# 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.

**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?
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?
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.

# Chapter N4: Motion from Forces

## N4.1: The Reverse Kinematic Chain

As we saw in the last chapter, velocity is the time derivative of position. And acceleration is the time derivative of velocity:

$$v(t) = \frac{dx(t)}{dt} \text{ and } a(t) = \frac{dv(t)}{dt} \; . \tag{2}$$

This tells us how to go from position $x(t)$ to acceleration $a(t)$. And Netwon's second law ($\vec{F} = m\vec{a}$) lets us figure out what force caused the motion.

This chapter is about "working backwards." Given a force, we can figure out an object's acceleration. We can then take anti-derivatives to go from acceleration to velocity, and velocity to position.

## N4.2: Graphical Derivatives

**Example:**

1. A bug crawls at a constant speed of 3 m/s. Sketch its speed and position as a function of time.

2. A physics textbook falls straight down at a constant acceleration of 10 m/s$^2$. Sketch its acceleration, velocity, and position as a function of time.