PHYSICS 231

INTRODUCTORY PHYSICS I

Lecture 4
Main points of last lecture

- **Scalars vs. Vectors**
- Vectors $\vec{A}$: $(A_x, A_y)$ or $|A|$ & $\theta$
  - Addition/Subtraction

- **Projectile Motion**
  - X-direction: $a_x = 0$ ($v_x = \text{constant}$)
  - Y-direction: $a_y = -g$
  - Parabolic trajectory
Example 3.4a

The X-component of \( v \) is smallest (in magnitude) at:

a) A  
b) B  
c) C  
d) Same at all points
Example 3.4b

The Y-component of $v$ is smallest (in magnitude) at:

a) A  
b) B  
c) C  
d) Same at all points
The acceleration is smallest (in magnitude) at:

- a) A
- b) B
- c) C
- d) Same at all points
Range Formula

- **Good for when** \( y_f = y_i \)

\[
x = v_{i,x} t
\]

\[
y = v_{i,y} t - \frac{1}{2} gt^2 = 0
\]

\[
t = \frac{2v_{i,y}}{g}
\]

\[
x = \frac{2v_{i,x}v_{i,y}}{g} = \frac{2v_i^2 \cos \theta \sin \theta}{g}
\]

\[
x = \frac{v_i^2}{g} \sin 2\theta
\]
Range Formula

\[ R = \frac{v_i^2}{g} \sin 2\theta \]

- Maximum for \( \theta = 45^\circ \)
Example 3.5a

A softball leaves a bat with an initial velocity of 31.33 m/s. What is the maximum distance one could expect the ball to travel?

100 m
Example 3.6

A cannon hurls a projectile which hits a target located on a cliff $D=500$ m away in the horizontal direction. The cannon is pointed 50 degrees above the horizontal and the muzzle velocity is $75$ m/s. Find the height $h$ of the cliff?

68 m
Relative velocity

- Velocity always defined relative to reference frame.
Example 3.7

An airport walkway moves at 3 mph. A man walks at a leisurely pace of 2 mph.

a) If he walks on the walkway in the same direction as the walkway, what is his speed as seen from the ground?

b) If he walks on the walkway in the opposite direction as the walkway, what is his speed as seen from the ground?

a) 5 mph
b) 1 mph
Relative velocity in 2-d

- Sum velocities as vectors
- velocity relative to ground
  = velocity relative to medium + velocity of medium.

\[ \mathbf{v}_{be} = \mathbf{v}_{br} + \mathbf{v}_{re} \]

- Boat wrt earth
- boat wrt river
- river wrt earth
2 Cases

- Pointed perpendicular to stream
- Travels perpendicular to stream
Example 3.8

An airplane is capable of moving 200 mph in still air. The plane points directly east, but a 50 mph wind from the north distorts his course.

What is the resulting ground speed?
What direction does the plane fly relative to the ground?

206.2 mph
14.0 deg. south of east
Example 3.9

An airplane is capable of moving 200 mph in still air. A wind blows directly from the North at 50 mph. The airplane accounts for the wind (by pointing the plane somewhat into the wind) and flies directly east relative to the ground.

What is the plane’s resulting ground speed? In what direction is the nose of the plane pointed?

193.6 mph
14.5 deg. north of east
Chapter 4

Forces and Motion
What is a force?

- Usually a push or pull
- A Vector

Fundamental Forces:
1. Strong Nuclear
2. Electromagnetic
3. Weak Nuclear
4. Gravity
Newton’s First Law

• If the net force exerted on an object is zero, its velocity remains constant (both magnitude and direction).

• Objects at rest feel no net force
• Objects moving with constant velocity feel no net force

• No net force means \( \sum \vec{F} = 0 \)
Mass

• A measure of the resistance of an object to changes in its motion due to a force
• Scalar
• SI units are kg
Newton’s Second Law

• Acceleration is proportional to net force and inversely proportional to mass.

\[ \sum \vec{F} = m \vec{a} \]
Units of Force

- **SI unit is Newton (N)**
  
  \[ F = ma \]

  \[
  1 \text{ N} = 1 \frac{\text{kg} \cdot \text{m}}{\text{s}^2}
  \]

- **US Customary unit is pound (lb)**
  - \( 1 \text{ N} = 0.225 \text{ lb} \)
Weight = magnitude of Gravitational Force on an object near the surface of the Earth

Galileo: $|\vec{a}| = g$  \[ \text{mass} \]

$\Rightarrow \text{weight} = mg$

- Weight is different on surface of other planets/moons.
- Mass is same everywhere.
Newton’s Third Law

\[ \vec{F}_{12} = -\vec{F}_{21} \]

Force on “1” due to “2”

- Single isolated force cannot exist
- For every action there is an equal and opposite reaction
- Action and Reaction Forces act on different objects
Action-Reaction Pairs

\[ \vec{n} = -\vec{n}' \]
\[ F_g = -F'_g \]

\[ \vec{n} = \text{Normal force of table holding up TV} \]
\[ \vec{n}' = \text{Normal force of TV pushing down on table} \]
\[ F_g = \text{Weight of TV (attracted to Earth)} \]
\[ F'_g = \text{Gravitational force on Earth (attracted to TV)} \]
Defining the Object: Free-body Diagram

- Newton’s Law uses the forces acting ON object
- \( n \) and \( F_g \) act on object
- \( n' \) and \( F_{g'} \) act on other objects

Ignore rotational motion for now. Treat object as a particle.
Definition of Equilibrium

\[ \sum \vec{F} = 0 \]

Object is at rest or moving with constant velocity
Example 4.1a

A Ford Pinto is parked in a parking lot.

There is no net force on the Pinto.

A) True
B) False
Example 4.1b

A Ford Pinto is parked in a parking lot.

The contact (normal) force acting on the Pinto from the parking lot surface is ____________.

A) Points upwards
B) Is zero
C) Points downward
Example 4.1c

A Ford Pinto drives down a highway on the moon at constant velocity (where there is no air resistance)

The Pinto’s acceleration is __________

A) Less than zero
B) Equal to zero
C) Greater than zero
Example 4.1d

A Ford Pinto drives down a highway on the moon at constant velocity (where there is no air resistance)

The force acting on the Pinto from the contact with the highway is vertical.

A) True
B) False
Mechanical Forces

- Gravity
- Normal forces
- Strings, ropes and Pulleys
- Friction
- Springs (later)
Rules for Ropes and Pulleys

- Force from rope points AWAY from object
  - (Rope can only pull)
- **Magnitude of the force is** Tension
  - Tension is same everywhere in the rope
- Tension does not change when going over pulley

Approximations: Neglect mass of rope and pulley, neglect friction in pulley
Example 4.2

I pull a 5 kg mass up with a rope, so that it accelerates 2 m/s². What is the tension in the rope?

\[ T = 59 \text{ N} \]
Example 4.3

a) Find acceleration
b) Find $T_1$, the tension above the bowling ball
c) Find $T_3$, the tension in the rope between the pails
d) Find force ceiling must exert on pulley

\[
a = \frac{g}{6} = 1.635 \text{ m/s}^2
\]
\[
b) T = 57.2 \text{ N}
\]
\[
c) T_3 = 24.5 \text{ N}
\]
\[
d) F_{pulley} = 2T = 114.5 \text{ N}
\]
Example 4.4a

2) Which statements are correct?
Assume the objects are static.

\[
\cos(10^\circ) = 0.985 \\
\sin(10^\circ) = 0.173
\]

\[T_1 \text{ is } \underline{\quad} \text{ } T_2\]

A) Less than
B) Equal to
C) Greater than
Example 4.4b

2) Which statements are correct?
Assume the objects are static.

\[ T_2 \text{ is } \underline{\phantom{0}} \text{ } T_3 \]

A) Less than  
B) Equal to  
C) Greater than

\[ \cos(10^\circ) = 0.985 \]  
\[ \sin(10^\circ) = 0.173 \]
Example 4.4c

2) Which statements are correct? Assume the objects are static.

\[ \cos(10^\circ) = 0.985 \]
\[ \sin(10^\circ) = 0.173 \]

\( T_1 \) is _____ Mg

A) Less than  
B) Equal to  
C) Greater than  

\( T_1 \)
2) Which statements are correct?
Assume the objects are static.

\[ T_1 + T_2 \text{ is } \underline{\text{________}} \text{ Mg} \]

A) Less than  
B) Equal to  
C) Greater than

\[ \cos(10^\circ) = 0.985 \]
\[ \sin(10^\circ) = 0.173 \]