Chapter N1: Newton's Laws

N1.1: The Newtonian Synthesis

This is a nice historical summary.

N1.2: Newton's First Law

For an isolated system, $\vec{v_{\text{CM}}}$ is constant. This is equivalent to the principle of conservation of momentum.

N1.3: Newton's Third Law

An interaction between two objects A and B exerts forces on each other that are opposite but equal in magnitude: $\vec{F_A} = -\vec{F_B}$.

N1.4: Newton's Second law

$$\vec{F}_{\text{net}} = m\vec{a} \tag{1}$$

and, for a system of objects

$$\vec{F}_{\text{net,ext}} = m\vec{a}_{\text{CM}} \tag{2}$$

Example: A 150g baseball is thrown at 30 m/s. The act of throwing takes around 0.2 seconds. What is the average force exerted on the ball?

N1.5: Classification of Forces

- Normal force $\vec{F_{\text{N}}}$: The part of the contact force acting perpendicular to an interface between solids
- Static friction $\vec{F_{\text{SF}}}$: contact force that prevents surface from moving relative to each other. "Sticking force."
- Kinetic friction: $\vec{F_{\text{KF}}}$: contact force that oppose motion of surfaces relative to each other.
- Drag forces $\vec{F_{\text{D}}}$: oppose motion of object relative to a fluid
- Lift forces $\vec{F_{\text{L}}}$: perpendicular to object's motion relative to a fluid
- Thrust forces $\vec{F_{\text{Th}}}$: exerted when propeller, jet engine, etc. forces fluid to move.

N1.6: Free-Body Diagrams

Learning to make accurate free-body diagrams is essential for applying Newton's laws. Page 13 contains helpful advice, some of which is excerpted below:

1. Start by imagining the object in its context. Think about things that might interact with the object.
2. Draw a sketch of the object alone. Free-body diagrams apply to a *single* object.
3. Draw an arrow for each force acting directly on the object. Label each arrow.
4. All arrows should correspond to a force. Remember, that a force always arises as the result of an interaction between two objects.

Examples: Draw a free-body diagram for the following situations:

1. A person sitting on a chair.
2. A box sliding down an inclined plane.

Practice:

1. A 1500 kg car accelerates from 0 to 30 m/s in 10 seconds. What is the average force exerted on the car during this time interval?

2. An $80,000$ kg airplane cruises at $10,000$ feet at a constant speed of 500 m/s.

   (a) Draw a free-body diagram for the plane.

   (b) What is the force due to gravity acting on the plane (magnitude and direction)?

   (c) What is the lift force acting on the plane (magnitude and direction)?

3. A 50 kg box of tofu is suspended from a rope.

   (a) Draw a free body diagram for the box.

   (b) What is the tension in the rope?

4. I give a book on a table a shove. It slides for a while and then stops. Draw the free-body diagram for the book while it's sliding after I've shoved it.

5. I push a book against the wall, pinning it so it does not fall. Draw a free-body diagram for the book.

6. A rock on the end of a string is whirled in a vertical circle. Draw the free-body diagram for the rock when it is at the top of the circle.

7. A 50 kg skydiver jumps out of an airplane and after accelerating for a while reaches a constant velocity of 120 m/s.

   (a) Draw a free-body diagram for the skydiver once she's reached 120 m/s.

   (b) What is the net force acting on the skydiver?

   (c) What is the force due to gravity acting on the skydiver (magnitude and direction)?

   (d) What is the force due to friction acting on the skydiver (magnitude and direction)?

8. I throw a .5 kg ball at 3 m/s against a wall. The ball bounces back to me at essentially the same speed. The ball is in contact with the wall for .05 seconds. What is the average force exerted by the wall on the ball?