Ch. 5, Force and Motion-I

- Newton’s First Law
- Force
- Mass
- Newton’s Second Law

(Newton’s Third Law → Next Thursday)

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Newton’s Laws of Motion

Isaac Newton’s work represents one of the greatest contributions to science ever made by an individual. Most notably, Newton derived the law of universal gravitation, invented the branch of mathematics called calculus, and performed experiments investigating the nature of light and color.
Kinematics and Dynamics

**Kinematics**
Describing object's motion by answering:
without asking: Why is object moving in a certain way?

**Dynamics**
Describing object's motion by answering:
- Why is the object moving in a certain way?
- What causes the object to change its velocity?
- How the interaction between objects influence their motion?
Dynamics studies motion on a deeper level than kinematics:
it studies the causes of changes in objects' motion!

Language and Questions of Dynamics

- **Force:** The measure of interaction between two objects (pull or push). It is a vector quantity – it has a magnitude and direction
- **Mass:** The measure of how difficult it is to change object’s velocity (sluggishness or inertia of the object)
A Force as a Measure of Interaction Between Two Objects

An example of measuring forces:
A simple spring scale shows the strength of the interaction between the Earth and the object. The stronger the interaction is, the more the spring scale stretches! The force of attraction between the Earth and the object is called WEIGHT of the object. We can measure weight in lbs or in Newtons. 1 lbs = 4.45N

Forces:
- Gravitational Force: \( F = mg \)
- Archimedes Force
- Friction Force:
- Tension Force
- Spring Force
- Normal Force
Gravitational Force:

\[ F = mg; \quad g = 9.8 \text{ m/s}^2 \]

Direction: Pointing downward

**Weight:** The force that the Earth is pulling the object with. Weight is a vector quantity, it has a magnitude and direction (unit: \( N \))

\[ \text{(weight)} = \text{(mass)} \times g \]

Normal Force: \( \vec{N} \)

Force from a solid surface which keeps objects from falling through

\( \vec{N} \perp \text{surface} \)

Force on surface = - \( \vec{N} \)
An object of interest can interact with more than one object. → More than one force can be exerted on a given object.

Example: You

Earth pulls you downwards. The chair pushes you upwards.

NET FORCE ($F_{\text{net}}$) : A resultant force acting on an object.

To find the resultant force ($F_{\text{net}}$), add up all the forces acting on an object. Remember that forces are vector quantities.
Which diagrams illustrate vector addition of the two forces?

**EXAMPLES of Free Body Diagrams**

<table>
<thead>
<tr>
<th>Picture of Situation</th>
<th>FBD</th>
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<td><img src="image4.png" alt="Image" /></td>
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Newton’s First Law of Motion
(The Law of Inertia)

- An object at rest remains at rest as long as no $F_{net}$ acts on it
- An object moving with constant velocity continues to move with the same speed and in the same direction (the same velocity) as long as no net force acts on it
- Every object continues in its state of rest, or uniform motion in a straight line, unless it is compelled to change that state by unbalanced forces impressed upon it
- Inertia is a property of objects to resist changes in motion!

An additional force is NOT required to keep a cart moving with a constant speed on a frictionless track!

What is the magnitude of an additional force which results in
(a) a stationary block and
(b) a block moving to the left with a constant speed of 5 m/s?
Newton’s Second Law of Motion

- **Unbalanced forces** cause object to accelerate.
- An object of mass $m$ has an acceleration $a$, equal to the net force $F$, divided by the mass of the object, $m$.

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

Dimensional Analysis

A net force of 1N exerted on a 1-kg object will accelerate it at a rate of 1m/s$^2$.

Comment: Notice that an unbalance force (unbalanced interaction with other objects) is a cause of acceleration.

Newton’s 2nd law for each component

$$F_{\text{net},x} = ma_x ; \quad F_{\text{net},y} = ma_y ; \quad F_{\text{net},z} = ma_z$$
Sample Problem 5-1

In Figs. 5-3a to c, one or two forces act on a puck that moves over frictionless ice along an x axis, in one-dimensional motion. The puck's mass is \( m = 0.20 \text{ kg} \). Forces \( \mathbf{F}_1 \) and \( \mathbf{F}_2 \) are directed along the x axis and have magnitudes \( F_1 = 4.0 \text{ N} \) and \( F_2 = 2.0 \text{ N} \). Force \( \mathbf{F}_3 \) is directed at angle \( \theta = 30^\circ \) and has magnitude \( F_3 = 1.0 \text{ N} \). In each situation, what is the acceleration of the puck?

Common exam #2: 8:30-9:45am on Mar. 2nd(Fri.) at 205 Kupfrian Hall (arrive by 8:15am)

All of Chapters 4 and 5. Bring scientific calculators

New Physics Learning Center schedule- Check website tomorrow

Problem #8 in Common Exam 1 is discarded. (total score = 16)

Even if it is not announced:

Quiz on every Thursday -- Bring a scientific calculator.

Reading assignment each week
Course information: Grades

- Three Common Exams: 45% (15% each)  
  (Feb.9, Mar.2, Apr.13)
- Quizzes during Lect./Reci.: 7%
- Homework: 8%
- Workshop: 10%
- Final exam: 30%

A  80+
B+ 75-79
B  70-74
C+ 65-69
C  55-64
D  50-54
F  <  50

Example: Grades

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SUM

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B+ 75-79
B  70-74
C+ 65-69
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**Example: Grades**

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**Ch. 5, Force and Motion-I**

*Continued*

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(Newton's Third Law → Next Thursday)
Example: Person in a elevator

A person with a mass 50 Kg in an elevator is moving upward with an acceleration $a = 1.1 \text{ m/s}^2$

What is the magnitude of the force of the elevator on the person?

Free Body Diagram - FBD

Denoting forces:
A force has to have:
- a magnitude and direction (an arrow);
- two indices:
  - $F_{\text{Earth on Person Standing}}$
  - $F_{\text{Person Standing on Floor}}$
Sample Problem 5-3 (equilibrium system)

\[ \vec{F}_A \text{ has magnitude } 220N \]

\[ \vec{F}_C \text{ has magnitude } 170N \]

What is \( \vec{F}_B \)?

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