Unit 1 B: Dynamics - An Extension

Section 1: Review of Newton's Three Laws (Text 4.1-4.5, pages 125-144)

Inertia: is that property which causes a body to **resist a change in its state of motion**. The amount of inertia that an object has depends upon the amount of mass it has; the greater the mass the greater its inertia. This property is possessed by all bodies.

Newton's First Law of Motion or Newton's Law of Inertia states

When no external, unbalanced forces act on an object, its velocity remains unchanged. In other words, an object at rest tends to stay at rest and an object that is moving will keep on moving in a straight line at a fixed speed unless it is acted upon by some external, unbalanced force.

IE: If $F_{net} = 0$, then the object is at rest or the object is moving at a fixed speed in a straight line.

Forces are Balanced

Objects at rest
($v = 0$ m/s)

$a = 0$ m/s^2

Stay at Rest

Objects in Motion
($v \neq 0$)

$a = 0$ m/s^2

Stay in Motion
(same speed and direction)

A good example of this first law is the basis on which **seat belts** were developed. During an accident you will continue to stay in motion until an external, unbalanced force acts upon you. In the best case scenario, the seat belt will be that external, unbalanced force and hopefully it will reduce the seriousness of the accident for you. At worst, the external, unbalanced force is a telephone pole or windshield, in which case you will incur injuries.

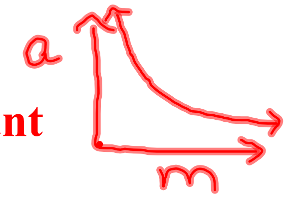
There are many more applications of Newton's first law of motion.

- blood rushes from your head to your feet when riding on a descending elevator which suddenly stops.
- the head of a hammer can be tightened onto the wooden handle by banging the bottom of the handle against a hard surface.
- to dislodge ketchup from the bottom of a ketchup bottle, the bottle is often turned upside down, thrust downward at a high speed and then abruptly halted.
- headrests are placed in cars to prevent whiplash injuries during rear-end collisions.
- while riding a skateboard (or wagon or bicycle), you fly forward off the board when hitting a curb, a rock or another object which abruptly halts the motion of the skateboard.

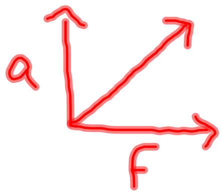
Newton's Second Law of Motion or Newton's Law of Acceleration states:

If an unbalanced force acts on an object, the object accelerates in the direction of the force. The acceleration varies directly with the unbalanced force and inversely with the mass of the object.

$a \ \alpha \ \frac{1}{m}$ if the force remains constant



$a \ \alpha \ F$ if the mass remains constant



These proportions can be combined into one statement:

$F_{Net} = ma$ **where:**

m is the mass of the object in kg
a is the acceleration of the object in m/s^2
F is the net force on the object in kgm/s^2 or Newtons (N)

One newton is the force, that when applied to a mass of 1 kg, produces an acceleration of 1 m/s^2.

$$1 \text{ N} = 1 \text{ kgm/s}^2$$

Newton's Third Law

- often called Newton's Law of Action and Reaction.
- It states that for each action there is an equal but opposite reaction.
- In other words, **whenever one object exerts a force on a second object, the second object exerts an equal but opposite force on the first object**.
- One force is called the **action force** and the other force is called the **reaction force**.
- It does not matter which force is called action and which force is called reaction. What is important is **that neither force exists without the other.**

Mathematically: $F_{AB} = - F_{BA}$

- **A recipe for treating action-reaction forces:**

  Identify the interacting objects A and B

  If the **action is A on B**, then the **reaction is B on A.**

In every interaction, **the forces always occur in pairs**.

- You interact with the floor when you walk on it. You push backward on the floor and the floor simultaneously pushes forward on you.
- The tires of a car interact with the road to produce the car's motion. The tires push back against the road and the road simultaneously pushes forward on the tires.
- When swimming, you interact with the water. You push backward on the water and the water pushes you forward.
- Notice that the interactions in these examples depend on friction. For example a person trying to walk on ice, where the friction is minimal, may not be able to exert an action force against the ice.
- **Without the action force, there cannot be a reaction force, and thus there is no resulting forward motion. It is these reaction forces, those acting in the direction of our resulting accelerations, that account for our motion in these cases.**

Free Body Diagrams (FBD)

- Objects are acted upon by a number of forces simultaneously.
- If we want to analyze these cases, we have to find the **net, resultant or unbalanced force (symbol F_{net}).**
- To do this, we must draw a **free body force diagram** that shows all the forces that are acting on a body.
- Then we can find the net force by adding all the forces acting on the object. The **net force** may be found algebraically or by a vector diagram.

$$F_{Net} = \Sigma F$$
$$= F_1 + F_2 + F_3 + \dots$$

$$F_{net} = ma$$

To draw a free body force diagram:

1. Draw a diagram of the object isolated from it surroundings. This can be simplified by drawing a box to represent the object.

2. Locate, with a point, the approximate center of mass of the object.

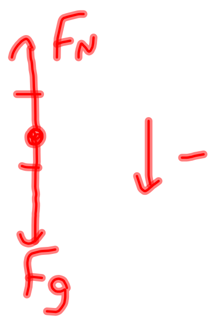
3. From the point, draw a force vector to represent each force acting on the object.

4. **Do not include forces that the object exerts on the other objects.**

Examples

use $g = 9.8 m/s^2$

1. A person of mass 55kg is sitting on a box. What is the normal force acting on the person?



~~$\vec{F}_{net} = \vec{F}_N + \vec{F}_g$~~

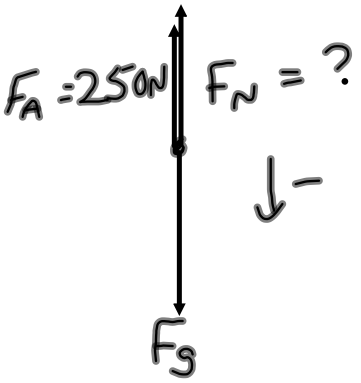
$F_{net} = F_N - F_g$

$0 = F_N - mg$

$0 = F_N - (55kg)(9.8m/s^2)$

$\underline{540N = F_N}$

2. A friend is now trying to lift the person off the box by exerting a force of 250N. Find the normal force.



$F_{Net} = F_N + F_A - F_g$

$0 = F_N + 250N - (55kg)(9.8\frac{m}{s^2})$

$289N = F_N$

$\underline{290N = F_N}$

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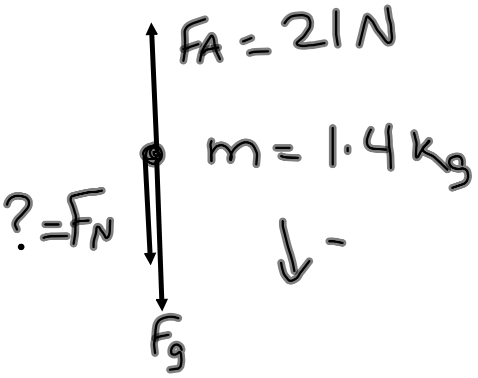
FBD for light

Impt ↓



$F_{Net} = F_A - F_g + F_N$

$0 = 21N - (1.4kg)(9.8\frac{m}{s^2}) + F_N$

$\underline{-7.3N} = F_N$

page 187-188, questions # 32-38

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