{ m/s}^2$

$3\text{ N} = (2\text{ kg})a_y \quad a_y = 1.5\text{ m/s}^2$

Steps for drawing a free body diagram and applying Newton's 2nd law:

1. Establish the origin and the positive directions of the ***x*** and ***y*** axes. This will determine whether each force is positive or negative when added together. It's useful to set up one of the axes parallel to the direction of the object's motion, or to have the axes parallel to most of the force vectors.
2. Draw a free body diagram of the object and all of the forces acting on the object. If a force is not parallel to one of the axes, find the ***x*** and ***y*** components of the force.
3. Add the forces in the ***x*** direction and apply Newton's 2nd law in the ***x*** direction: $\sum F_x = ma_x$
4. Add the forces in the ***y*** direction and apply Newton's 2nd law in the ***y*** direction: $\sum F_y = ma_y$
5. Use those equations to solve for an unknown variable or answer a question.





$T_y = T\sin(\theta)$

$T_x = T\cos(\theta)$

3 $\sum F_x = T_x - f = ma_x$

4 $\sum F_y = F_n + T_y - F_g = ma_y$