PHYS 2211

Look over:
Chapter 5 sections 1-9
examples:1, 2, 3, 4, 5, 6, 7, 8, 9
Chapter 6 sections 1-3, 5
examples:1, 2, 3

PHYS 1111

Look over:
Chapter 4 sections ~~1-9.~~ 1-6
Examples: 1, 2, 3, 4, 5, 6, 7, 8, 9, ~~11, 12, 13, 15, 16, 19, 20 and 21~~
Chapter 5 sections ~~1, 2, 6.~~ 1-5
Examples: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, ~~and 12~~

Topics Covered

- Newton's first law of motion.
- Inertia and mass.
- Newton's second law.
- Force
- Newton's third law.
- Weight.
- Free-Body Diagrams
- Problem solving guide lines.
- Incline planes problems.
- Static and Kinetic friction μ_k and μ_s
- Uniform Circular Motion

Classical Mechanics

Classical Mechanics is the study of motion and what causes motion.

The central problem of classical mechanics is this:

1)We are given a particle whose characteristics we know.

2)We place this particle, with a known initial velocity, in an environment of which we have a complete description.

3)**Problem**: what is the subsequent motion of the particle.

Newton's Path

Isaac Newton, a British physicist and mathematician formulated the the laws of motion, discovered the law of universal gravity, and invented calculus before he was 30 years old.

Newton but forward path that would lead to a solution to the central problem of classical mechanics (how to find the motion of an object)

The Steps on Newton's Path

Step 1 We introduce the concept of **Force** and define it in terms of the acceleration experienced by a particular standard object.

Step 2 We develop a procedure for assigning a **Mass** to an object so that we may understand the fact that different particles of the same kind experience different accelerations in the same environment.

Step 3 Finally, we try to find ways of calculating the forces that act on objects from the properties of the particle and its environment: That is we look for force laws.

Aristotle on Motion

According to Aristotle every object in the world has an appointed place in nature.

Galileo on Motion

Galileo found that if there is no outside interactions acting on an object then the object will continue as it is either moving ant a constant speed or remaining at rest.

Newton's Three Laws of Motion

Based on the work of Galileo, Newton came up with three laws of motion.

Newton’s First Law of Motion

Every object persists in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by forces impressed on it.

A **Force** is any influence that can change the speed or direction of motion of an object.

Inertia

Inertia is the tendency of an object to maintain its state of rest or uniform motion or the ability of an object to resist a force.

Force and Mass

Imagine pulling a standard object (which we will take to be 1 kg) until the standard object has a uniform acceleration of a_s=1 m/s^2.

We will define one Newton (1 N) of force to be the force we exerted on the standard object to give it a uniform acceleration of 1 m/s^2

We can repeat this experiment and measure an acceleration a_s=2 m/s^2 for the standard object.

We now declare the force we are exerting on the standard object is 2 N.

We can continue this for any size force we want to define.

Newton's Second Law of Motion

The acceleration of an object is directly proportional to the sum of all forces acting on it and is inversely proportional to its mass. The direction of the acceleration is in the direction of the applied net force.

$$\vec{a} = \frac{\Sigma \vec{F}}{m} \text{ or } \Sigma \vec{F} = m\vec{a}$$

The Units of Force

Force is a vector and it will have in principal three components.

$$\vec{F} = F_x \hat{i} + F_y \hat{j} + F_z \hat{k}$$ where

$$\Sigma F_x = m a_x,\ \Sigma F_y = m a_y,\ \Sigma F_z = m a_z$$

The unit of force in the metric system is the Newton.

Units Alert!

In the metric system of units mass, length, and time are all fundamental quantities.

Force is a derived quantity determined from **F**=m**a**.

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

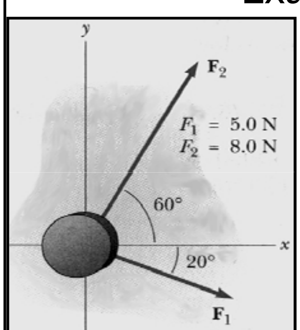
In the British system of units force, length, and time are all fundamental quantities.

Mass is a derived quantity determined from m=**F/a**.

$$Slug = \frac{lb}{ft/s^2} = \frac{lb \cdot s^2}{ft}$$

System of Units	Force	Mass	Acceleration
SI	Newton (N)	Kilogram (kg)	m/s^2
Cgs	Dyne	Gram (g)	cm/s^2
British	Pound (lb)	Slug	ft/s^2

Example 1



1)A hockey puck having a mass of *0.30 kg* slides on the horizontal, frictionless surface of an ice rink. Two forces act on the puck, as shown. The forces $\boldsymbol{F_1}$ has a magnitude of *5.0 N*, and the force $\boldsymbol{F_2}$ has a magnitude of *8.0 N* Determine both the magnitude and the direction of the puck's acceleration.

Newton's Third Law of Motion

To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

In other words, if **object A** exerts a force on **object B**, **object B** exerts an equal but oppositely directed force on **object A**; and furthermore the forces lie along the line joining the objects.

Notice that action and reaction forces act on different objects.

The Normal Force

The Normal Force is the force a surface (like a table or the floor) exerts on an object preventing it from falling.

The normal force can take on any value need to support the weight of objects, until the surface breaks.

Force Laws

Newton's 2nd law (**F**=m**a**) is not a law of nature but a definition of force.

We need to identify functions of the type:

F = (A function of the properties of the particle and of the environment)

Force is a concept that connects the acceleration of the particle on the one hand with the properties of the particle and its environment on the other.

Weight

Weight is the force with which an object is attracted by the earth's gravitational pull.

Weight is a vector pointing toward the center of the Earth.

$$\vec{W} = m\vec{g}$$

If we are given the weight we can find the mass using:

$$m = \frac{W}{g}$$

Free-Body Diagrams

Free-Body Diagrams is a picture that shows all the forces acting on an object.

The three steps of drawing a free body diagram are as follows:

Free-Body Diagrams

1) Choose the object you wish to isolate and draw it. Show objects as simple particles or blocks and keep the diagram simple and uncluttered.

2) Draw all forces acting on the object as vector arrows, in approximately correct size and direction. Label all forces clearly.

3) Indicate a coordinate system and show the positive direction of displacement, velocity, or acceleration, depending on the problem.

Problem-Solving Strategy

You will need to work problems in order to deepen you understanding of the laws of motion. Developing your skills for problem requires practice. To help solve problems here are 7 steps you should keep in mind.

1)Read the entire problem carefully. Then read it again, focusing on what you are being told.

2)Draw and label a diagram of the physical situation. Draw a free-body diagram where appropriate. Choose a coordinate system and indicate it on your drawing. The diagram is more then a simplified picture it is part of the solution. In complicated situations, drawing several free-body diagrams separates the problem into manageable pieces so that you can find the appropriate equations.

Problem-Solving Strategy (2)

3)After you understand what is given and after you have labeled the diagram, then tackle the question. Briefly restate the question, perhaps in symbols, on your paper. It may help to make a list of the known quantities given in the problem as well as the unknown quantities being sought.

4)Sate the basic principles or concepts that apply. Find a mathematical relationship between the known and unknown quantities and write it in the form of an equation, or perhaps several equations.

5)Solve the equations for the unknown quantity (or quantities) so that you have an equation with only unknown quantities on the left-hand side of the equal sign and all of the known quantities and constants on the right-hand side.

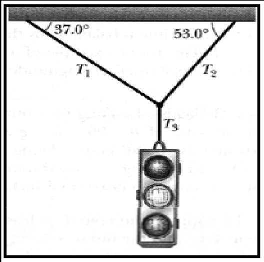
Problem-Solving Strategy (3)

6)Now substitute the numerical values into the equation if the problem has a numerical solution. Include both the numerical value and the units for each quantity. Then compute the numerical answer.

7)As a final check you should ask yourself whether your answer is reasonable.

Then you can do your victory tap dance.

Example 2

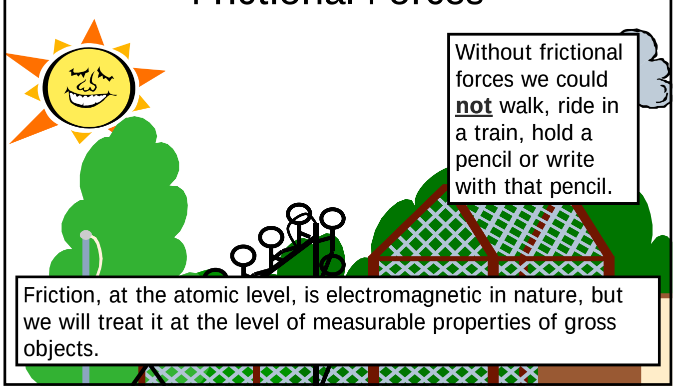


2)A traffic light weighing 125 N hangs from a cable tied to two other cables fastened to a support. The upper cables make angles of 37.0° and 53.0° with the horizontal. Find the tension in the three cables

Example 3

3)Two masses are connected by a light string that passes over a frictionless pulley. If the incline is frictionless and if $m_1=2.00\ kg$ and $m_2=6.00\ kg$ and ›$=55.0°$, find a) the acceleration of the masses. b)the tension in the string, and c)the speed of each mass *2.0 s* after being released form rest.

Frictional Forces



Without frictional forces we could **not** walk, ride in a train, hold a pencil or write with that pencil.

Friction, at the atomic level, is electromagnetic in nature, but we will treat it at the level of measurable properties of gross objects.

Two Types of Frictional Forces

1)The frictional forces acting between surfaces at rest with respect to each other are called forces of **Static Friction**.

The maximum force of static friction will equal the smallest force needed to start the object moving.

2)Once the motion has started, the frictional forces between the surfaces usually decreases so that a smaller force is needed to maintain the uniform motion.

Frictional forces acting between surfaces in relative motion are called **Kinetic Friction**.

Static Friction

The **maximum** force of static friction between two dry surfaces follows two empirical rules:

1)The static frictional force is approximately independent of the area of contact.

2)The static frictional force is proportional to the normal force.

Static Friction

$$F_s \leq \mu_s N$$

Where μ_s is the **Coefficient of Static Friction**

The equality sign holds only when F_s has its maximum value which is just before motion starts.

The direction of F_s is opposed to the applied force.

Kinetic Friction

The force of kinetic friction between two dry surfaces follows three empirical rules:

1)The kinetic frictional force is approximately independent of the area contact.

2)The kinetic frictional force is proportional to the normal force.

3)The kinetic frictional force is reasonably independent of the relative speed with which the surfaces move over each other.

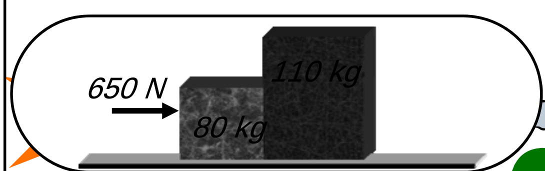
Kinetic Friction

$$F_k = \mu_k N$$

Where μ_k is the **Coefficient of Kinetic Friction**

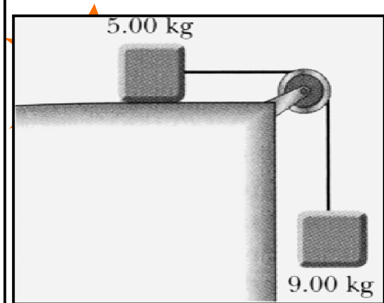
The direction of F_k is opposed to the applied force.

Example 4



4)Two crates, of mass 80 kg and 110 kg are in contact and at rest on a horizontal surface.
a)What is the maximum force that can be exerted on the 80 kg crate before the crates start to move?
A 650 N force is then exerted on the 80 kg crate. If the coefficient of kinetic friction is 0.20, calculate:
b)The acceleration of the system.
c)The force that each crate exerts on the other.

Example 5



5)A 9.00 kg hanging weight is connected by a string over a pulley to a 5.00 kg block that is sliding on a flat table. If the coefficient of kinetic friction is 0.200, find the tension in the string and the acceleration.

Friction at The Atomic Level

Many points of contact actually become "Cold-Welded" together.

This phenomenon, is called **Surface Adhesion**

Example 6

6)A boy drags his *60.0 N* sled at constant speed up a *15.0°* hill. He does so by pulling with *25.0 N* force on a rope attached to the sled. If the rope is inclined at *35.0 °* to the horizontal, a)what is the coefficient of kinetic friction between sled and hill?b)At the top of the hill he jumps on the sled and slides down the hill. What is the his acceleration?

Uniform Circular Motion

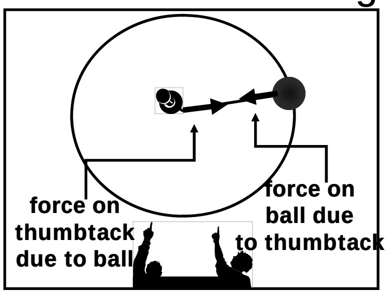
Forces responsible for uniform circular motion are called **Centripetal Forces** because they are directed "toward the center" of the circular motion.

Using the centripetal acceleration and Newton's 2nd law we can write:

$$a_c = \frac{v^2}{r}$$

$$F_c = ma_c = m\frac{v^2}{r}$$

The Centrifugal Force

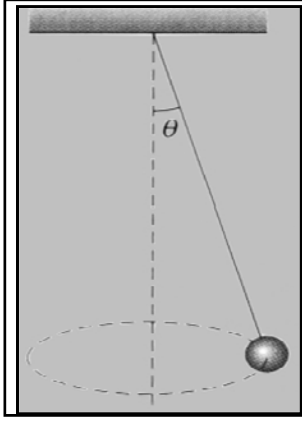


There is a misconception that there is an outward "**Centrifugal**" (center-fleeing) force pulling on the ball.

This centrifugal force is nothing more then the reaction force to the force keeping the object moving in a circle.

Causes of Centripetal Forces

Centripetal forces are not new forces. They are caused by other forces that we have seen



Example 7

7)Consider a conical pendulum with an *80.0 kg* bob on a *10.0 m* wire making an angle of *5.00°* with the vertical. Determine: a) the horizontal and vertical components of the force exerted by the wire on the pendulum, b) the radical acceleration of the bob.

Summary of Chapter 5 and 6

- Newton's first law: If the net force on an object is zero, it will remain either at rest or moving in a straight line at constant speed.
- Newton's second law: $\Sigma\vec{\mathbf{F}} = m\vec{\mathbf{a}}$
- Newton's third law: $\vec{\mathbf{F}}_{AB} = \quad \vec{\mathbf{F}}_{BA}$
- Free-body diagrams are essential for problem-solving
- The frictional force depends on the normal force and a constant that depends on the surfaces involved.
- Uniform circular motion depends on the centripetal acceleration
- Newton's law of universal gravity depends on the masses of the objects involved and the square of the distance between them