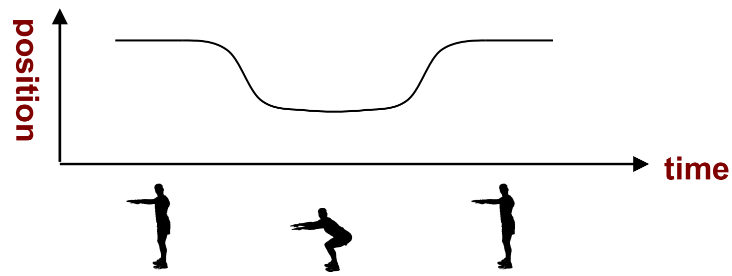
PS 12A Names:

Lab 3: Forces

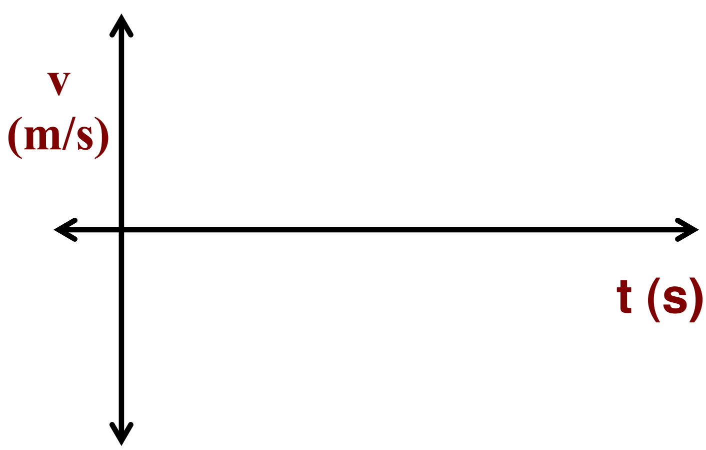
In this lab we will explore the connection between motion and force. If a force F is exerted onto an object with mass m, it leads to the object being accelerated with acceleration a. And vice versa, if we see an object's motion change, forces must have been involved. This is governed by Newton's second law: $F = m \cdot a$. In this lab we will explore this concept by measuring forces that occur as we move objects, and apply it to build a device that allows us to measure our position solely based on measuring acceleration. Such a device is called an "inertial navigation system".

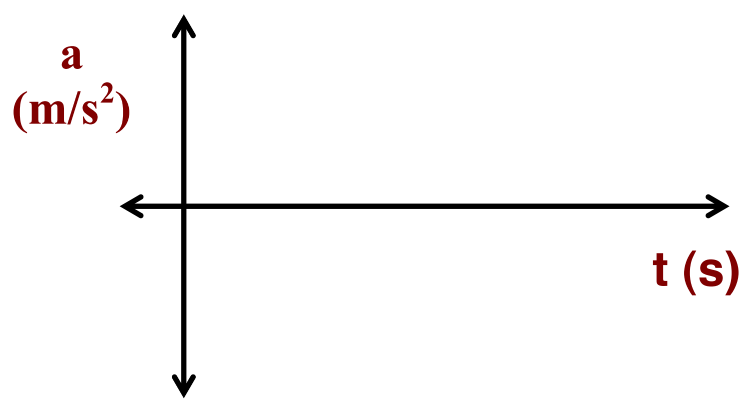
Warm Up: Deep Knee Bends

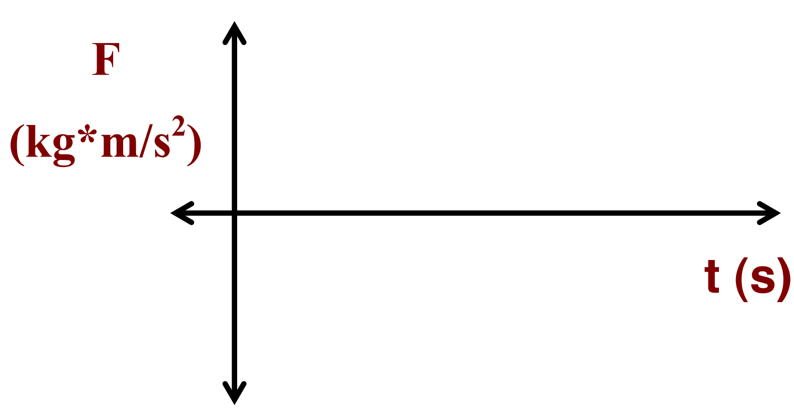


Imagine you stand on a scale, lower your body by bending your knees, and go up again. In the graph shown, the body position y (height) is plotted versus the time t. Sketch the graph you expect for the velocity v=dx/dt, and the acceleration a=dv/dt of your body.
Sketch a graph for the force that the scale would measure vs. time.

Sketch those here:







Part I: Collecting Force Data

Have the person on the plate stand still. Have another member of your group click the Collect button in Logger Pro. The force plate will then collect data for 10 seconds; you'll see the trace appear on the graph. Under the file menu export the data as a .csv file.

The force plates are pretty sturdy, but they can be permanently damaged if you apply very large forces to them (greater than 5000 N). In ordinary standing or jumping, the forces involved are quite a bit less than this, but if you intentionally stomp as hard as you can on it, or jump and land with your knees locked, you can exceed 5000 N and break the force plate.

1. Import the data to MATLAB
2. Start a new script to do 3, 4, and 5
3. Trim the data appropriately
4. Create a Force vs. Time graph
5. Also create Acceleration, Velocity, and Displacement vs. Time graphs.
   (Hint: `doc cumtrapz`, `doc subplot`)

.

Q1. Have one group member stand on the force plate. What physical quantity does the scale measure? Calculate the mass of this person?

Q2. Attach a copy of all of your labeled graphs to the end of the lab report.

Q3. Explain the features of the graph and how they relate to the motion and position of the person at certain points:

a. When the net force is equal to zero, max, min, and the axis crossing

b. Where is the person's velocity greatest in magnitude during the crouch? How do you know?

c. Why does the trace of the force graph go both up and down? Is the reading at the end the same as at the beginning? Should it be?

Part II: Tracking Motion During an Elevator Ride

In this part of the lab we will use a force sensor as an inertial navigation tool. By measuring the forces applied to the sensor we should be able to track its motion during an elevator ride. Use the cart set-up provided to collect the data. In the elevator make a few stops on the way up and a couple on the way down. Take note of the floors you stop at.

Q4. What forces do you expect as you stand in the elevator while it is

a. Standing still

b. Moving up/down with constant velocity

c. Accelerating upward or downwards

Q5. Create a vs. t, v vs. t, and y vs. t graphs from your data of the weight hanging from the force sensor. Attach all of the labeled graphs at the end of the lab report.

Q6. We have been able to track the motion (in this case vertical = altitude) with our force sensor. Use your data to

a. Estimate the height of the Science's eighth floor.

b. Determine maximum speed of the elevator.

c. How does the acceleration of the elevator compare on take off to when it stops?

Q7. How could you extend your set-up to measure acceleration in all three dimensions? What else would you need to have a real navigation sensor?

Challenge: Can you experimentally estimate the mass of your arms using the force plate? Devise a method and then try it out. What was your result?