AP Physics Study Guide

Dynamics

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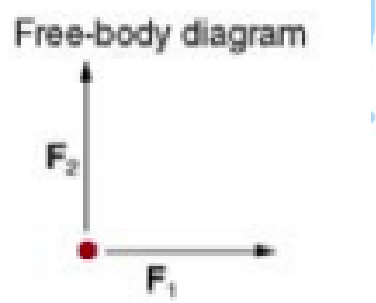
Dynamics is the study of forces that cause objects and systems to move

- A **force** is a push or pull
  - It has both magnitude and direction (it is a vector)
  - It is the result of an interaction of two or more objects
    - No object can exert force on itself

A **free-body diagram** is a technique used to illustrate all the **external forces** acting on a body

- The body is represented by a single isolated point (or free body)
- Only those forces acting *on* the body from the outside (external forces) are shown
- These diagrams are useful in analyzing forces acting on a system



Newton's first law of motion states that there exists an inertial frame of reference such that a body at rest remains at rest, or, if in motion, it remains in motion at a constant velocity unless acted on by a net external force

- There must be a *cause* (a net external force) for there to be any change in velocity (magnitude or direction) in an inertial reference frame.
- Basically any change in velocity must be caused by an external force

Inertia is the property of a body to remain at rest or to remain in motion with constant velocity

- Newton's first law is often called the **law of inertia**

- The inertia of an object is measured by its **mass**
    - An object with a small mass will exhibit less inertia and be more affected by other objects.
    - An object with a large mass will exhibit greater inertia and be less affected by other objects.
- The inertial mass of an object is a measure of how difficult it is to alter the uniform motion of the object by an external force.

Mass is a measure of the amount of matter in something

- The amount of matter in an object is determined by the numbers of atoms and molecules of various types it contains.
- Mass does not vary with location (unlike weight).

Newton's second law of motion discusses the cause and effect relationship between force and changes in motion.

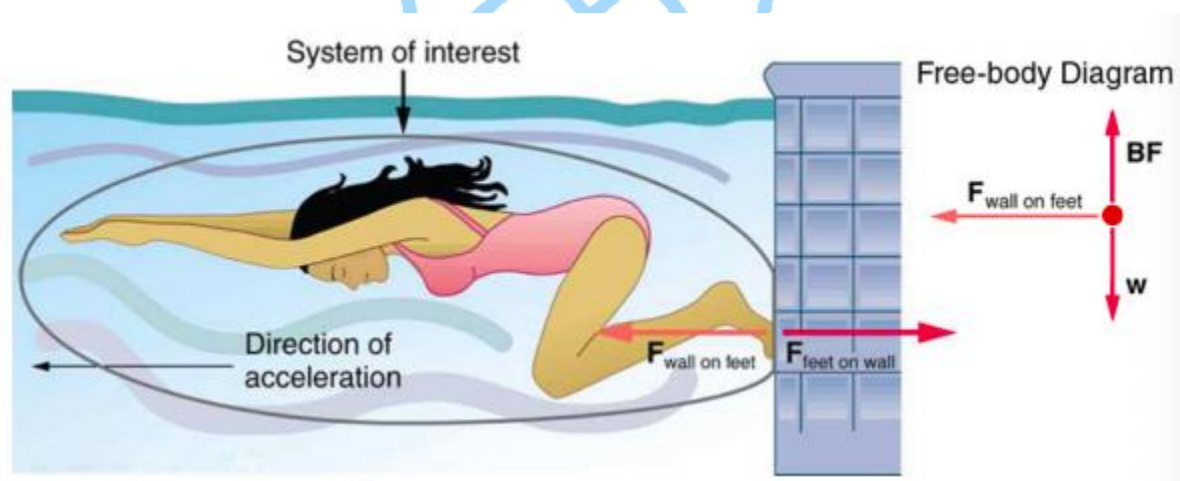
- **Acceleration** is a change in velocity (aka a change in motion)
- An **external force** acts from outside the **system** of interest
    - It has been **experimentally** found that the acceleration of an object depends only on the net external force and the mass of the object
- Definition: The acceleration of a system is directly proportional to and in the same direction as the net external force acting on the system, and inversely proportional to its mass
    - $F_{net} = ma$

If air resistance is negligible, the net force on a falling object is the force of gravity, also known as its **weight.**

- It is a vector because it has magnitude and direction (down)
- $w = mg$
    - Since g = -9.8 down (negative is down in this scenario) on earth, the weight of a 1 kg object on Earth is 9.8 N
- When the net external force on an object is its weight, we say that it is in **free fall**
    - The only force acting on the object is the force of gravity

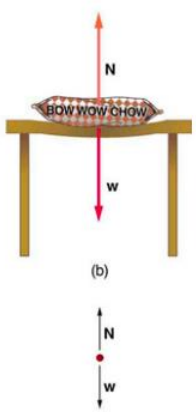
Newton's third law of motion states that whenever one body exerts a force on a second body, the first body experiences a force that is equal in magnitude and opposite in direction to the force that it exerts.

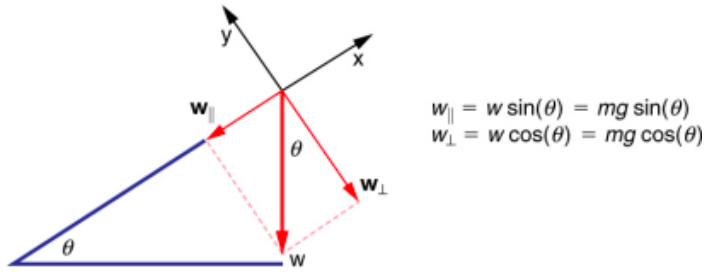
- Forces always occur in pairs, and one body cannot exert a force on another without experiencing a force itself
- Ex: rockets move forward by expelling gas backward at high velocity
    - This reaction force is called a **thrust**



Weight is a pervasive force that acts at all times and must be counteracted to keep an object from falling

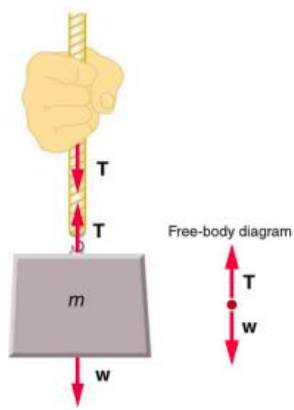
- Whatever supports a load must supply an upward force equal to the weight of the load
    - This force is called the **normal force** and is given the symbol N
        - The normal force can be less than the object's weight if the object is on an incline.





A **tension** is a force acting along the length of a medium, especially a force carried by a flexible medium, such as a rope or cable.

- A force carried by a flexible connector is a tension with direction parallel to the connector.
- Tension is a *pull* in a connector.
- By using Newton's second law, we can conclude that tension in the rope must equal the weight of the supported mass (if the object isn't moving)



Real forces are those that have some physical origin, such as the gravitational pull

- **Fictitious forces** are those that arise simply because an observer is in an accelerating frame of reference
- An **inertial frame of reference** is one in which all forces are real and one in which Newton's laws have the simple forms given in this chapter

These are steps you can take to solve problems using Newton's Laws of Motion

- Identify the physical principles involved
  - Draw a careful sketch of the situation
  - Use arrows to represent all forces and label them
- Identify what needs to be determined and what is known or can be inferred from the problem as stated
  - Carefully determine the system of interest
- After drawing a free-body diagram, Newton's second law can be applied to solve the problem
  - If the problem is one-dimensional, the forces add like scalars
  - If the problem is two-dimensional, it must be broken down into a pair of one-dimensional problems

In physics, only four distinct forces account for all known phenomena

- Action at a distance is explained by the existence of a **force field** rather than by physical contact
- These are the four basic forces in physics

Table 4.2 Properties of the Four Basic Forces[1]

Force	Approximate Relative Strengths	Range	Attraction/Repulsion	Carrier Particle
Gravitational	10^{-38}	∞	attractive only	Graviton
Electromagnetic	10^{-2}	∞	attractive and repulsive	Photon
Weak nuclear	10^{-13}	$< 10^{-18}\,\mathrm{m}$	attractive and repulsive	W^+, W^-, Z^0
Strong nuclear	1	$< 10^{-15}\,\mathrm{m}$	attractive and repulsive	gluons