

# Physics Notes

Matthew Stringer

# Contents

<b>I</b>	<b>Physics C: Mechanics</b>	<b>3</b>
<b>1</b>	<b>Kinematics</b>	<b>3</b>
1.1	Describing Motion 1 . . . . .	3
1.1.1	Average Speed . . . . .	3
1.1.2	Average Velocity . . . . .	3
1.1.3	Average Velocity . . . . .	3
1.1.4	Displacement . . . . .	3
1.2	Describing Motion 2 . . . . .	4
1.2.1	Kinematic Equations . . . . .	4
1.2.2	Acceleration Due to Gravity . . . . .	4
1.2.3	Objects Falling From Rest . . . . .	4
1.2.4	Objects Launched Upward . . . . .	4
1.3	Projectile Motion . . . . .	5
1.3.1	Independence of Motion . . . . .	5
1.3.2	Steps for any Projectile Motion Problem . . . . .	5
1.3.3	Graphing Projectile Motion . . . . .	5
1.4	Circular And Relative Motion . . . . .	6
1.4.1	Converting Linear to Angular Velocity . . . . .	6
<b>2</b>	<b>Dynamics</b>	<b>6</b>
2.1	Newton's First Law and Free Body diagrams . . . . .	6
2.1.1	Force . . . . .	6
2.1.2	Net Force . . . . .	7
2.1.3	Equilibrium . . . . .	7
2.1.4	Free Body Diagram . . . . .	7
2.2	Newton's 2nd and 3rd Laws of Motion . . . . .	7
2.2.1	Newton's 2nd Law of Motion . . . . .	7
2.2.2	Mass vs. Weight . . . . .	7
2.2.3	Newton's 3rd Law of Motion . . . . .	7
2.3	Friction . . . . .	8
2.3.1	Coefficient of Friction . . . . .	8
2.4	Retarding or Drag Forces . . . . .	8
2.4.1	Retarding Forces . . . . .	8
2.4.2	The Skydiver . . . . .	8
2.5	Ramps and Inclines . . . . .	8
2.5.1	Drawing FBD for Ramps . . . . .	8
2.6	Atwood Machine . . . . .	9
2.6.1	What is an Atwood Machine . . . . .	9
2.6.2	Properties of Atwood Machines . . . . .	9
2.6.3	Setup for Atwood Machines . . . . .	9
2.6.4	Solution . . . . .	9

## Part I

# Physics C: Mechanics

## 1 Kinematics

### 1.1 Describing Motion 1

#### 1.1.1 Average Speed

- Average speed is the distance traveled over change in time
- It is a scalar
- Measured in meters/second.
- Magnitude of Velocity Vector

#### 1.1.2 Average Velocity

- Average velocity is a vector.
- Measured in meters/second.

$$v_{avg} = \frac{\delta x}{\delta t} = \frac{x_f - x_i}{t_f - t_i}$$

#### 1.1.3 Average Velocity

- Rate that velocity changes
- Is a vector
- Units are meters/second/second

$$a = \frac{\delta v}{\delta t} = \frac{dv}{dt}$$

#### 1.1.4 Displacement

The displacement from  $t_0$  to  $t_1$  of a position function  $x(t)$  with velocity function  $v(t)$  is

$$\int_{t_0}^{t_1} v(t) dt$$

## 1.2 Describing Motion 2

### 1.2.1 Kinematic Equations

Variables	
$v_0$	Initial velocity
$v$	Final velocity
$\delta x$	Displacement
$a$	Acceleration
$t$	Time

- $v = v_0 + at$
- $x = x_0 + v_0t + \frac{1}{2}at^2$
- $v^2 = v_0^2 + 2a\delta x$

### 1.2.2 Acceleration Due to Gravity

- Near the surface of Earth, objects accelerate at a rate of  $9.8 \frac{m}{s^2}$
- This is acceleration due to gravity ( $g$ )
- This can be approximated to  $10 \frac{m}{s^2}$
- As you move from Earth, acceleration decreases.

### 1.2.3 Objects Falling From Rest

- Objects starting from rest have  $v_0 = 0$
- Typically down is the positive direction
- Acceleration is  $+g$ .

### 1.2.4 Objects Launched Upward

- Must examine the motion of object going up and down.
- Since object is going up, that is the positive direction.
- Acceleration is  $-g$ .
- At the highest point,  $v = 0$ .

## 1.3 Projectile Motion

A **projectile** is an object that is acted upon only gravity.

### 1.3.1 Independence of Motion

- Projectiles launched at an angle have motion in 2 dimensions.
  - Vertical - acceleration is gravity
  - Horizontal - 0 acceleration
- Vertical and Horizontal motion are treated separately

**Note:** An object will travel the maximum horizontal distance with a launch angle of  $45^\circ$

### 1.3.2 Steps for any Projectile Motion Problem

1. First, know that

$$a = \begin{bmatrix} 0 \\ -g \end{bmatrix}$$

2. Then find your  $v_0$  as a vector
3. Find your  $x_0$  as a vector
4. Substitute your vectors into the following formula

$$x(t) = -\frac{1}{2}at^2 + v_0t + x_0$$

### 1.3.3 Graphing Projectile Motion

In order to graph a path, solve for  $y = f(x)$ . Do this by solving for  $t$  in relation to  $x$  and then substitute into the  $y$  component.

For example:

$$x = f(t)$$

$$y = g(t)$$

$$\text{Find } y = h(x)$$

$$t = f^{-1}(x)$$

$$y = g(f^{-1}(x)) = h(x)$$

$$\text{so } h(x) = g(f^{-1}(x))$$

## 1.4 Circular And Relative Motion

### 1.4.1 Converting Linear to Angular Velocity

If we have an object moving counter clockwise around a point, let  $\omega = \frac{d\theta}{dt}$ . If we know that the object has velocity  $v$  and position  $s$ , we know that  $s = r\theta$  where  $r$  is the radius of the circular path. By taking the derivative of both sides,  $\dot{s} = r\dot{\theta}$ . Now we can substitute to find the angular velocity.

$$\dot{s} = r\omega$$

## 2 Dynamics

### 2.1 Newton's First Law and Free Body diagrams

#### Newton's First Law

An object at rest will remain at rest, and an object in motion will remain in motion, at constant velocity and in a straight line, unless acted upon by a net force.

#### 2.1.1 Force

- A force is a push or pull on an object.
- Units of force are in Newtons (N).
- A newton is roughly the weight of an apple

$$1N = 1 \frac{kg * m}{s^2}$$

#### Contract Force

A force that arises that from direct contact between objects.

- Tension
- Applied Force
- Friction

#### Field Force

Forces that act at a distance.

- Gravity
- Electrical
- Magnetic

### 2.1.2 Net Force

A net force is the vector sum of all the forces acting on an object.

$$F_{net} = \sum F$$

### 2.1.3 Equilibrium

- Static Equilibrium
  - Net force is 0
  - Net torque is 0
  - Object is at rest
- Mechanical Equilibrium
  - Net force is 0
  - Net torque is 0
- Translational Equilibrium
  - Net force is 0

### 2.1.4 Free Body Diagram

A Free Body Diagram (FBD) is a diagram that maps all of the forces that are applied to a single object.

## 2.2 Newton's 2nd and 3rd Laws of Motion

### 2.2.1 Newton's 2nd Law of Motion

- The acceleration of an object is in the direction of and directly proportional to the net force applied, and inversely proportional to the object's mass.
- Valid only in *inertial reference frames*.

$$F_{net} = \sum F = ma$$

### 2.2.2 Mass vs. Weight

- Mass is the amount of stuff that something is made up of (independent of gravity)
- Weight is the force of gravity on an object. (dependent on gravity)

### 2.2.3 Newton's 3rd Law of Motion

- All forces come in pairs

- If Object 1 exerts a force on Object 2, then Object 2 must exert a force back on Object 2.
- This counter force is equal in magnitude and opposite in direction.

$$F_{1on2} = -F_{2on1}$$

## 2.3 Friction

### 2.3.1 Coefficient of Friction

- Ratio of the frictional force and the normal force
- 2 kinds:
  1. Kinetic (when 2 objects are rubbing)
  2. Static (when 2 objects are not sliding)

$$\mu = \frac{F_f}{F_N}$$

which results in

$$F_f = \mu F_N$$

where  $F_f$  is the force of friction,  $F_N$  is the normal force, and  $\mu$  is the coefficient of friction.

## 2.4 Retarding or Drag Forces

### 2.4.1 Retarding Forces

- Frictional forces can be functions of the object's velocity
- These forces are called drag or retarding forces

### 2.4.2 The Skydiver

Typically drag forces on a free-falling object take the form of

$$F_{drag} = bv$$

or

$$F_{drag} = cv^2$$

By using Newton's 2nd Law, create a differential equation. Then use separation of variables to solve for velocity, then acceleration, then position.

## 2.5 Ramps and Inclines

### 2.5.1 Drawing FBD for Ramps

1. Choose the object and draw it as a dot or box



2. Draw and Label all the External Forces
3. Sketch a Coordinate System

## 2.6 Atwood Machine

### 2.6.1 What is an Atwood Machine

Two objects connected by a light string over a massless pulley

### 2.6.2 Properties of Atwood Machines

- Ideal pulleys are frictionless and massless
- Tension is constant in a light string passing over an ideal pulley

### 2.6.3 Setup for Atwood Machines

1. Adopt a sign convention for positive and negative motion
2. Analyze each mass separately using Newton's 2nd Law.

### 2.6.4 Solution

$$\begin{aligned}F_y = m_1g - m_2g &= (m_1 + m_2)a \\(m_1 - m_2)g &= (m_1 + m_2)a \\a &= \frac{(m_1 - m_2)}{(m_1 + m_2)}\end{aligned}$$