HUMBER ENGINEERING

ENGI 1000 - Physics 1

WEEK 4 - MODULE 4

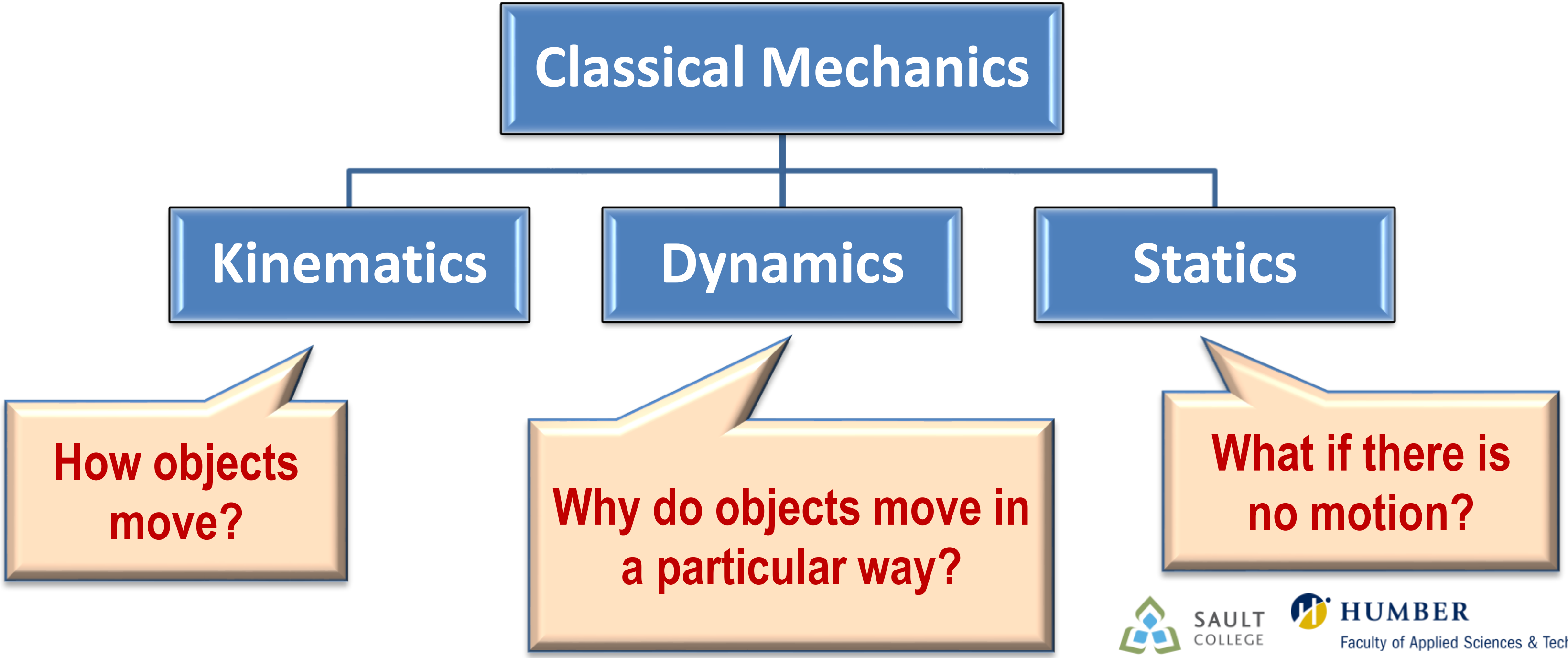
Module 4

Newton’s Laws of Motion – Part 1

- The Concept of Force
- Newton’s First Law of Motion
- Concept of Mass and Inertia
- Newton’s Second Law of Motion
- The Gravitational Force and Weight
- Newton’s Third Law of Motion
- Free-body Diagram

Classical Mechanics

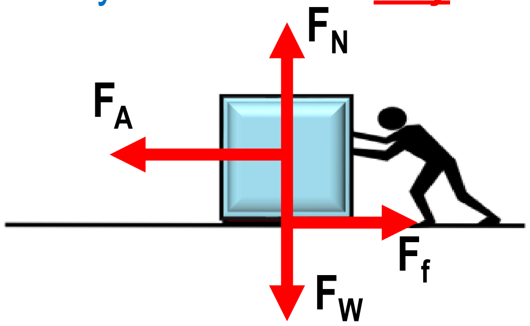
- Classical Mechanics is the branch of physics that investigates the motion of objects.



What is Kinematics and Dynamics?

- **Kinematics** is the study of geometry of motion through properties such as position, velocity and acceleration.
  - Kinematics shows **how** the object moves.

- **Dynamics** is the study of the cause behind the changes of motion using the Newton's Laws of Motion.
  - Dynamics shows **why** the object moves in a particular way.



In this lecture we will focus on the Dynamics.

The Concept of Force

- A force refers to simply a push or pull acting on an object as a result of its interaction with another object. It can change motion and velocity of the object.
  - Examples:
    - Kicking ball, Pushing book away from you on table

- Forces do not always cause motion:
  - Examples:
    - When sitting $\rightarrow$ gravitational force acts on your body $\rightarrow$ you remain stationary
    - Pushing a large boulder $\rightarrow$ boulder doesn't move

- Force is a vector quantity. It has both magnitude and direction.

Units of Force

- The SI unit of force is the newton (N).
- A force of $1\ N$ is the force that, when acting on an object of mass $1\ kg$, produces an acceleration of $1\ m/s^2$.
- Therefore, the newton can be expressed in terms of the following fundamental SI units of mass, length, and time:

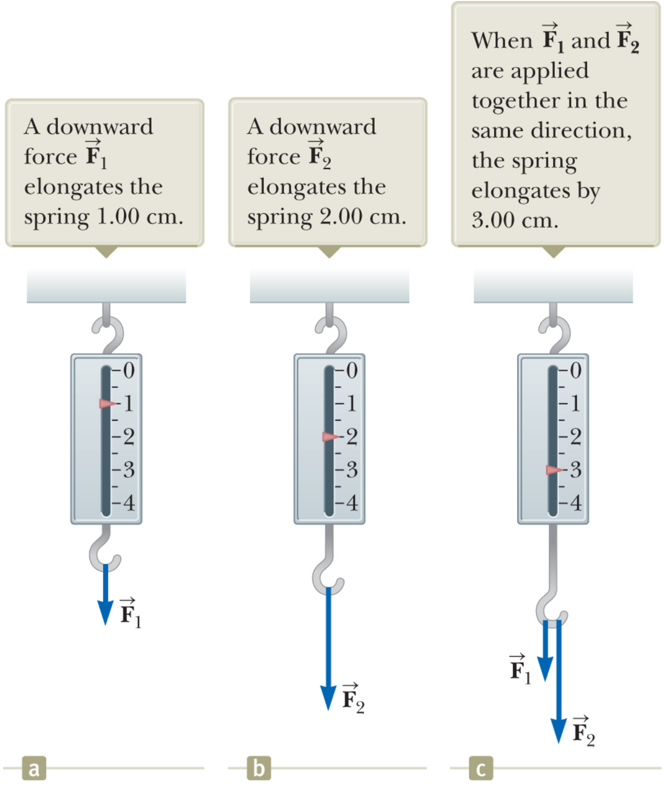
$$\boxed{1\ N = 1\ kg.m/s^2}$$

- Sir Isaac Newton was one of the greatest mathematical physicists.
- He published the book *Mathematical Principles of Natural Philosophy*, usually referred to as the *Principia*.
- He formulated the basic concepts and laws of mechanics, discovered the law of universal gravity and invented the mathematical methods of calculus.

Isaac Newton
English physicist and mathematician
(1642–1727)

The Vector Nature of Force

- It is possible to use the deformation of a spring to measure force.
- Imagine a calibrated spring scale that has a fixed upper end.
- When the force $\vec{F}_1 = 1N$ is applied, the pointer on the scale shows 1.00 cm.
- When the force is doubled, $\vec{F}_2 = 2\vec{F}_1 = 2N$, the pointer moves to 2.00 cm.
- This experiment shows that the combined effect of two collinear forces is the sum of the effects of the individual forces.



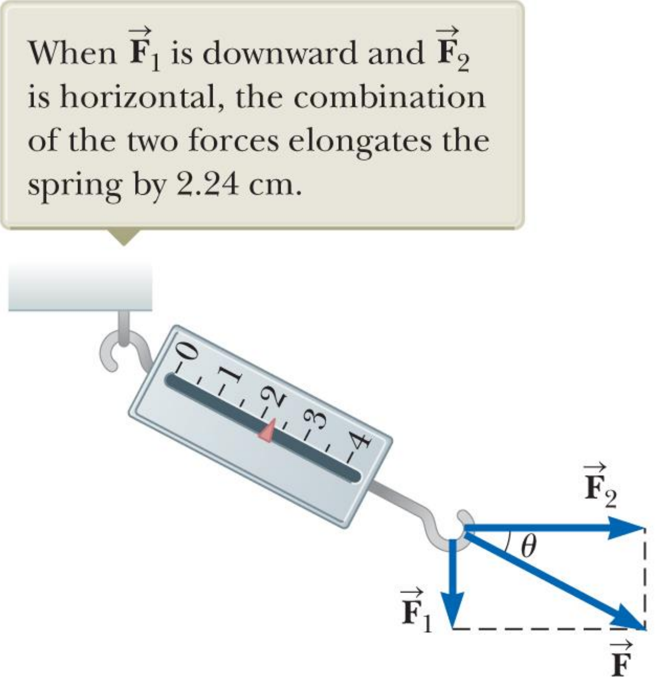
The Vector Nature of Force

- Suppose the two forces are applied simultaneously with $\vec{F}_1$ downward and $\vec{F}_2$ horizontal.
- In this case the pointer reads 2.24 cm.
- The single force $\vec{F}$ that would produce this same reading is the sum of the two vectors $\vec{F}_1$ and $\vec{F}_2$.

$$\left|\vec{F}\right| = \sqrt{{F_1}^2 + {F_2}^2} = 2.24\ N$$

$$\theta = \tan^{-1}\left(\frac{1.00\ N}{2.00\ N}\right) = \tan^{-1}(0.500) = 26.6°$$

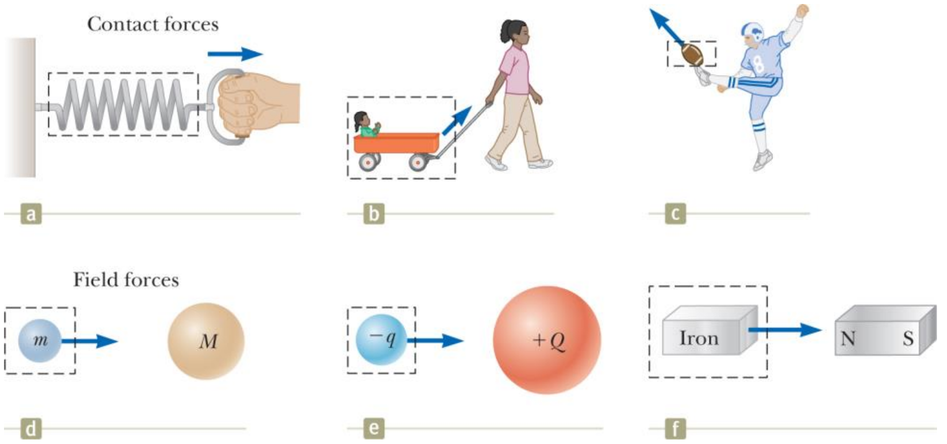
- This experimentally verified to behave forces as vectors.



Types of Force

- Forces can be classified as contact forces and non-contact or field forces.
  1) <u>**Contact forces**</u> are forces that act between two objects that are physically touching each other.
  2) <u>**Field forces**</u> are non-touching, which means that contact between the objects is not required to apply the force on an object.

- Following figure shows examples of contact and non-contact forces.

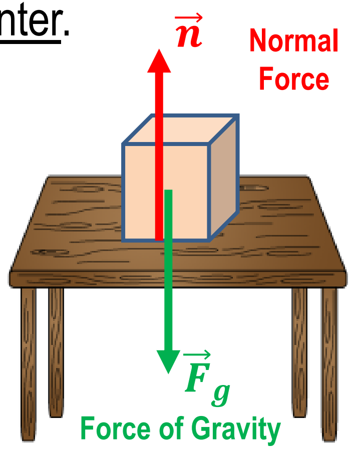


Types of Force

- Distinction between contact forces and field forces not sharp.
- At atomic level, all forces we classify as contact forces caused by electric (field) forces.
- In developing models for macroscopic phenomena, it is convenient use both classifications of forces.
- The only known fundamental forces in nature are all field forces:
    1. *Gravitational forces* between objects
    2. *Electromagnetic forces* between electric charges
    3. *Strong forces* between subatomic particles
    4. *Weak forces* that arise in certain radioactive decay processes
- All other forces are just some variation of one of these four forces.
- In classical physics, we are concerned only with gravitational and electromagnetic forces.

Types of Force

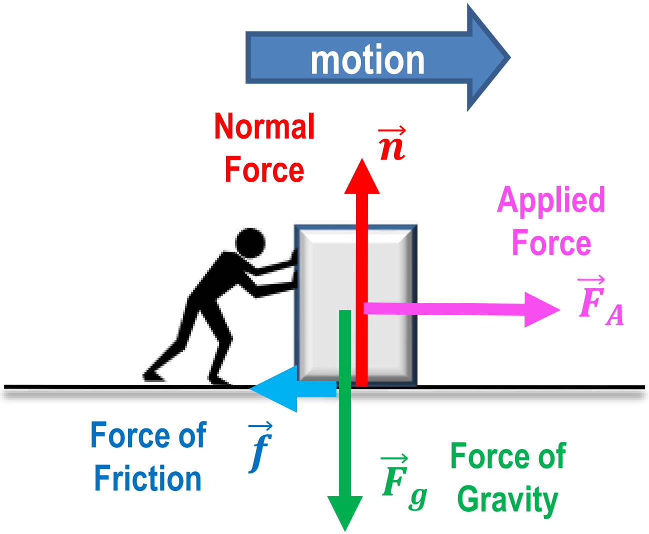
- **Gravitational Force, $\vec{F}_g$**: The force by which a planet or other body draws objects towards its center.
  - For example, the force of gravity keeps all the planets in orbit around the sun.
  - The gravitational attraction of the Earth on an object is called weight of the object.
  - The force of gravity on an object acts downward, <u>toward the Earth's center</u>.

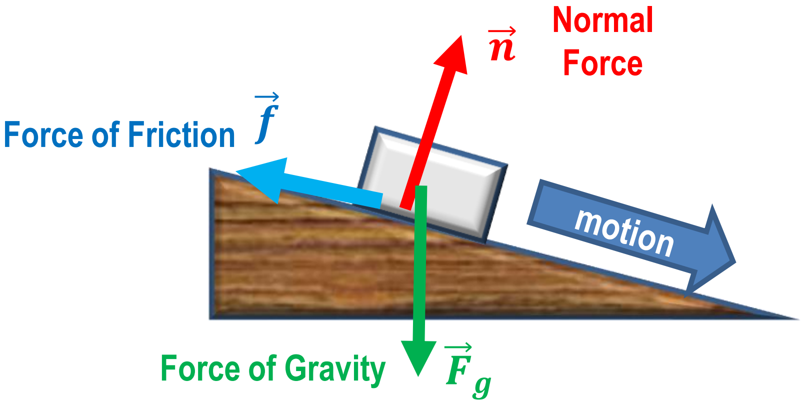


- **Normal Force, $\vec{n}$ or $\vec{F}_N$**: The force of a surface exerts on an object to support it.
  - The normal force always perpendicular to the surface and points away from the surface.

Types of Force

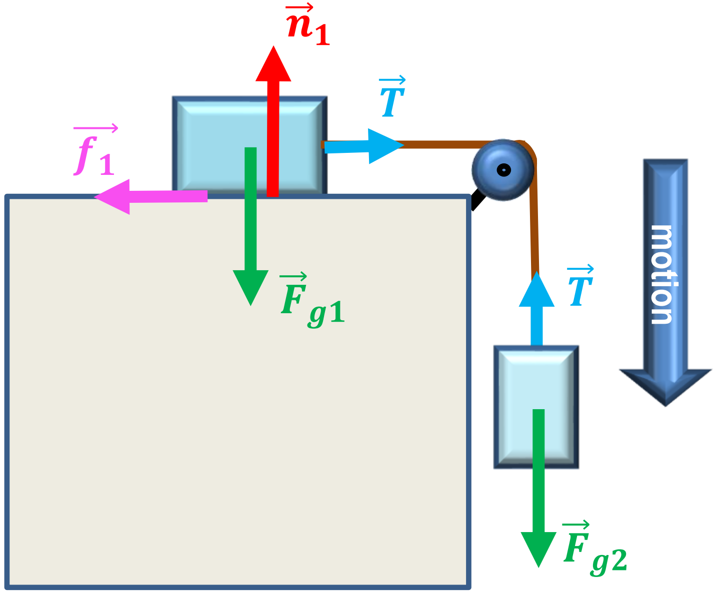
- **Applied Force, $\vec{F}_A$**: An external force used to help move an object.
  - For example, pulling a box or pushing a desk across the room.
- **Force of Friction, $\vec{f}$ or $\vec{F}_f$**: A force that opposes sliding motion between surfaces.
  - The force of friction always acts in the direction opposite to the direction of motion.

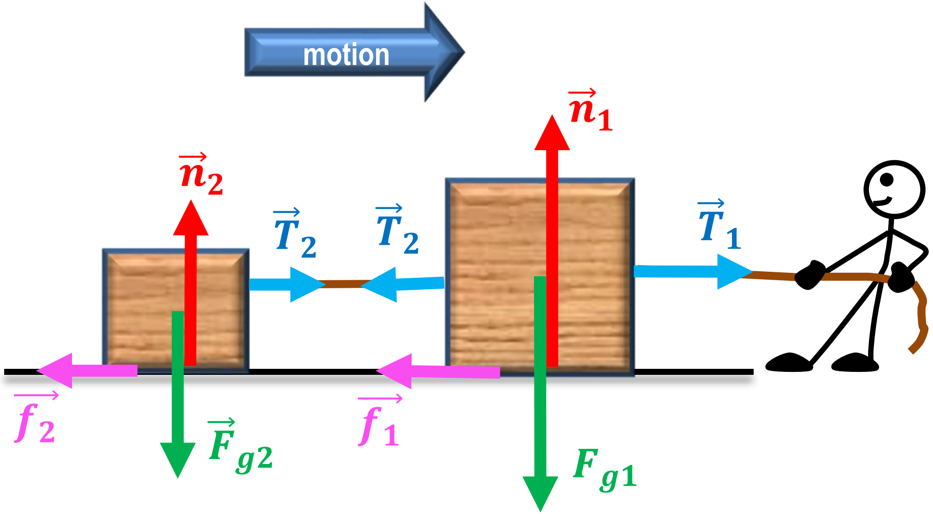




Types of Force

- **Tension Force, $\vec{T}$ or $\vec{F}_T$:** The pulling force exerted by materials that can be stretched.
  - For example, ropes, fibers, cables, chains and rubber bands.
  - The more the material stretched, the greater the tension is.





Laws of Motion in Classical Mechanics

- There are three main laws of motion in classical mechanics, which governs the dynamic motion of the objects:
  - **Newton's First Law of Motion**
    - It is also called the Law of Inertia.
    - It explains what happens to object when no forces act on it.
  - **Newton's Second Law of Motion**
    - It explains what happens to object when one or more forces act on it.
    - It shows the relation between kinematics and dynamics of the motion.
  - **Newton's Third Law of Motion**
    - It also called the law of action and reaction.
    - It describes the forces as a result of mutual interaction between two objects.

Newton's First Law of Motion: Law of Inertia

- **Statement of Newton's First Law of Motion:**

In the absence of external forces and when viewed from an *inertial reference frame*, an object at rest remains at rest and an object in motion continues in motion with a constant velocity in a straight line.

- The inertial reference frame is one in which Newton's law of inertia is valid.
- The acceleration of an inertial frame is zero, so it moves with a constant velocity.
- For example, the Earth itself is a good approximation of an inertial reference frame.

Newton's First Law of Motion: Law of Inertia

- Think about the game of ice hockey.
  - If a player does not hit a stationary puck, it will remain at rest on the ice
  - If puck is struck, it moves on the ice, but slowing down only slightly because of friction.

- If it were possible to remove all friction and wind resistance, and if the rink were infinitely large, the puck would move forever in a straight line at a constant speed.

Scott Gardner/AP/Wide World Photos

Newton's First Law of Motion: Law of Inertia

- If all the forces acting on a body are balanced, (net force is zero) then the object will not change speed or direction.
    - An object at rest has tendency to remain at rest, unless acted on by an unbalanced force.
    - An object in motion has tendency to remain in motion with constant velocity, ($a = 0$), unless acted on by an unbalanced force.

- For example, Newton's first law can explain
    - why a book sitting on the table remains at rest.
    - why a hockey puck moving across a smooth frictionless ice surface moves at a constant velocity.

Inertia and Mass

- The ability of an object to resist changes to its motion is a fundamental property called *inertia*.
- Inertia tends to keep a stationary object at rest or a moving object in motion in a straight line at a constant speed.
- Thus, Newton's first law is also called the **law of inertia**.
  - Inertia is directly proportional to the mass of the object.
  - The more mass an object has the more inertia it has.

- Mass is a property that specifies how much resistance an object exhibits to changes in its velocity.
- Mass is a quantitative measure of inertia.
- The greater the mass of an object, the less that object accelerates under the action of a given applied force.

$$\frac{m_1}{m_2} \equiv \frac{a_2}{a_1}$$

Quick Quiz 1

- Which of the following statements is correct?

  a) It is possible for an object to have motion in the absence of forces on the object.

  b) It is possible to have forces on an object in the absence of motion of the object.

  c) Neither statement (a) nor statement (b) is correct.

  d) Both statements (a) and (b) are correct.

Quick Quiz 1: Solution

- Which of the following statements is correct?

  a) It is possible for an object to have motion in the absence of forces on the object.

  b) It is possible to have forces on an object in the absence of motion of the object.

  c) Neither statement (a) nor statement (b) is correct.

  d) Both statements (a) and (b) are correct.

Quick Quiz 2

- Assume an object is in equilibrium. Which of the following statements is correct?
  a) The speed of the object remains constant.
  b) The acceleration of the object is zero.
  c) The net force acting on the object is zero.
  d) The object must be at rest.
  e) There are at least two forces acting on the object.

Quick Quiz 2: Solution

- Assume an object is in equilibrium. Which of the following statements is correct?
  a) The speed of the object remains constant. [True]
  b) The acceleration of the object is zero. [True]
  c) The net force acting on the object is zero. [True]
  d) The object must be at rest. [False]
  e) There are at least two forces acting on the object. [False]

Newton's Second Law of Motion: F = ma

- Newton's first law explains what happens to object when ***no*** forces act on it.
- Newton's second law answers question of what happens to object when one or more forces act on it.
- **Statement of Newton's Second Law of Motion:**

When viewed from an *inertial reference frame*, the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass:

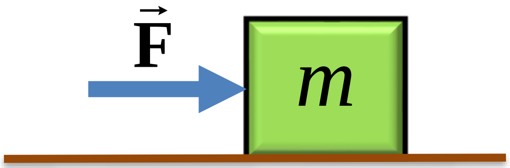
$$\left|\vec{\mathbf{a}}\right| \propto \frac{\sum \vec{\mathbf{F}}}{m}$$

- Newton's second law equation:

$$\boxed{\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}}$$

Newton’s Second Law of Motion: F = ma

- If there is an unbalanced force acting on an object, it will accelerate in the direction of the net force.
  - The net force applied to the object is non-zero.
  - The magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportion to the mass of the object.
  - The more force means the more acceleration.
  - Mass resist acceleration, more mass means more inertia.
  - Here, the mass is also called inertial mass.



$$\boxed{|\vec{\mathbf{a}}| \propto F}$$

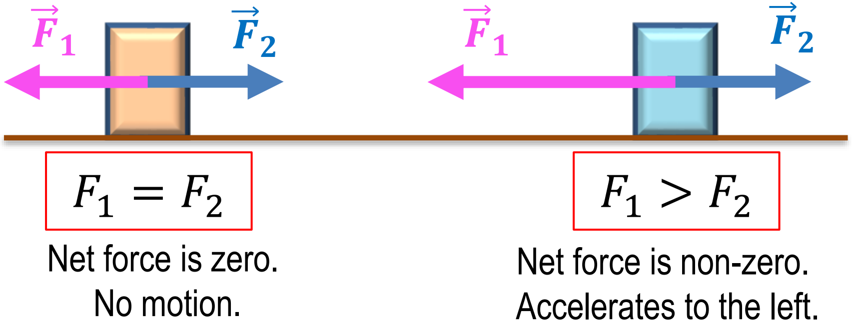
$$\boxed{|\vec{\mathbf{a}}| \propto \frac{1}{m}}$$

Net Force

- The Net Force, $\vec{F}_{NET}$, or Total Force is the sum of all the forces acting on an object.
  - If the net force is zero, then the object will not move or move with constant velocity.
  - If the net force is non-zero, then the object will accelerate in the direction of the net force.
- Some tips to determine the Net Force:
  - Forces are vector quantities and have direction.
  - Add the forces in the same direction.
  - Subtract the forces in the opposite direction.
- The component equations of Newton's second law:

$$\boxed{\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}}$$

$$\sum F_x = ma_x \quad \sum F_y = ma_y \quad \sum F_z = ma_z$$

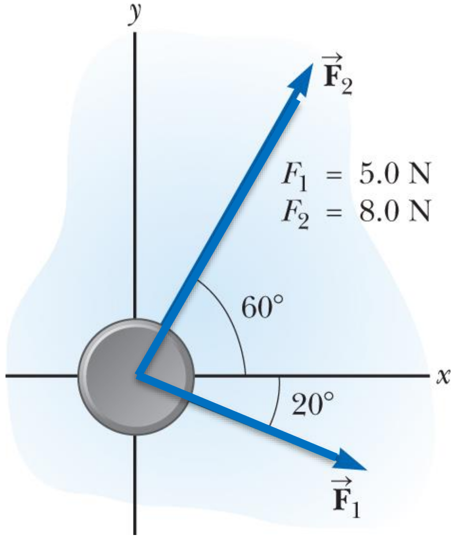


Newton's Second Law of Motion: F = ma

Example 1 (An Accelerating Hockey Puck): A hockey puck having a mass of $0.30\ kg$ slides on the frictionless, horizontal surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in the figure.

The force $\vec{\boldsymbol{F}}_1$ has a magnitude of $5.0\ N$ and is directed at $\theta = -20°$ below the x-axis.

The force $\vec{\boldsymbol{F}}_2$ has a magnitude of $8.0\ N$ and its direction is $\phi = 60°$ above the x-axis.



The given information:

$$m = 0.30\ kg$$
$$F_1 = 5.0\ N, \qquad \theta = -20°$$
$$F_2 = 8.0\ N, \qquad \phi = 60°$$

Newton's Second Law of Motion: F = ma

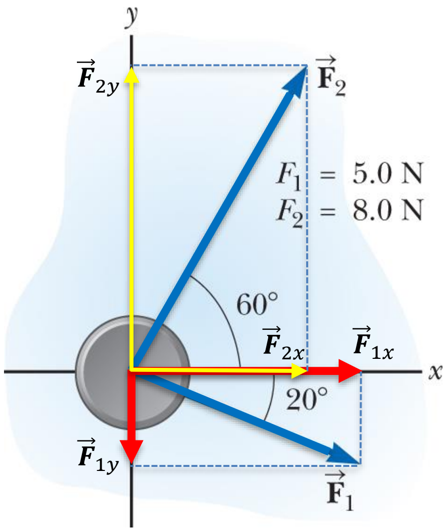
Example 1 (An Accelerating Hockey Puck): A hockey puck having a mass of $0.30\ kg$ slides on the frictionless, horizontal surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in the figure.

(a) Determine and draw the net force acting on the puck.

First find the components of the net force acting on the puck in the x and y directions:

$$\sum F_x = F_{1x} + F_{2x} = F_1 \cos\theta + F_2 \cos\phi$$

$$\sum F_y = F_{1y} + F_{2y} = F_1 \sin\theta + F_2 \sin\phi$$



Newton's Second Law of Motion: F = ma

Example 1 (An Accelerating Hockey Puck): A hockey puck having a mass of $0.30\ kg$ slides on the frictionless, horizontal surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in the figure.

(a) Determine and draw the net force acting on the puck.

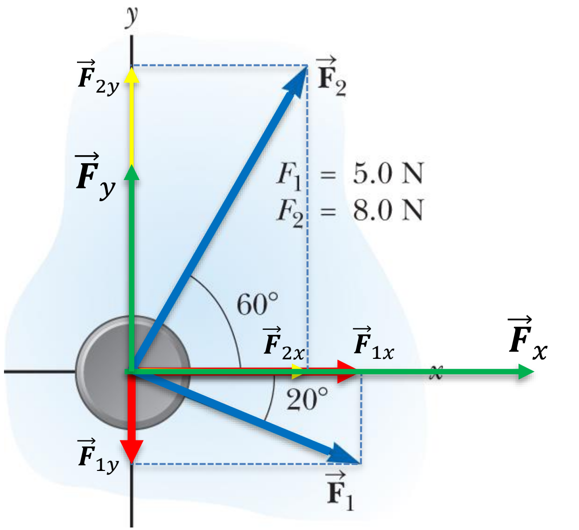
First find the components of the net force acting on the puck in the x and y directions:

$$\sum F_x = F_{1x} + F_{2x} = F_1 \cos\theta + F_2 \cos\phi$$

$$= (5.0\ \text{N})\cos(-20°) + (8.0\ \text{N})\cos(60°) = \boxed{8.7\ N}$$

$$\sum F_y = F_{1y} + F_{2y} = F_1 \sin\theta + F_2 \sin\phi$$

$$= (5.0\ \text{N})\sin(-20°) + (8.0\ \text{N})\sin(60°) = \boxed{5.2\ N}$$



Newton's Second Law of Motion: F = ma

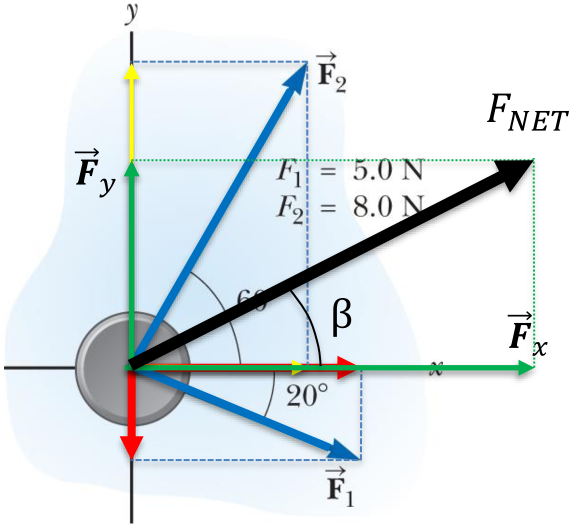
Example 1 (An Accelerating Hockey Puck): A hockey puck having a mass of $0.30\ kg$ slides on the frictionless, horizontal surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in the figure.

(a) Determine and draw the net force acting on the puck.

Then find the magnitude and direction of the net force:

$$F_{NET} = \sqrt{F_x^2 + F_y^2} = \sqrt{(8.7\text{ N})^2 + (5.2\text{ N})^2} = \boxed{10\ N}$$

$$\beta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{5.2\text{ N}}{8.7\text{ N}}\right) = \boxed{31°}$$



Newton's Second Law of Motion: F = ma

Example 1 (An Accelerating Hockey Puck): A hockey puck having a mass of $0.30\ kg$ slides on the frictionless, horizontal surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in the figure.

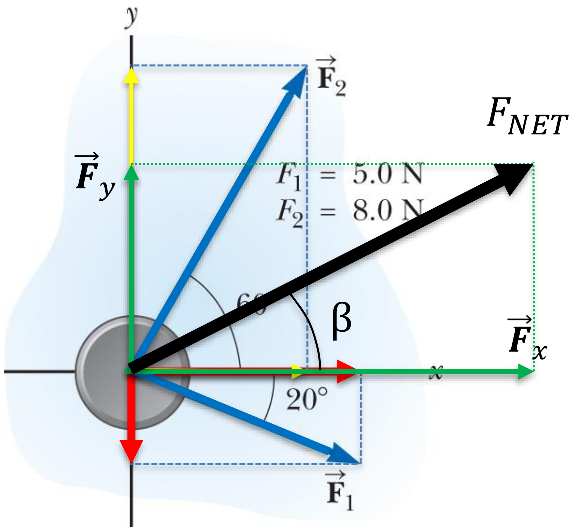
(b) Determine the magnitude and the direction of the puck's acceleration.

Use Newton's second law to find the magnitude of the puck's acceleration:

$$F_{NET} = ma \quad \rightarrow \quad a = \frac{F_{NET}}{m} = \frac{10\ \mathrm{N}}{0.30\ \mathrm{kg}} = 33\ \mathrm{m/s^2}$$

Direction of the acceleration is the same as the direction of the net force:

$$\beta = \boxed{31°}$$



Newton's Second Law of Motion: F = ma

Example 1 (An Accelerating Hockey Puck): Suppose three hockey sticks strike the puck simultaneously, with two of them exerting the forces shown in the figure. The result of the three forces is that the hockey puck shows *no* acceleration.

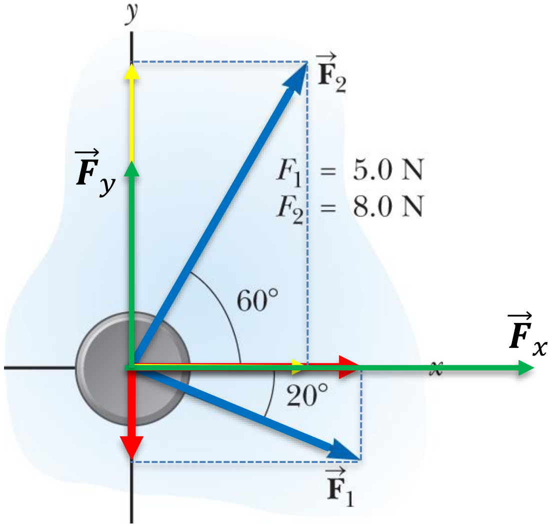
What must be the components of the third force?

Since there is no acceleration, the net force in x and y directions must be zero. From part (a) we have:

$$\boxed{F_x = 8.7\ N, \qquad F_y = 5.2\ N}$$

$$F_{3x} = -\sum F_x = -8.7\ \text{N}$$

$$F_{3y} = -\sum F_y = -5.2\ \text{N}$$



Quick Quiz 3

- An object experiences no acceleration. Which of the following *cannot* be true for the object?

a) A single force acts on the object

b) No forces act on the object

c) Forces act on the object, but the forces cancel

Quick Quiz 3: Solution

- An object experiences no acceleration. Which of the following *cannot* be true for the object?

    a) A single force acts on the object

    b) No forces act on the object

    c) Forces act on the object, but the forces cancel

Quick Quiz 4

- You push an object, initially at rest, across a frictionless floor with a constant force for a time interval Δt, resulting in a final speed of v for the object. You then repeat the experiment, but with a force that is twice as large. What time interval is now required to reach the same final speed v?

a) $4\Delta t$

b) $2\Delta t$

c) Δt

d) $\Delta t/2$

e) $\Delta t/4$

Quick Quiz 4: Solution

- You push an object, initially at rest, across a frictionless floor with a constant force for a time interval Δt, resulting in a final speed of v for the object. You then repeat the experiment, but with a force that is twice as large. What time interval is now required to reach the same final speed v?

  a) $4\Delta t$
  b) $2\Delta t$
  c) Δt
  d) $\Delta t/2$
  e) $\Delta t/4$

Newton's Third Law of Motion: Action & Reaction

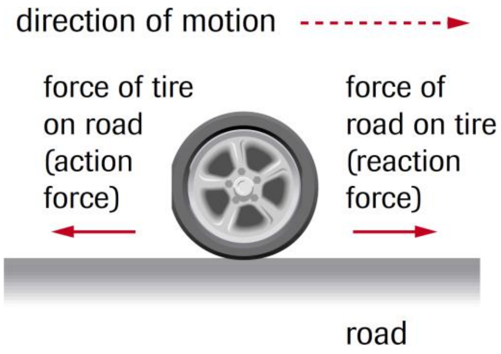
- For every action force, there is a simultaneous reaction force that is equal in magnitude, but opposite in direction.

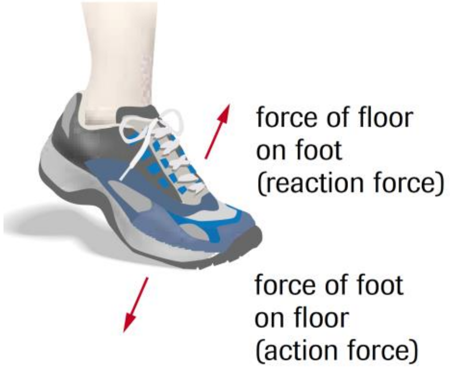
If two object interacts, the force $\vec{F}_{12}$ exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force $\vec{F}_{21}$ exerted by object 2 on object 1

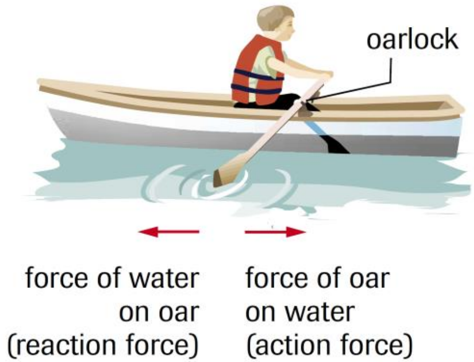
$$\boxed{\vec{\mathbf{F}}_{12} = -\vec{\mathbf{F}}_{21}}$$

Newton's Third Law of Motion: Action & Reaction

- For every action force, there is a simultaneous reaction force that is equal in magnitude, but opposite in direction.







- The interactive forces always occur in pairs.
- The action-reaction forces are never on the same object.

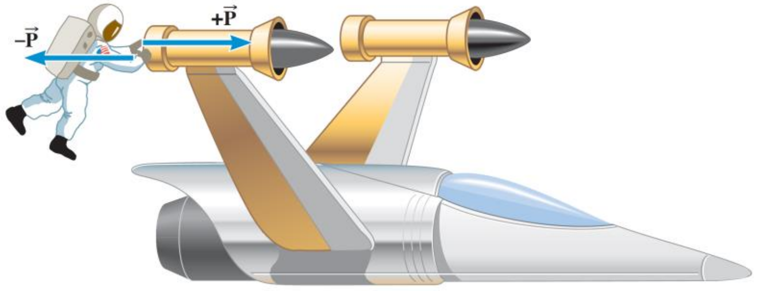
Newton's Third Law of Motion: Action & Reaction

Example 2 (Acceleration Produced by Action and Reaction Forces): Suppose that the mass of a spacecraft is $m_s = 11000\ kg$ and that the mass of the astronaut is $m_A = 92\ kg$. In addition, assume that the astronaut pushes with a force of $\vec{\mathbf{P}} = +36\ N$ on the spacecraft. Find the acceleration of the spacecraft and the astronaut.

Based on Newton's third law, the spacecraft applies a reaction force $-\vec{\mathbf{P}} = -36\ N$ to the astronaut.

The acceleration of the spacecraft is:

$$\vec{\mathbf{a}}_s = \frac{\vec{\mathbf{P}}}{m_s} = \frac{+36\ \mathrm{N}}{11000\ \mathrm{kg}} = +0.0033\ \mathrm{m/s^2}$$



The acceleration of the astronaut is:

$$\vec{\mathbf{a}}_A = \frac{-\vec{\mathbf{P}}}{m_A} = \frac{-36\ \mathrm{N}}{92\ \mathrm{kg}} = -0.39\ \mathrm{m/s^2}$$

Quick Quiz 5

- If a fly collides with the windshield of a fast-moving bus, which experiences an impact force with a larger magnitude?

  a) The fly.
  b) The bus.
  c) The same force is experienced by both.

Quick Quiz 5: Solution

- If a fly collides with the windshield of a fast-moving bus, which experiences an impact force with a larger magnitude?

  a) The fly.
  b) The bus.
  c) The same force is experienced by both.

Quick Quiz 6

- If a fly collides with the windshield of a fast-moving bus, which experiences the greater acceleration?

  a) The fly.
  b) The bus.
  c) The same force is experienced by both.

Quick Quiz 6: Solution

- If a fly collides with the windshield of a fast-moving bus, which experiences the greater acceleration?

  a) The fly.
  b) The bus.
  c) The same force is experienced by both.

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The Gravitational Force and Weight

- On Earth, all objects have a gravitational force ($\vec{F}_g$) acting on them, in the direction of the center of the planet.

- The gravitational force exerted on any object is equal to its mass (m) multiplied by the acceleration due to gravity (g).

$$\sum \vec{F} = m\vec{a} \xrightarrow{\vec{a}=\vec{g} \text{ and } \sum \vec{F}=\vec{F}_g} \boxed{\vec{F}_g = m\vec{g}}$$

- The magnitude of $\vec{F}_g$ is called the weight of the object.
- In this equation, the mass (m) is called gravitational mass.
- Note that weight and mass are **NOT** the same!

The Gravitational Force and Weight

- The acceleration due to gravity on Earth is approximately $g = 9.8\ m/s^2$ (downward).
- The actual value of g varies depending on the geographic location on Earth.
- Since g decreases with increasing distance from the center of the Earth, objects weight is less at higher altitudes than at sea level.

$$F_g = mg$$

- Suppose a student has a mass of $m = 70\ kg$.
- The student's weight in a location where $g = 9.8\ m/s^2$ is:

$$F_g = (70\ kg)\left(9.8\frac{m}{s^2}\right) = 686\ N$$

- However, at the top of a mountain, where $g = 9.77\ m/s^2$ the weight is:

$$F_g = (70\ kg)\left(9.77\frac{m}{s^2}\right) = 684\ N$$

Quick Quiz 7

- Suppose you are talking by interplanetary telephone to a friend who lives on the Moon. He tells you that he has just won a newton of gold in a contest. Excitedly, you tell him that you entered the Earth version of the same contest and won a newton of gold! Knowing $g_{Earth} \approx 9.8\ m/s^2$ and $g_{Moon} \approx 1.6\ m/s^2$, who is richer?

a) You are.

b) Your friend is.

c) You are equally rich.

Quick Quiz 7: Solution

- Suppose you are talking by interplanetary telephone to a friend who lives on the Moon. He tells you that he has just won a newton of gold in a contest. Excitedly, you tell him that you entered the Earth version of the same contest and won a newton of gold! Knowing $g_{Earth} \approx 9.8\, m/s^2$ and $g_{Moon} \approx 1.6\, m/s^2$, who is richer?

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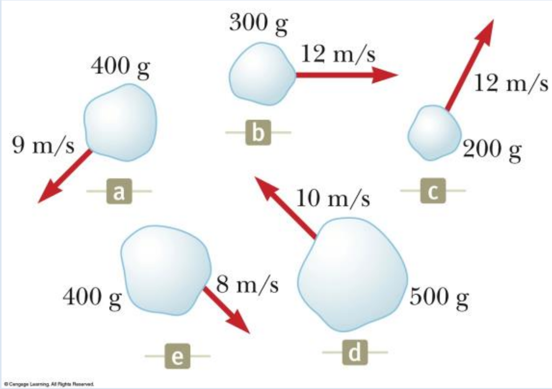
Quick Quiz 8

- Suppose the students in the schoolyard are throwing snowballs at each other. Between them, snowballs of various masses are moving with different velocities as shown in the figure. Rank the snowballs (a) through (e) according to the magnitude of the total force exerted on each one. Ignore air resistance. If two snowballs rank together, make that fact clear.

a) d > a > e > b > c
b) c > b > a > e > d
c) d = e = a > b > c
d) d > a = e > b > c



Quick Quiz 8: Solution

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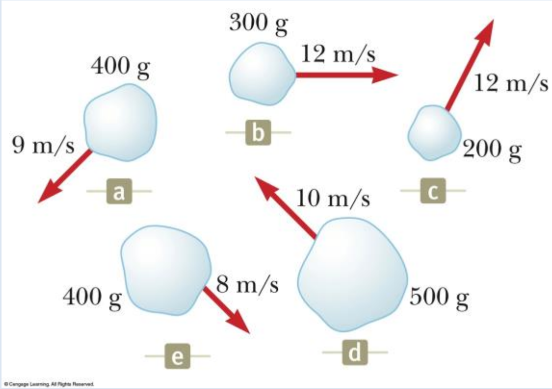
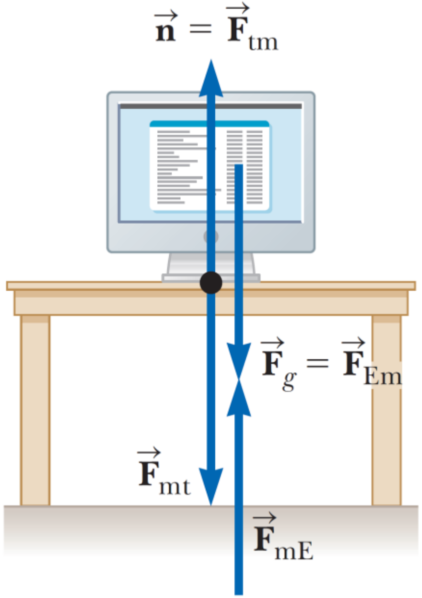


Force Diagram

- Consider a computer monitor at rest on a table.
- The following set of forces are applied in this system.
  - The gravitational force on the monitor by Earth: $\vec{F}_g = \vec{F}_{Em}$
  - The reaction force on $\vec{F}_{Em}$ is the force exerted by the monitor on the Earth: $\vec{F}_{mE} = -\vec{F}_{Em}$
  - The normal force exerts on the monitor by the table: $\vec{n} = \vec{F}_{tm}$
  - The reaction force on $\vec{F}_{tm}$ is the force exerted by the monitor on the Earth: $\vec{F}_{mt} = -\vec{F}_{tm} = -\vec{n}$



- Since the monitor has no acceleration, the net force on the monitor is zero.

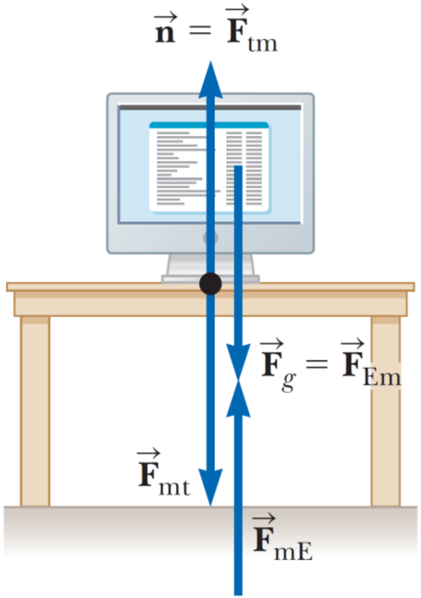
Force Diagram

- This figure shows many of the forces in the situation: those are acting on the monitor, on the table and on the earth.
- We can also show the forces acting on only *one object*, the monitor.
- The diagram is called a force diagram.
- Note that the forces acting on the monitor are $\vec{F}_g$ and $\vec{n}$.
- Since the monitor has no acceleration, the applied net force is zero:

$$\sum \vec{F} = \vec{n} + m\vec{g} = 0$$

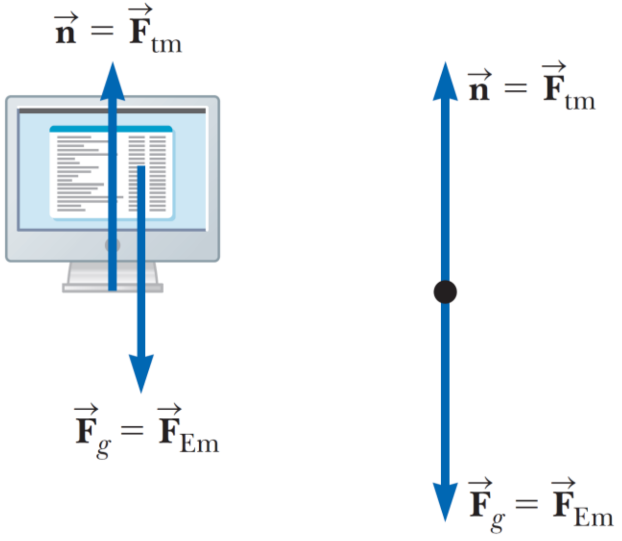
$$n\hat{\mathbf{j}} - mg\hat{\mathbf{j}} = 0$$

$$n = mg$$



Free-Body Diagram

- The important pictorial representation is called a free-body diagram.
- A free-body diagram is used to show the magnitude and direction of all the forces acting on a single object.
- If helps to isolate only the forces on the single object and eliminate the other forces from our analysis.
  - Use a dot or a box to represent the object.
  - Use arrows to represent the forces.
    - Arrows point outwards from the object
    - The length of an arrow shows the size of the force.
    - Forces must be labeled.



Quick Quiz 9

How Much Do You Weigh in an Elevator

- You have most likely been in an elevator that accelerates upward as it moves toward a higher floor. In this case, you feel heavier.
- In fact, if you are standing on a bathroom scale at the time, the scale measures a force having a magnitude that is greater than your weight.
- Therefore, you have tactile and measured evidence that leads you to believe you are heavier in this situation.

***Are* you heavier?**

Quick Quiz 9: Solution

How Much Do You Weigh in an Elevator

- You have most likely been in an elevator that accelerates upward as it moves toward a higher floor. In this case, you feel heavier.
- In fact, if you are standing on a bathroom scale at the time, the scale measures a force having a magnitude that is greater than your weight.
- Therefore, you have tactile and measured evidence that leads you to believe you are heavier in this situation.

***Are* you heavier?**

NO; your weight is unchanged. The reading on the scale gives only the apparent weight rather than true weight.

SAULT COLLEGE HUMBER Faculty of Applied Sciences & Technology

Quick Quiz 9: Solution

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

(a) No acceleration ($a = 0$):

$$\sum F_y = +n - mg = 0 \quad \rightarrow \quad n = mg$$

$$n = mg$$

(b) Upward acceleration ($a > 0$):

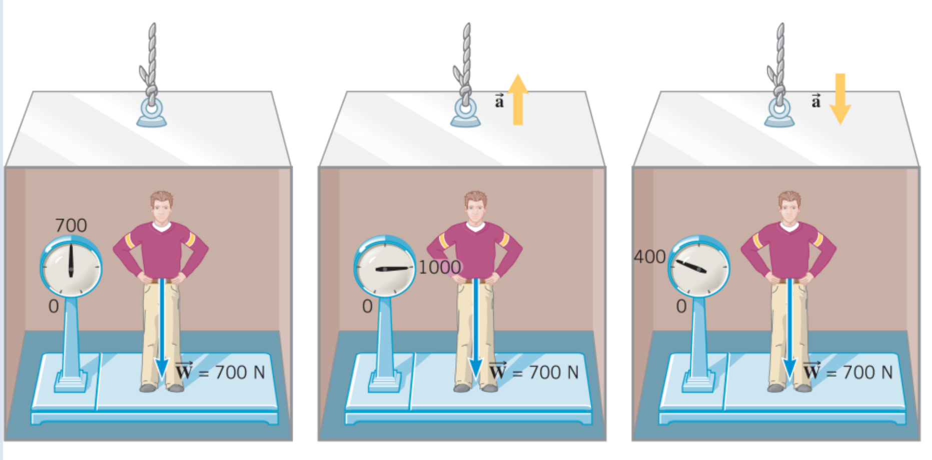
$$\sum F_y = +n - mg = ma \quad \rightarrow \quad n = ma + mg$$

$$n > mg$$

(c) Downward acceleration ($a < 0$):

$$\sum F_y = +n - mg = ma \quad \rightarrow \quad n = ma + mg$$

$$n < mg$$



(a) No acceleration ($\vec{v}$ = constant) (b) Upward acceleration (c) Downward acceleration

THANK YOU

HUMBER

WE ARE HUMBER