Class Four: General Physics 3114
Kigali Institute of Science and Technology

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Outline for Today:

1. Introduction to Dynamics: Newton's Laws
2. Some simple examples and free body diagrams
3. Classifying forces
4. Some less simple examples

Last class was about kinematics—describing motion. We describe motion with position, velocity, and acceleration: $x(t)$, $v(t)$, and $a(t)$. Kinematics concerns these three quantities and the relations among them. These relations can be expressed graphically or algebraically.

Today, we start **dynamics**, which seeks to *explain* motion, not just describe it. The first part of today's lecture is on last week's handout, starting with the section title "Introduction to Dynamics: Forces and Newton's Laws." Read that section if you haven't already done so.

Newton's three laws are simple to state, but applying them takes some practice. We start with some simple examples.

Example: A 10 kg object, initially at rest, experiences a force of 100 N for 5 s. How far does it move?

When multiple forces act on a single object, a very useful technique for keeping track of the forces is a **Free Body Diagram** (FBD). This is best illustrated by an example. You sit in a chair and the earth exerts a gravitational force of 400 N on you. (a) Draw a free body diagram for this situation. (b) What force does the chair exert on you? Why? (c) What forces do you exert on the chair? Why?

Note: Forces related by the third law always act on different objects. Forces related by the second law always act on the same object.

Classifying forces: Here are some commonly occurring forces. Note that forces always results from an *interaction* between two objects. One object exerts a force on another.

1. **Gravitational Forces:** Any two objects will exert attractive gravitational forces on each other. This is described in the handout for class 3.
2. **Normal Force.** Force that one object exerts on another to resist compression. Acts perpendicular to the surface. Ex. Floor exerts a normal force on my feet.
3. **Friction Force.** Force between two objects. Acts parallel to surfaces. Acts to prevent one surface from sliding across the other.
   (a) **Static Friction.** Force between two objects when the "stick together." E.g., I push on board but it doesn't move.
   (b) **Kinetic Friction.** Friction between two objects that are moving relative to each other. Ex. I drag a table across the floor and friction exerts a force in the direction opposite to the motion.
4. **Tension.** Force exerted by a rope or a string that resists its extension. Tension can only pull, not push.
5. **Drag:** A type of friction force exerted by a fluid (like water or air) that opposes an object's motion through it.

Here are **some less simple examples** that we will do in class:

1. A 2 kg box hangs from a rope. Draw a FBD for the box. What is the tension in the rope?
2. A 2 kg ball is dropped out of an airplane. After a little while the ball is moving at a constant speed of 110 km/hr. Draw a FBD for the ball. What is the drag force acting on the ball?
3. I push horizontally against a 100 g eraser with a force of 20 N. Draw a FBD for the eraser. What is the friction force acting on the eraser? What is the normal force on the eraser?
4. I throw an eraser straight up. Draw a FBD for the eraser (a) when it is halfway to its highest point, (b) when it is at its highest point, and (c) when it is halfway down from its highest point. Ignore drag.
5. A 50 kg box rests on the back of a truck. The truck and the box accelerate to the right at 2 m/s^2. Draw a FBD for the box. Determine all forces acting on the box. Ignore drag.
6. A 50 kg box is on the floor of an elevator. The elevator and the box accelerate up at 2 m/s^2. Draw a FBD for the box. Determine all forces acting on the box. Ignore drag.
7. A 50 kg box is pushed across the floor with a force of 500 N. The box moves at the constant rate of 1.5 m/s. Draw a FBD for the box. Determine all forces acting on the box. Ignore drag.