2 Physics Club Handout: Newton's Laws

For all these problems, assume acceleration due to gravity is 9.81 m/s^2.

Beginner problems:

1. A 50 kg human in freefall experiences a force from air resistance equal to $\vec{F}_{air} = -\vec{v}^2 * 0.3141 \frac{\text{kg}}{\text{m}}$, where $\vec{v}$ is the person's instantaneous velocity. Find the human's terminal velocity.

2. A hawk flies in a horizontal circle of radius 12 m at a constant velocity of 4 m/s. Find its centripital acceleration under these conditions. The hawk then increases its speed at a rate of 1.2 m/s^2; find its new acceleration (and the direction of its acceleration).

3. A 40.0-kg child swings in a swing supported by two chains, each 3.00 m long. The tension in each chain at the lowest point is 350 N. Find the child's speed at the lowest point and the maximum height to which the child rises.

Intermediate problems:

4. An object moving through a fluid (at sufficiently high velocity such that viscous forces are insignificant) experiences a retarding force of $\vec{F}_{drag} = -\frac{1}{2}\vec{v}^2 * C$, where $\vec{v}$ is the object's instantaneous velocity, and C is some constant based on the fluid's density and the object's shape.

   Given that an object of mass m is dropped in air at time $t = 0$, find the velocity of the object at any given time in terms of m, t, and C.

5. An amusement park ride is set up as a giant swing that starts at an angle of 80° to the vertical, and allows the swing to fall freely. For legal reasons, the maximum g-force a rider can experience is $5g$'s (where $g = 9.81$ m/s^2). Assuming no air resistance, what is the largest they can make the swing and still avoid litigation?

6. A plumb bob (a weight hanging from a string) usually does not hang perfectly vertically (i.e. along a line directed towards the center of the earth). By how much does a plumb bob deviate from vertical here in Palo Alto (latitude of 37.4° N), assuming the earth is spherical and has radius 6380 km?

Advanced problems:

7. An object moving througha a fluid experiences a force $\vec{F}_{drag} = -(ar\vec{v} + br^2\vec{v}^2)$ exerted on a sphere of radius r moving through a fluid at speed v, where a and b are constants based on the shape of the object and the surrounding atmosphere. For spherical objects in air at sea level, $a = 3.10 \times 10^{-4}\,\text{Pa} \cdot \text{s}$ and $b = 0.870$ g/L. Find the velocity of a water droplet of 100 µm freefalling at time t, where t is the time elapsed since it was released from rest.

8. A 1 kg block is sitting on a table – the coefficient of static friction between the toaster and the table is 0.4. A string is attached to the block. You pull on the string to make the block move; at what angle should you pull the string to minimize the force necessary to move the block, and what is the force?

9. A time-dependant force $\vec{F} = (8.00\,\hat{i} - 4.00\,t\,\hat{j})\,\text{N}$ (where t is in seconds) is exerted on a 2 kg object initially at rest. At what time will it be moving at a speed of 15 m/s? What is the total displacement and distance of the object at this time?