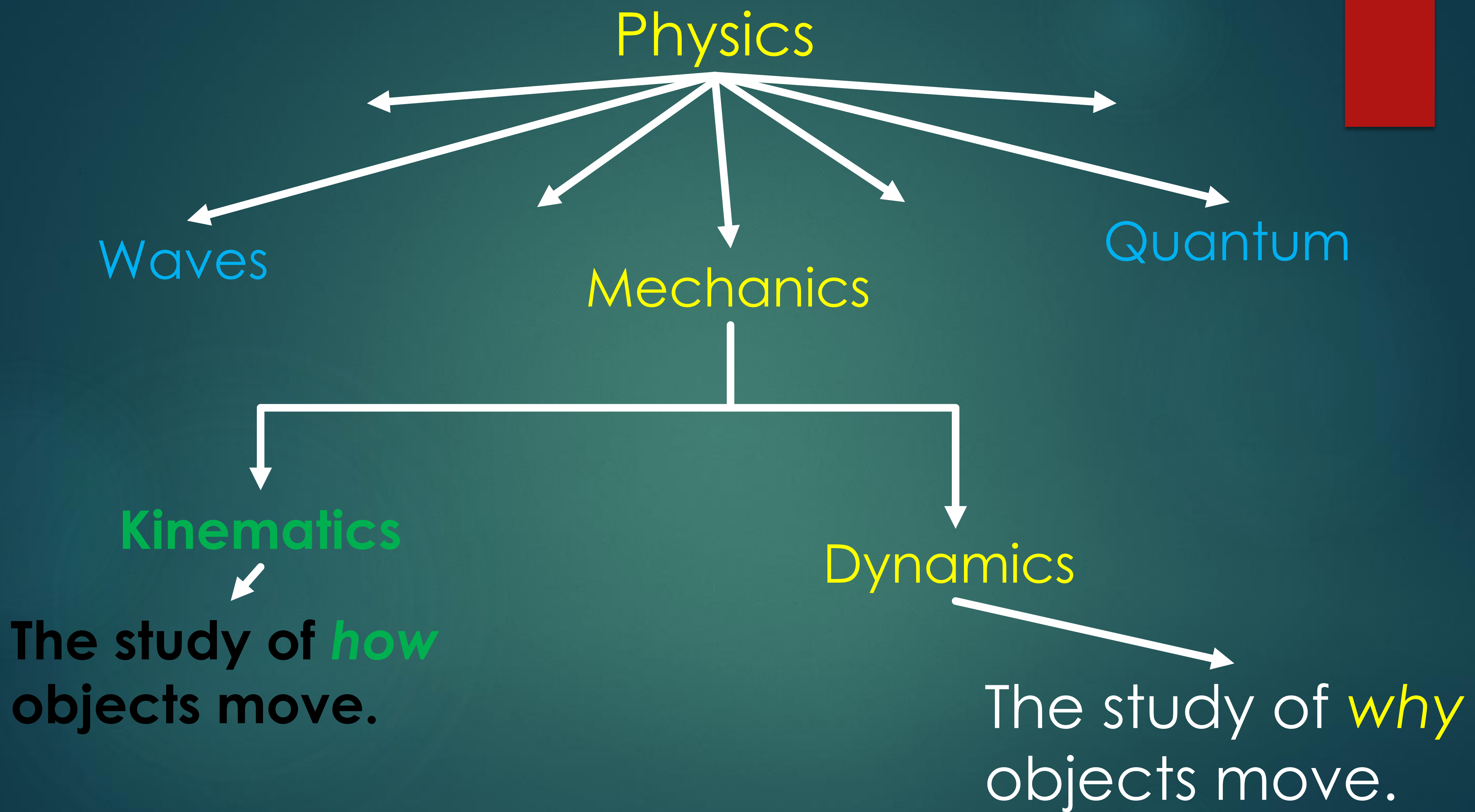
Dynamics

TYPES OF FORCES & NEWTON'S LAWS OF MOTION


Physics
Waves
Mechanics
Quantum
Kinematics
The study of *how* objects move.
Dynamics
The study of *why* objects move.

Force

- A push or a pull.
- Vector quantity.
- Usually results in an acceleration.
- Measured in Newtons, N.
- Many forces can act on an object all at once.

Types of Forces: Contact or Non-Contact

Forces

Contact ⟷ Non-Contact

Contact

A force exerted in direct contact with another object.

- Friction
- Tension
- Normal
- Applied
- Elastic

Non-Contact

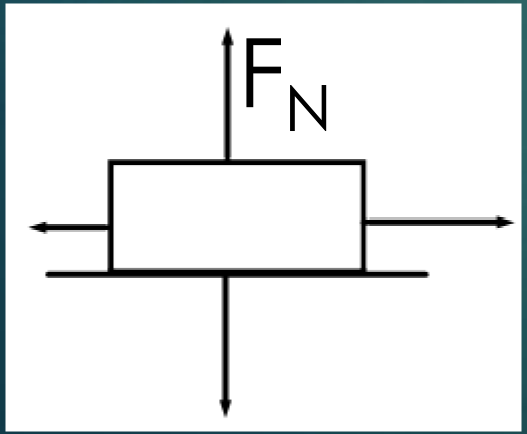
A force exerted in over a distance.

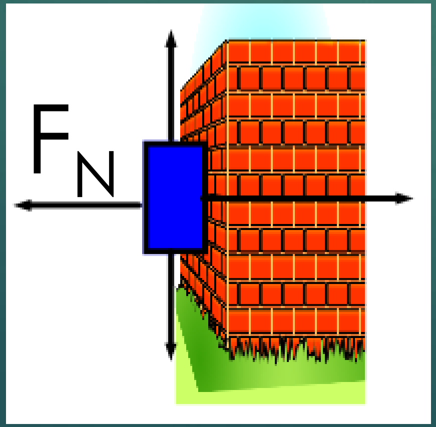
- Gravity
- Magnetic
- Electric

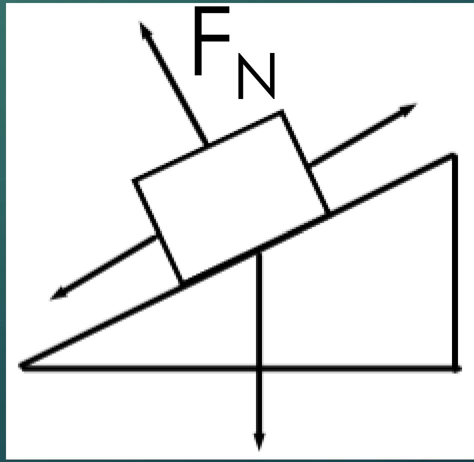
All of these forces can act on an object at the same time!

Common Types of Forces

- F_a: applied force. Usually exerted by a person or a machine on an object.
- F_f: friction. Acts between two surfaces.
- F_T: force of tension. Usually along a string, rope or wire.
- F_g: Force of gravity. Pull from an object's mass.
- F_N: Normal force. Acts perpendicular to a surface.

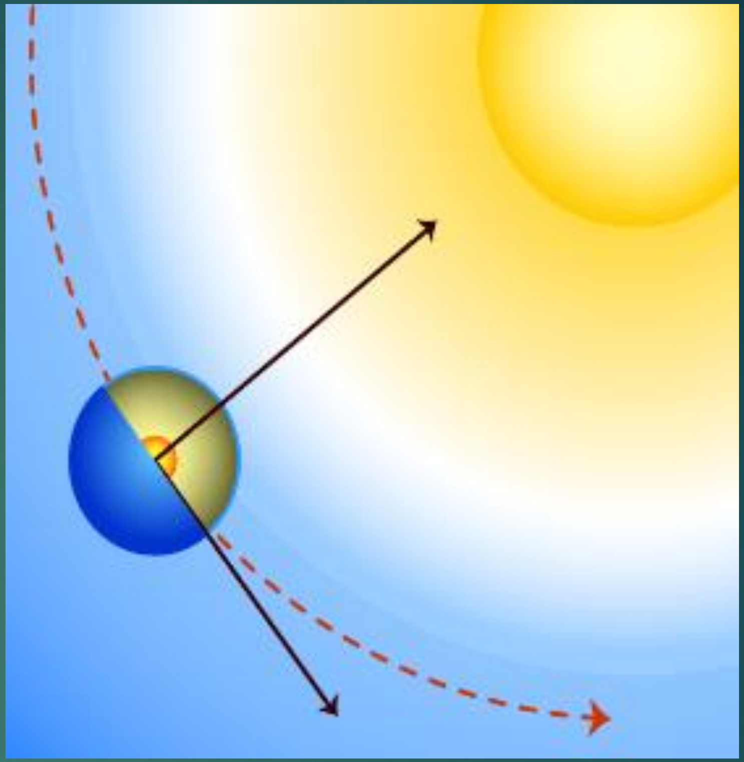


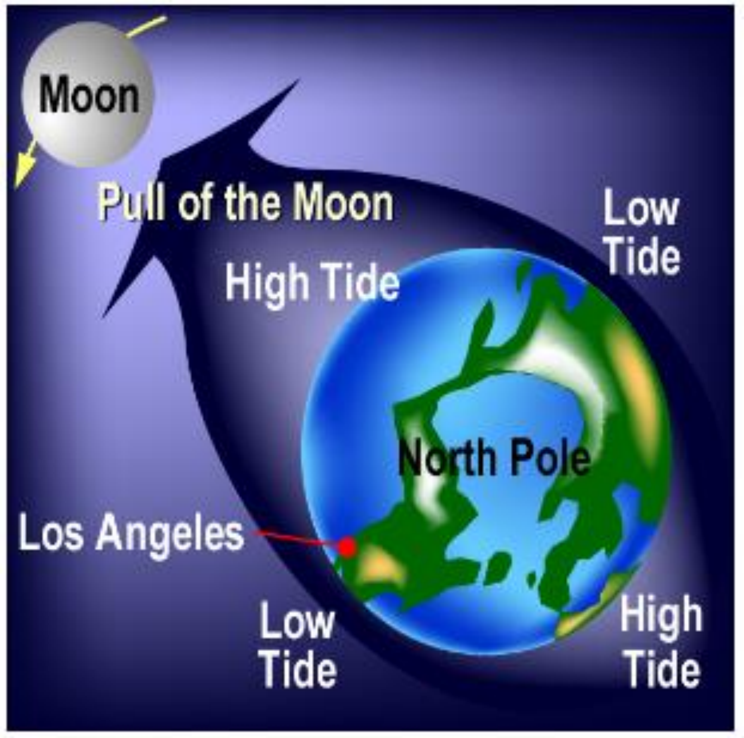




The Force of Gravity

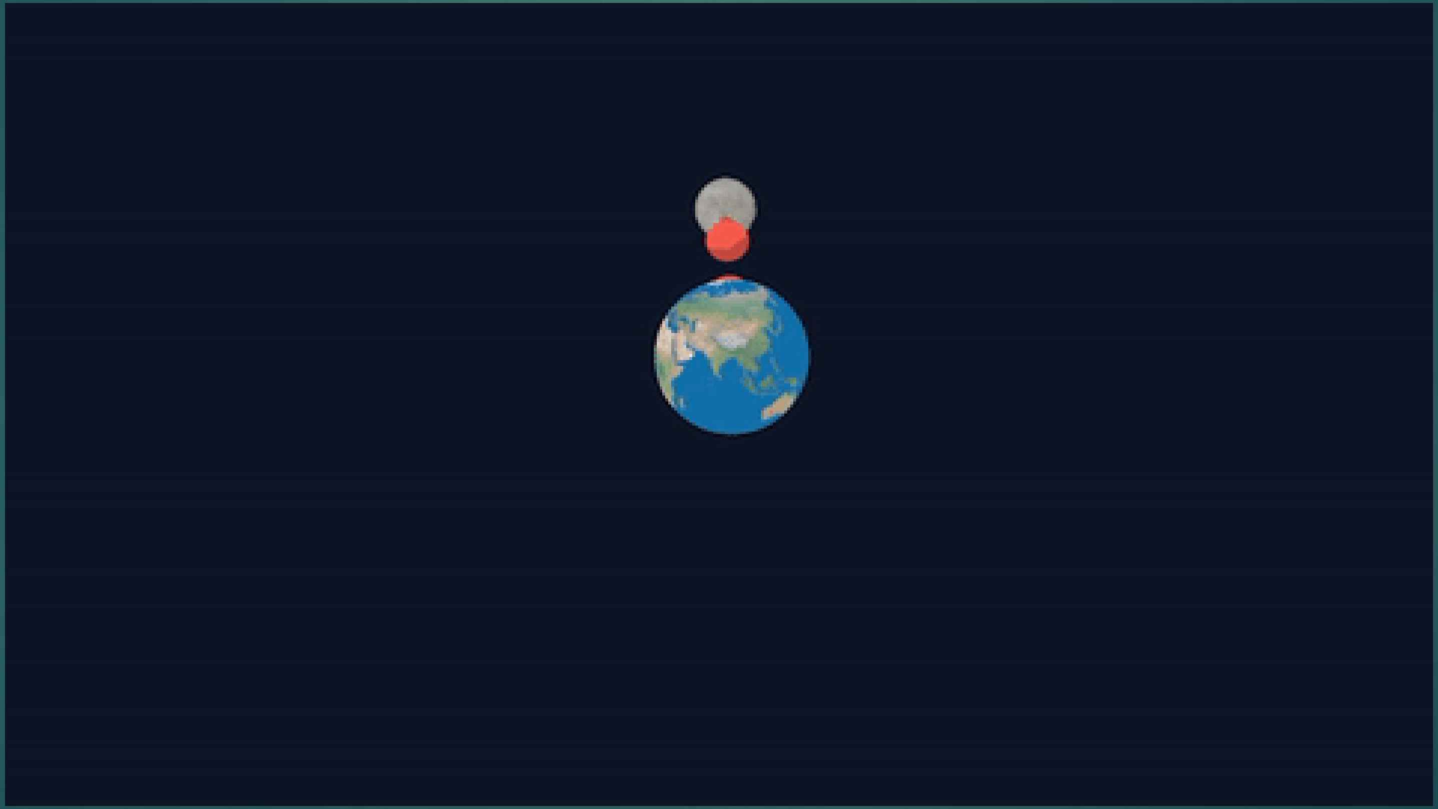
- F_g: An attractive force that acts over a distance between masses.





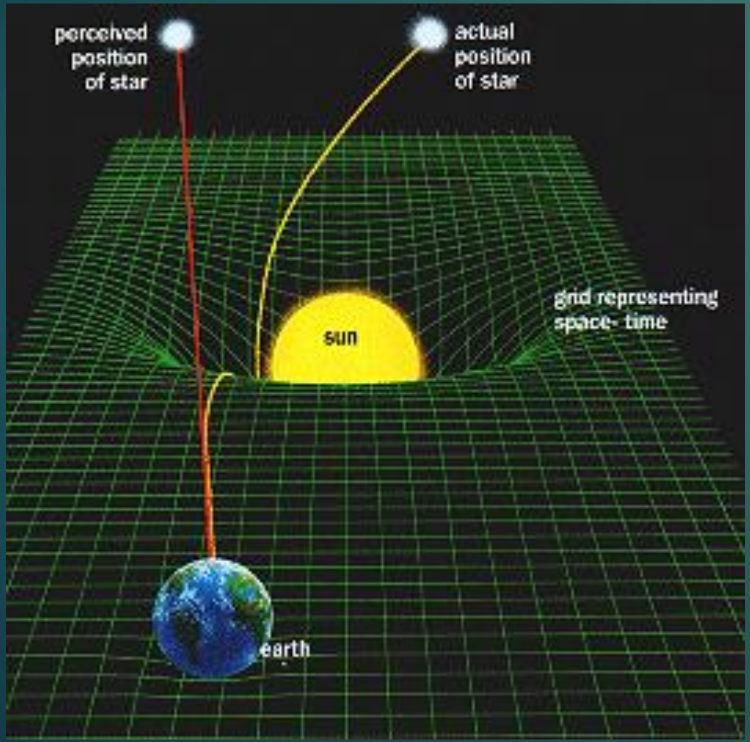
Force of Gravity

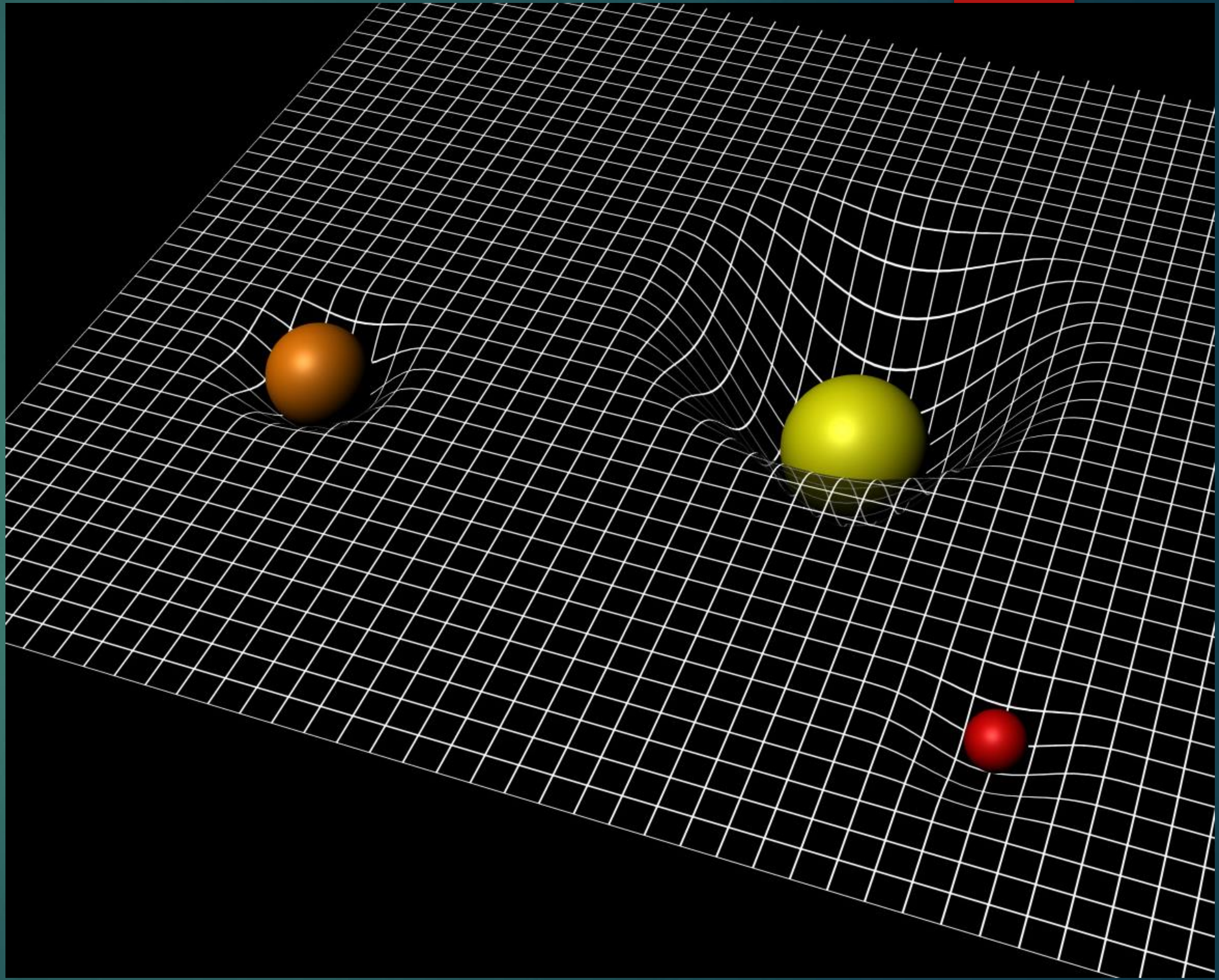
- An attractive force that acts over a distance between masses.



Force of Gravity

- More accurately, it is the curving of space-time resulting from objects with mass.





Calculating the Force of Gravity

$$\overrightarrow{F_g} = m\vec{g}$$

Takes into account the distance between the object and the center of the Earth

- F_g = force of gravity in Newtons, N
- m = mass in kilograms, kg
- g = acceleration due to gravity, 9.81 m/s^2 on Earth

- F_g: measures a weight (like pounds), the pull of gravity. It changes slightly at different locations on the Earth or on different solar system objects.
- *m*: measures a mass in kg, which is a measure of how much matter the object is made up of. Does not change with location.

Force of Gravity: Problems

1. Calculate the magnitude of the force of gravity on a 45 kg mass located at the peak of Mt. Everest.
2. Calculate the mass of a person that has a weight magnitude of 1075 N at the equator.

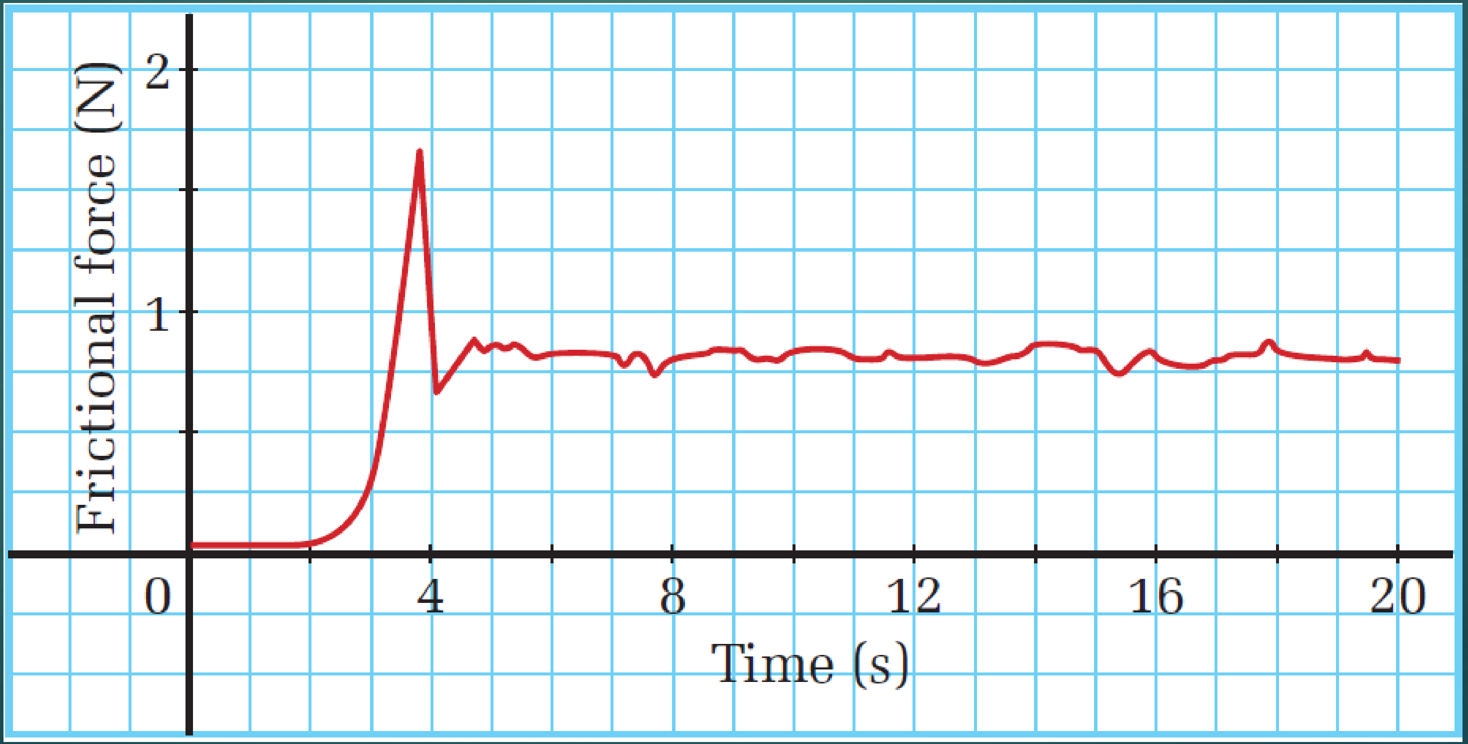
Unless given a specific location, take the ***magnitude*** of the acceleration to be $g = 9.81\ m/s^2$.

The Force of Friction

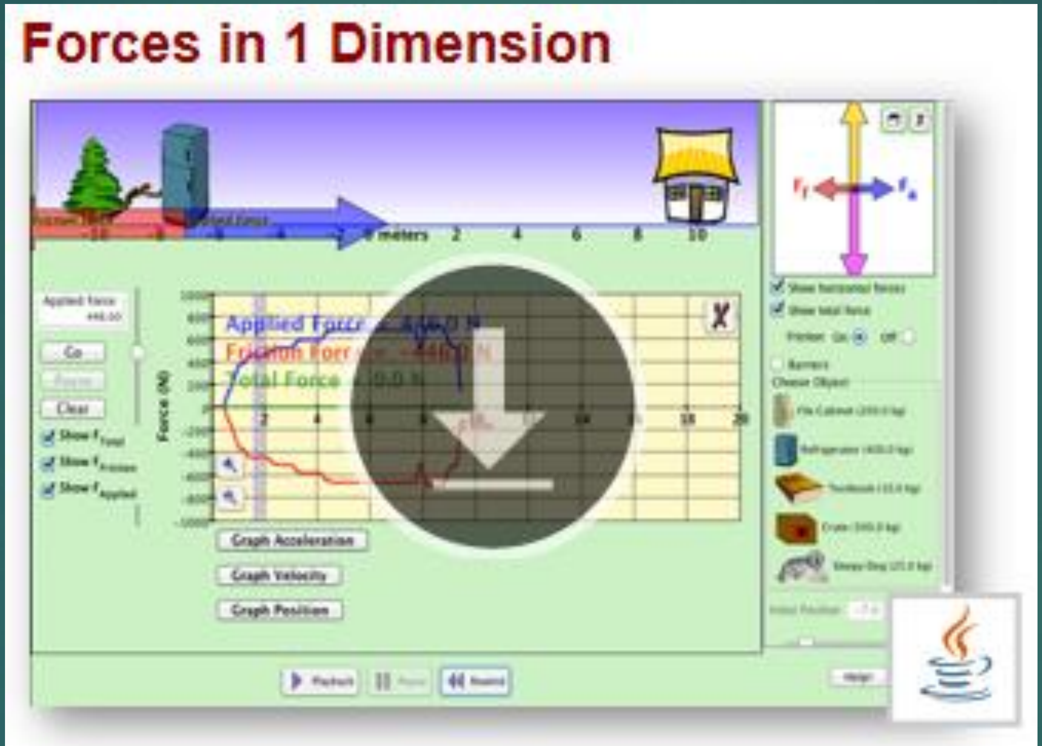
- When two surfaces come in contact, the surface atoms of each form relatively strong electromagnetic bonds (between the positive nucleus and motion of negative electrons).
  - Static Friction: Exists when you start to move an object from rest.
  - Kinetic Friction: Exists while an object is moving.

Static vs Kinetic Friction

- Objects won't move until static friction is overcome.
- The force of kinetic friction is less than static friction. In other words, when friction is a factor, it is easier to keep an object in motion than to get it moving.



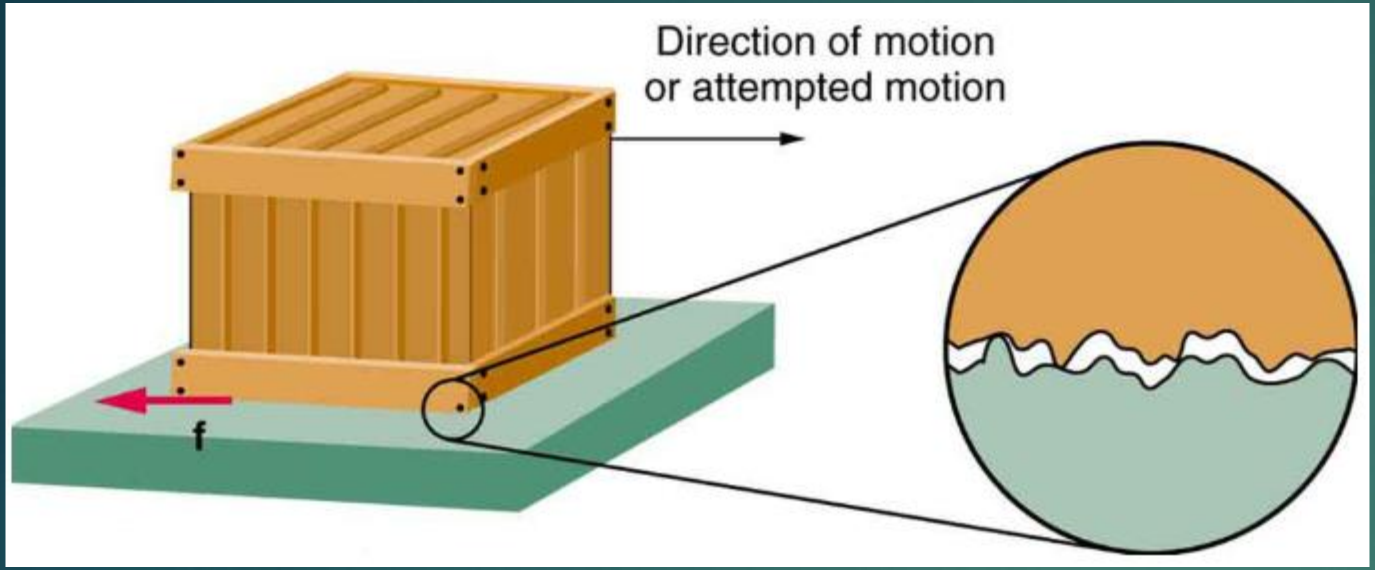
Static vs Kinetic Friction

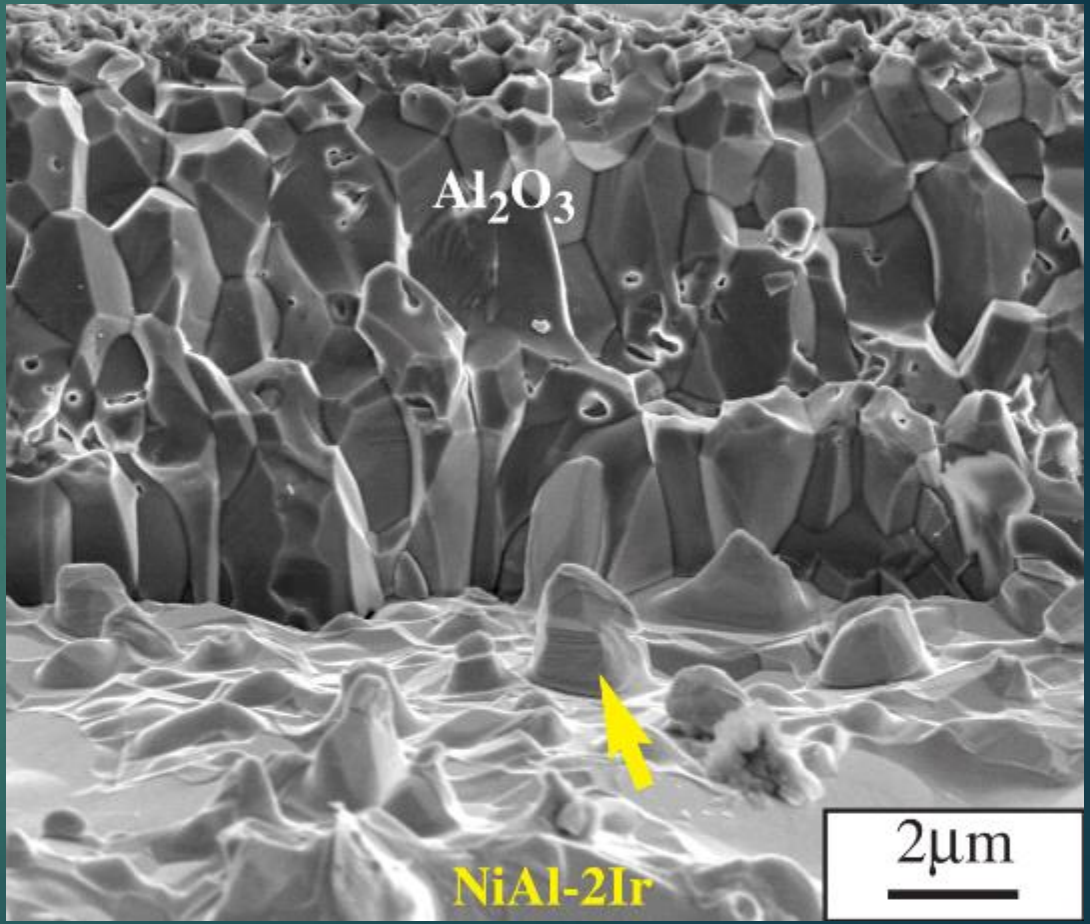


Static vs Kinetic Friction

- Surfaces may feel smooth but are not so when you look with electron microscopes at the atomic level.
- Static friction arises from the electromagnetic bonds of surface atoms "pushing back" against an applied force.
- Once broken the object begins to move, but surface atoms are continually forming EM bonds, but they are weaker because of the motion.
- This process is responsible for the noise we hear when two objects are moved against each other.
- Heat is released when the bonds are broken.

The Force of Friction



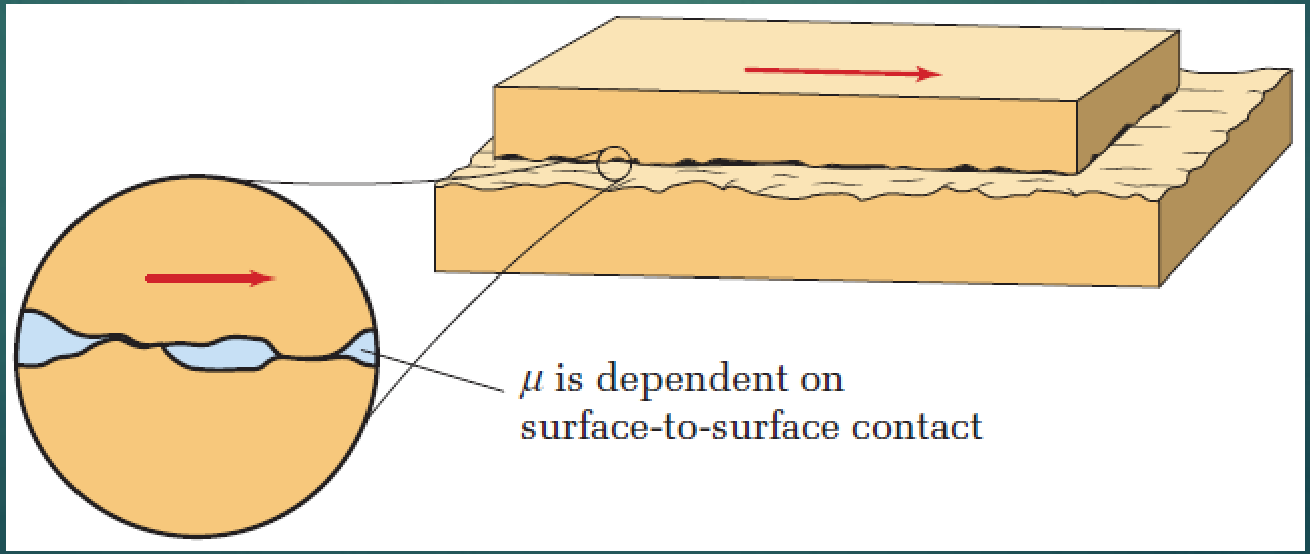


Force of Friction: Conditions

- The interaction of atoms is complex and our formula is a good approximation of the forces involved if:
  - The mass of the object is evenly distributed (not heavier at one end).
  - No adhesives.
  - No penetrating spikes.

The Coefficient of Friction, μ

- The "stickiness" between two surfaces is called the coefficient of friction.
  - Independent of location, force of gravity, surface area, etc.
- μ_s: Coefficient of static friction.
- μ_k: Coefficient of kinetic friction.



Calculating Force of Friction

- F_f depends on the two surfaces as well as how strongly they are being pushed together.
- How much a surface pushes back is called the Normal Force.

$$\left|\vec{F}_f\right| = \mu\left|\vec{F}_N\right|$$

- Notice the absolute value symbols, this equation uses magnitudes only (only positive numbers).
- This is because these force act in perpendicular directions.
- If the object is not moving use μ_s, otherwise, μ_k.

Determining Normal Force

- Draw a diagram and identify the forces pushing against the surface. The magnitude of the normal force is the sum of all the forces pushing on the surface.
- An object on the floor or ground: same as the force of gravity plus any applied force (F_a could be positive or negative).
- An object pressed against a wall: same as the applied force.

Determining Normal Force Examples

- Ex 1. A 20 kg box sits on the ground. Calculate the normal force provided by the ground.
- Ex 2. A person applies a 340 N [down] force on the 20 kg box. Calculate the normal force.
- Ex 3. A 12 kg box is held up against a wall with an applied force of 100 N. Determine the normal force.
- Ex 4. A 50 kg box is pulled up by an applied force of 275 N. Calculate the normal force.

Calculating Force of Friction, Ex. 1

- A 31 kg object is being pushed along the floor starting from rest. μ_s is 0.45 and μ_k is 0.22. Calculate the forces of static and kinetic friction.

Calculating Force of Friction, Ex. 2

- A large box is pushed along the floor. The force of kinetic friction is 75 N and the coefficient of kinetic friction is 0.27. Calculate the mass of the box.

Calculating Force of Friction, Ex. 3

- A 45 kg dresser is resting on the floor. A person pushes down on the dresser with a force of 125 N. If $\mu_s = 0.56$, calculate the F_f.

Calculating Force of Friction, Ex. 4

- A 45 kg dresser is resting on the floor. A person pulls up on the dresser with a force of 125 N. If $\mu_s = 0.56$, calculate the F_f.

Calculating Force of Friction, Ex. 5

- A 5.8 kg book is pressed against the wall and held there with force of 75 N. Calculate the coefficient of static friction.

Force of Friction Practice

- Friction review from your worksheet.

Net Force

$$\vec{F}_{net} = \sum Forces$$

- Net force is the vector sum of all the forces acting on an object.
  - Vector sum means that only forces acting in the same ***dimension*** can be added together.
  - Forces acting left or right on an object can not be added to forces acting up or down.
  - Dimensions (coordinate system) is user-defined.
    - We will use **x** for horizontal and ***y*** for vertical vectors; like in your math courses.
  - Objects accelerate in the direction of the net force.

Net Force and Equilibrium

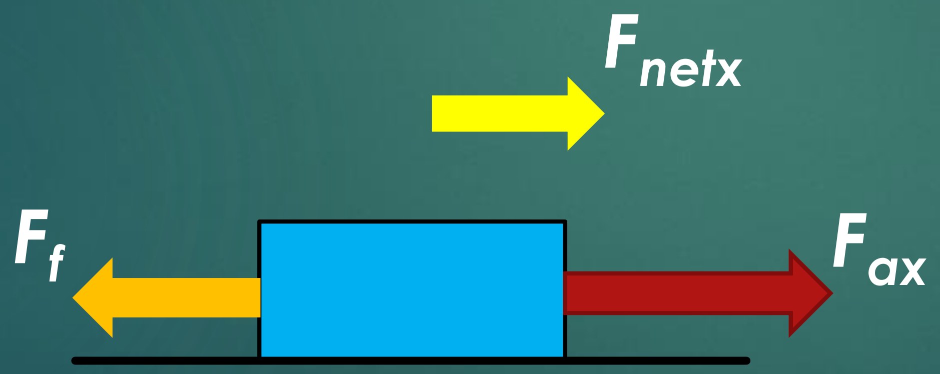
- If an object is said to be in equilibrium, that means the net force acting on it is ***zero***.
- This happens when the acceleration on the object is zero.
  - When the velocity is zero, there is zero acceleration.
  - When the velocity is constant, there is zero acceleration.
- A car could be driving 125 km/h, but if there is no acceleration, the net force is zero!

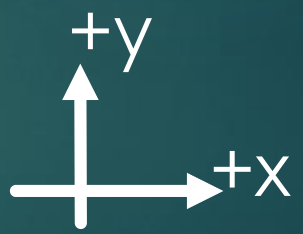
Solving Net Force Problems

- Determine a coordinate system.
- Sketch a diagram and label all relevant forces using arrows pointing away from the object.
- Apply the concept of net force in each dimension separately, as needed.
  - List the forces involved, taking direction into account using the coordinate system.
  - Solve for the unknown variable(s).

Net Force Problems

- A crate is moving along a flat surface under a net force of 25 N. The applied force is 135 N.
  a) Calculate the force of friction.





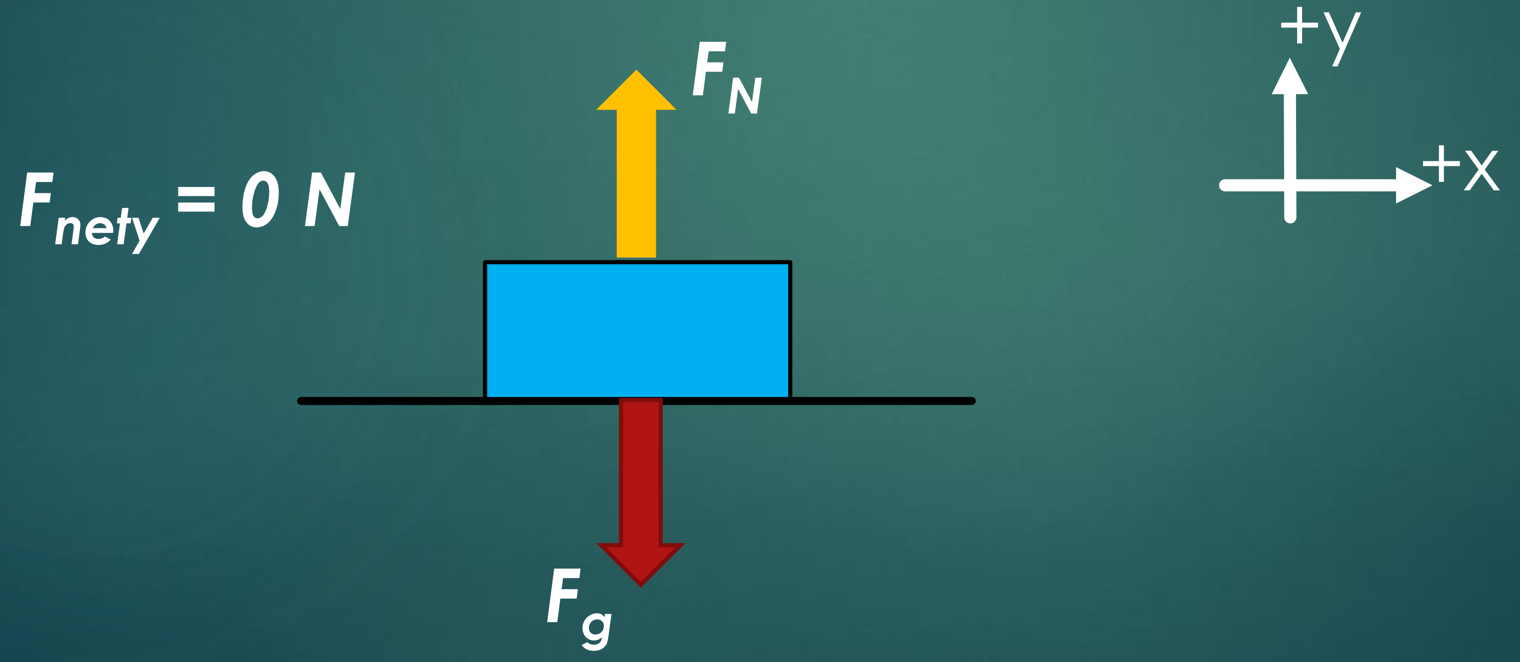
Net Force Problems

- A crate is moving along a flat surface under a net force of 25 N. The applied force is 135 N.
  - b. If $\mu_k = 0.19$ calculate the normal force.

$$\left|\vec{F}_f\right| = \mu\left|\vec{F}_N\right|$$

Net Force Problems

- A crate is moving along a flat surface under a net force of 25 N. The applied force is 135 N.
  - c) Calculate the mass of the crate.

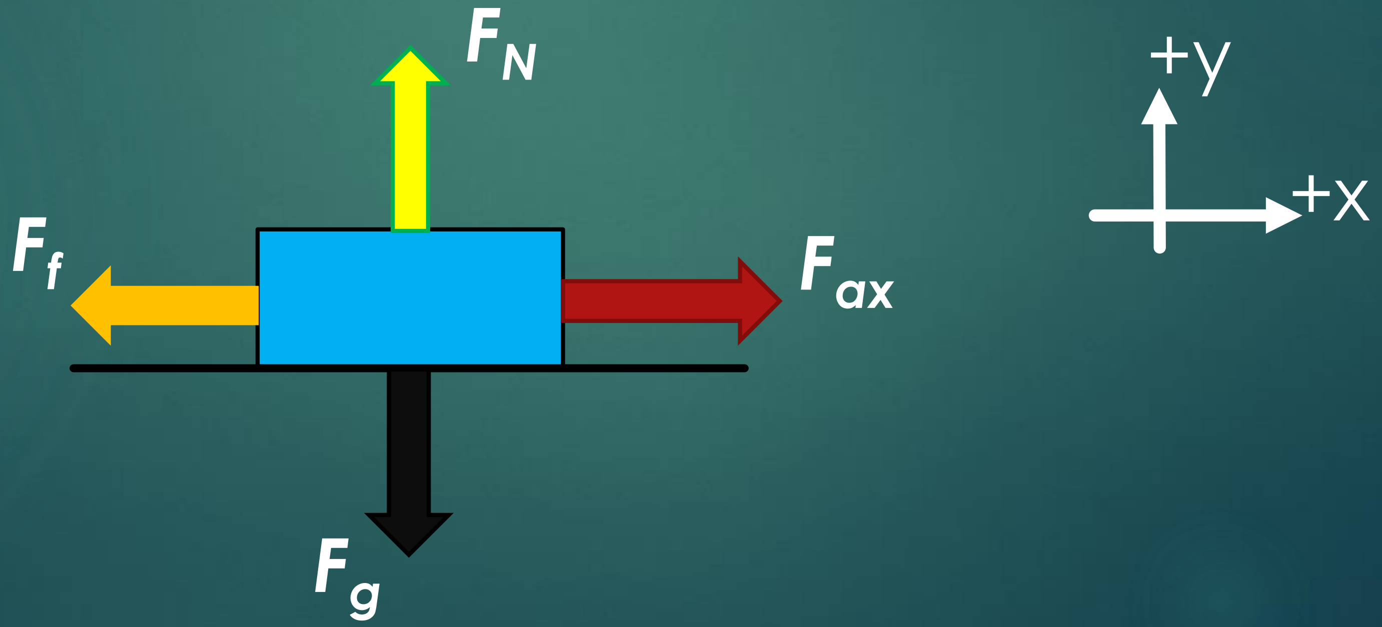


Net Force Problems

- A 62 kg crate is pulled at a constant velocity with an applied force of 337 N.
  a) Calculate the force of friction.
  b) Calculate the normal force.
  c) Calculate the coefficient of kinetic friction.

$F_{netx} = 0\ N$

$F_{nety} = 0\ N$

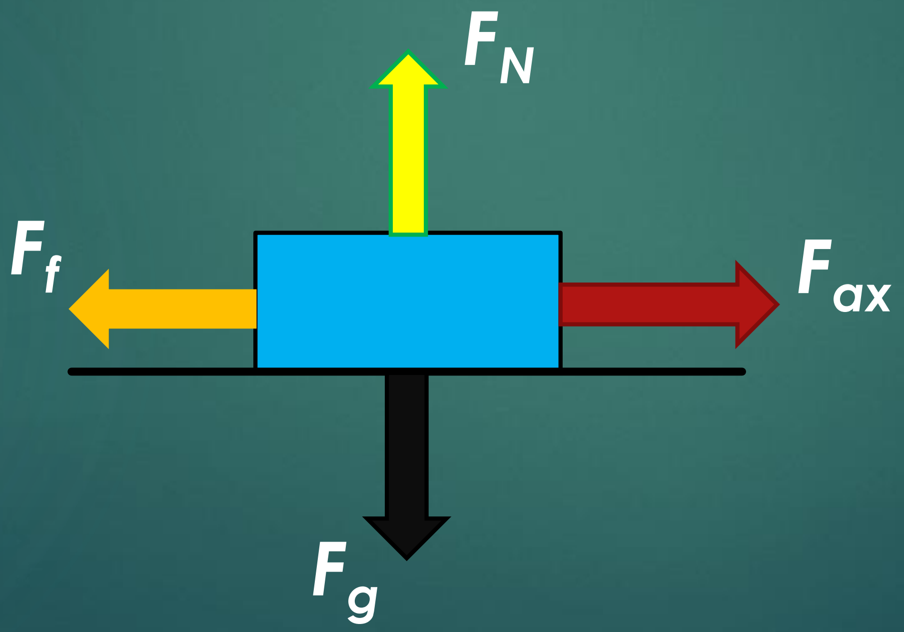


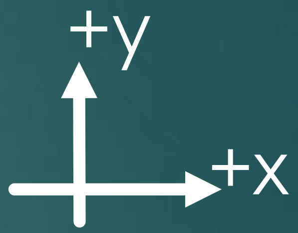
Net Force Problems

- A box has a weight of 625 N and is being pulled with a net force of 12 N. The coefficient of kinetic friction is 0.23. Calculate the force being applied to the box.

$F_{netx} = 12\ N$

$F_{nety} = 0\ N$



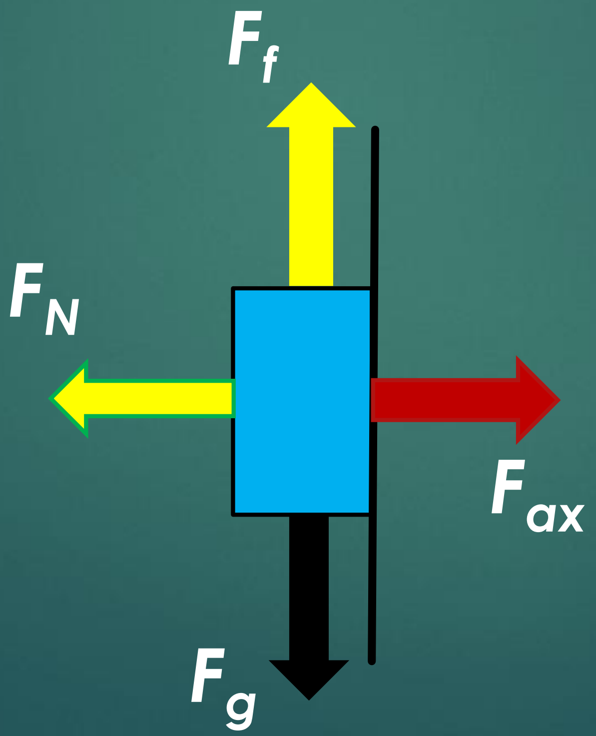


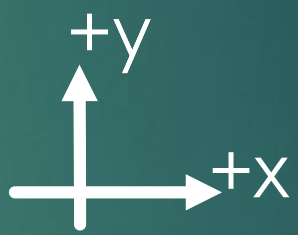
Net Force Problems

- A 3.4 kg book is pressed against a wall. If μ_s is 0.41, calculate the minimum force applied to keep the book from slipping down.

$F_{netx} = 0\ N$

$F_{nety} = 0\ N$





Net Force Worksheet

- Continue through the worksheet questions.
- Test day is coming…

Newton’s Laws

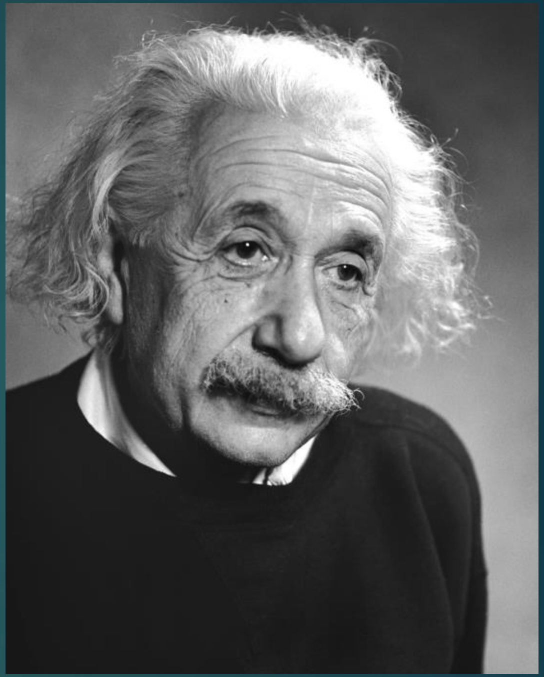
CLASSICAL MECHANICS

Classical & Quantum Mechanics

- The physics fields of kinematics and dynamics are divided into two very different categories: **Classical and Quantum Mechanics**.
- **Classical (Newtonian) Mechanics**:
  - Developed in the late 1600s by Sir Isaac Newton.
  - Matter and energy are treated a separate entities. Newton's laws can predict the motion and interaction of objects.
  - Objects much larger than an atom.
  - Objects traveling much slower than the speed of light.

Quantum Mechanics

- An extension of Newtonian mechanics primarily developed by Albert Einstein in the early 1900s.
- Required to model the motion and energy of subatomic particles and objects traveling near the speed of light, **c**.
- Theory of relativity: $E = mc^2$, energy and mass are related.
- According to Newtonian mechanics, stars should not exist!



Newton’s First Law – Law of Inertia

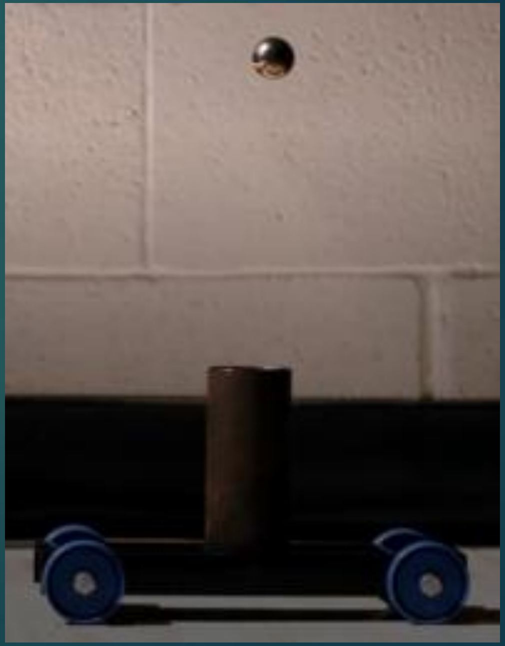
- An object at rest or in uniform motion, will remain at rest or in uniform motion unless acted on by an external force.
  - An external force is one that brings the object out of equilibrium (the net force would no longer be zero).
- Examples: being squished against the side of a car when turning quickly, or tossing a ball up while walking.

Inertial Frame of Reference

- A frame of reference in which Newton's laws of motion are valid and can be applied to objects.
  - The frame of reference must be in equilibrium, that is an acceleration of zero.
- All of the forces acting on an object can be explained within the frame of reference.
  - No ***fictitious*** forces.

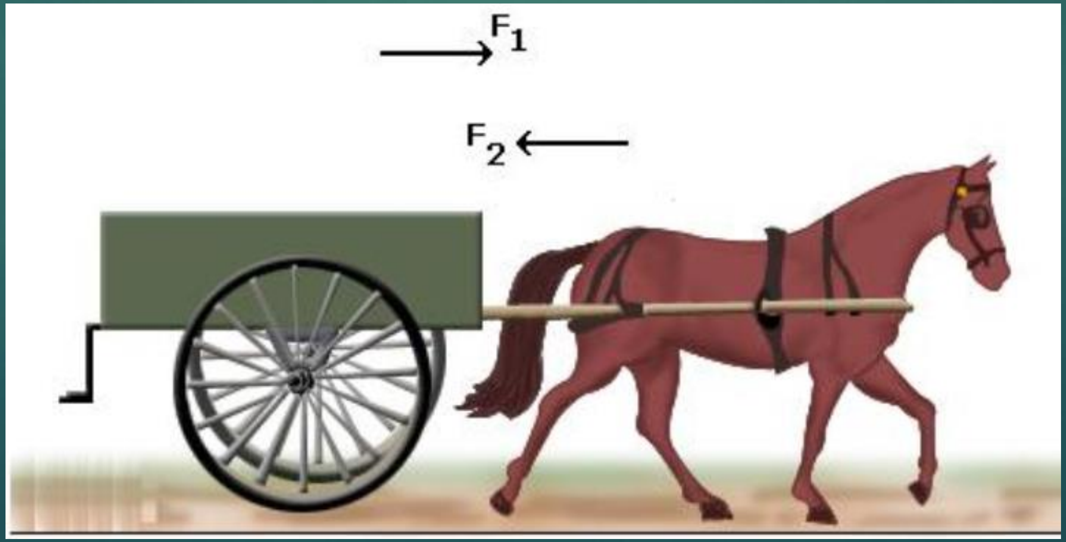
Non-Inertial Frames of Reference

- A frame of reference that is not in equilibrium so Newton's laws are not valid.
  - Some objects move with apparently no force acting on them! Such forces are called ***fictitious forces***.
  - A breaking or accelerating car is an example.



Newton's 3rd Law

- For every action, there is an opposite and equal reaction.
  - That is why you can hurt yourself if you punch a wall.
  - Forces always act in pairs.
- The floor pushes you!
- How come the force pairs don't cancel in the image below?



Newton's 2^{nd} Law

- Force is the project of mass and acceleration. $\boldsymbol{F} = m\boldsymbol{a}$
- If the acceleration is the net acceleration, then the force is the net force.
- Force calculated by $\boldsymbol{F} = m\boldsymbol{a}$ is always in the same direction as the acceleration.
- This equation relates the concepts of dynamics and kinematics.

Newton's 2^{nd} Law Examples

- Calculate the mass of an object that accelerates at $21 m/s^2$ under an average (net) force of 1200 N.

- Calculate the net force required to accelerate a 33 kg mass at $4.6\ m/s^2$.

Combining Dynamics and Kinematics

$$\overrightarrow{F_{net}} = m \times \vec{a}$$

Involve problems we've done previously with common forces like applied force, gravity and friction

Involve concepts from kinematics incorporating position, velocity and acceleration.

Example 1

- An applied force of 50 N is used to accelerate an object across a frictional surface. The object encounters 10 N of friction. The mass of the object is 8.0 kg.
  - Calculate the net force.
  - Calculate the acceleration.
  - Calculate the final position of the object.

Example 2

- A 750 kg car goes from 21 m/s [E] to 15 m/s [W] in 7.5 seconds. Calculate the net force acting on the car.

Example 3

- A 2.5 kg ball falls on an air mattress. Just as it hit the ball had a speed of 19 m/s. The air mattress depressed 0.75 m to stop the ball. Calculate the average stopping force acting on the ball.