Chapter N3: Forces from Motion

N3.1: The Kinematic Chain & N3.6: Graphs of 1D Motion

Velocity is the time derivative of position. And acceleration is the time derivative of velocity:

$$v(t) = \frac{dx(t)}{dt} \text{ and } a(t) = \frac{dv(t)}{dt} . \tag{1}$$

In English, this means that the velocity tells you how fast your position x is changing, and the acceleration tells you how fast your velocity is changing.

You should understand this relationship well enough to be able to make qualitatively correct graphs.

Example: For the following scenario, sketch separate plots of x, v, and a vs. t.

- I was driving fast and then I saw a police car and quickly slowed down.

N3.2: Net Force Diagrams & N3.3: Examples

To make a free body diagram, simply make a diagram of all the forces acting on a single object. The net force diagram is then obtained by rearranging the force arrows so that it's clear how the forces add together.

Examples:

1. A 3kg object hangs from a string.
2. A car accelerates along a straight, smooth road.

N3.5: Third-Law Pairs

- Pairs of forces linked by Newton's third law *always* act on different objects.
- When two forces acting on the *same* object are equal and opposite because the object is at rest, this is a result of the second law, not the third.
- See the discussion of this on p. 46.

Example:

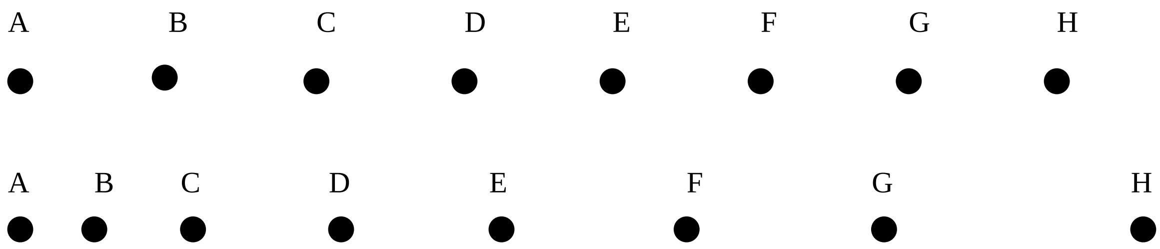

Figure 1:

The figure above shows motion diagrams to two objects. One of the objects is moving at a constant speed left to right. The other is accelerating down an inclined plane.

1. Which motion diagram corresponds to which object?
2. When do the two objects pass each other?
3. When do the two objects have the same speed?
4. Sketch x vs. t graphs for each object.
5. Sketch v vs. t graphs for each object.
6. Sketch a vs. t graphs for each object.

Practice:

Free Body Diagrams: For each of the following scenarios, draw a free-body diagram and a net-force diagram, and answer any additional quantitative questions.

1. A 50 kg box of tofu rests on the back of a pick-up truck. The truck accelerates at 2 m/s^2. What are the magnitudes of all the forces acting on the box? Ignore drag.
2. A 50 kg box of tofu rests on the floor of an elevator. The elevator accelerates upward at 2 m/s^2. What are the magnitudes of all the forces acting on the box? Ignore drag.
3. A 1000 kg car travels at a constant speed of 20 m/s along a road. There is a vertical dip in the road that is well approximated by a circle with a radius of 50 m. What is the net force acting on the car? What is the normal force exerted by the road on the car?

Kinematics: For the following scenarios, sketch separate plots of x, v, and a vs. t.

1. I was walking to class slowly and then I realized I was late so I started running.
2. I drove up slowly to the red light. I waited a while. Then I sped off.
3. I was driving quickly and then stopped suddenly at a red light. I was a little in the intersection so I drove backwards and got out of the intersection. I then waited a while for the light to change. When it changed, I drove off.

Reverse Kinematics:

1. A net force of 100 Newtons is applied to a 25 kg crate of tofu for 3 seconds. Sketch the acceleration, velocity, and position of the box.
2. A skydiver jumps out of an airplane. She falls toward the earth, and eventually reaches a constant velocity. For each of the following, sketch a free body diagram and net-force diagram:
   (a) The instant after she jumps out of the plane.
   (b) She's been falling for a little while, but hasn't reached her terminal velocity yet.
   (c) She's falling at her terminal velocity.
3. Make a sketch of the skydiver's y, v, and a vs. t.