VP150-RC3

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Force

Definition

A force is an interaction between two bodies or between a body and its environment.\

Unit

SI Unit: Newton $1N = 1kg \cdot 1m/s^2$

Others: dyne, pound, ...

Classification

Contact Force: A contact force is any force that occurs as a result of two objects making contact with each other.

Field Force: Force does not require contact.

At the atomic scale, contact forces are field forces (electromagnetic in their nature).

Four Fundamental Interactions

Interaction	Particles Involved	Relative Strength	Range
Gravitational always attractive holds planets in their orbits around Sun	any massive particle	$\sim 10^{-38}$	infinite
Electromagnetic attractive/repulsive fundamental in optics, chemistry, biology; source of friction	electric charge	$\sim 10^{-2}$	infinite
Weak necessary for buildup of heavy nuclei; responsible for radioactive decay (beta decay)	quarks, leptons	$\sim 10^{-6}$	short $\sim 10^{-18}$ m (0.1% of the diameter of the proton)
Strong holds protons and neutrons together in the nucleus	hadrons (protons, neutrons, mesons)	1	short $\sim 10^{-15}$ m (diameter of a medium sized nucleus)

Newton's Law

Inertial Frame of Reference

An inertial frame of reference is **a frame where Newton's law holds true**. That means if no external force is acting on a body it will stay at rest or remain in uniform motion.

Definition

Newton's First Law

A body acted on by no net force has a constant velocity (which may be zero) and zero acceleration.

Newton's Second Law

If a net external force acts on a body, the body accelerates. The direction of acceleration is the same as the direction of the net force. The mass of the body times the acceleration vector of the body equals the net force vector.

$$\vec{a} = \frac{\vec{F}}{m}$$

Newton's Third Law

If body A exerts a force on body B (an "action"), then body B exerts a force on body A (a "reaction"). These two forces have the same magnitude but are opposite in direction. These two forces act on different bodies.

$$\vec{F_{AB}} = \vec{F_{BA}}$$

Note: This law is significant for $\vec{N}$ and $\vec{f}$

> A rifle bullet traveling at $350m/s$ strikes a large tree and penetrates it to a depth of $0.130m$. The mass of the bullet is $1.80g$. Assume a constant retarding force.
>
> 1. How much time is required for the bullet to stop?
> 2. What force, in newtons, does the tree exert on the bullet?

Free Body Diagram

> *e.g.*

Different Force

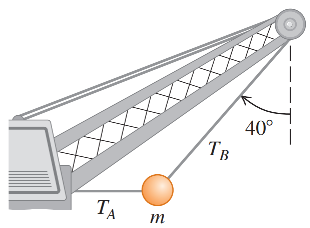
1. **Weight:** $\vec{G} = m\vec{g}$
2. **Tension:** Tension is described as the pulling force transmitted axially by the means of a string, a rope, chain, or similar object, or by each end of a rod, truss member, or similar three-dimensional object; tension might also be described as the action-reaction pair of forces acting at each end of said elements. Tension could be the opposite of compression.
3. **Normal Force:** The normal force $\vec{N}$ is the component of a contact force that is perpendicular to the surface that an object contacts
4. **Friction (Static friction, Sliding friction, Rolling friction):** $f_s \leq \mu_s N$ / $f_k = \mu_k N$ / $f_{rolling}$ is much smaller than $f_s \& f_k$
5. **Elastic Force:** Elasticity is the ability of a material to return to its original shape after being stretched or compressed.
   (Hook's Law) $F = -k\Delta x$ Springs in parallel: $k = k_1 + k_2$ Springs in series: $k = \frac{k_1 k_2}{k_1 + k_2}$

Exercises

Ex.1

5.6 •• A large wrecking ball is held in place by two light steel cables (**Fig. E5.6**). If the mass m of the wrecking ball is 3620 kg, what are (a) the tension T_B in the cable that makes an angle of 40° with the vertical and (b) the tension T_A in the horizontal cable?

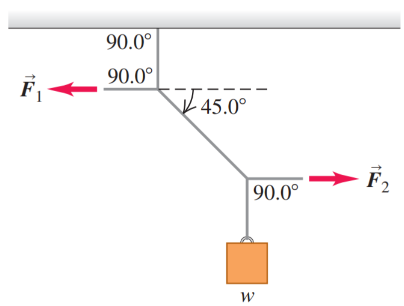
Figure **E5.6**



Ex.2

5.10 •• In **Fig. E5.10** the weight w is 60.0 N. (a) What is the tension in the diagonal string? (b) Find the magnitudes of the horizontal forces $\vec{F}_1$ and $\vec{F}_2$ that must be applied to hold the system in the position shown.

Figure **E5.10**



Ex.3

5.31 •• A box with mass 10.0 kg moves on a ramp that is inclined at an angle of 55.0° above the horizontal. The coefficient of kinetic friction between the box and the ramp surface is $\mu_k = 0.300$. Calculate the magnitude of the acceleration of the box if you push on the box with a constant force $F = 120.0$ N that is parallel to the ramp surface and (a) directed down the ramp, moving the box down the ramp; (b) directed up the ramp, moving the box up the ramp.

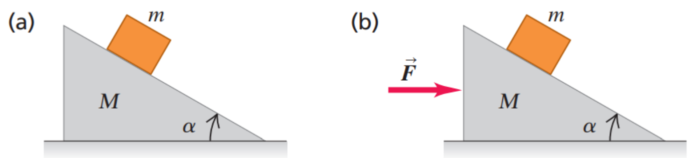
Ex.4

5.40 •• You throw a baseball straight upward. The drag force is proportional to v^2. In terms of g, what is the y-component of the ball's acceleration when the ball's speed is half its terminal speed and (a) it is moving up? (b) It is moving back down?

Ex.5

5.112 ••• **Moving Wedge.** A wedge with mass M rests on a frictionless, horizontal tabletop. A block with mass m is placed on the wedge (**Fig. P5.112a**). There is no friction between the block and the wedge. The system is released from rest. (a) Calculate the acceleration of the wedge and the horizontal and vertical components of the acceleration of the block. (b) Do your answers to part (a) reduce to the correct results when M is very large? (c) As seen by a stationary observer, what is the shape of the trajectory of the block?

Figure **P5.112**



5.113 ••• A wedge with mass M rests on a frictionless, horizontal tabletop. A block with mass m is placed on the wedge, and a horizontal force $\vec{F}$ is applied to the wedge (Fig. P5.112b). What must the magnitude of $\vec{F}$ be if the block is to remain at a constant height above the tabletop?

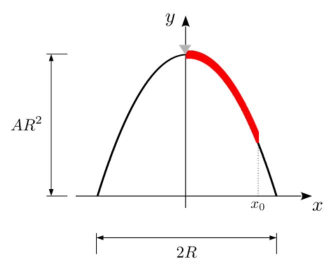
Ex.6

Problem 5. (*12 points*) One end of a uniform rope (red line in the figure) with linear density of mass λ is pinned at the top of a frictionless surface in the shape of a paraboloid with the diameter $2R$ at the base and height AR^2 at the top (see the figure for a cross-sectional sketch). The rope rests on the surface so that the free end of the rope is at the position with $x = x_0$.

(a) Find the tension at any point of the rope as a function of x.

(b) Discuss **qualitatively** how the result will change if the surface is rough.

The acceleration due to gravity g is known.



Reference

1. Wu Yufan, 2022SU VP150 RC.
2. Qu Zhemin, 2021SU VP150 RC.
3. Mateusz Krzyzosiak, 2023SU VP150 Slides.