Physics 336
HW2

1. An object of mass m is released from rest a distance y_0 above the floor. It falls with quadratic air drag, $D = -\frac{1}{2}\rho A C v^2$.

   (a) Assume that the object has mass of 4.5 g, and its shaped is a truncted cone (drag coefficient 1.0) of larger diameter 12 cm. Construct an Euler's-method code that will find the time it takes the object to fall to the floor. Let $y_0 = 2.00$ m and $\rho = 1.01$ kg/m^3.

   (b) Assuming uncertainties of 0.1 g for the mass, 0.1 for the drag coefficient, 1 cm for the diameter, 0.05 m for y_0 and 0.02 kg/m^3 for the air density, extend your model from (a) to calculate an uncertainty in the fall time by repeating the calculations a few thousand times.

   (c) Assess the relative affects of the different uncertainties in (b).

2. A small dense mass is attached to a light string (which is then attached to a fixed point) to form a pendulum. The mass is pulled to the side to an initial angle θ_0 and released from rest.

   (a) Neglect air drag and show that the angular acceleration is given by $\alpha = -\frac{g}{R}\sin\theta$.

   (b) Construct an Euler's method simulation that will determine the period of this pendulum (with its uncertainty), without making the small-angle approximation. Compare your result with the prediction using the small-angle approximation. Let $R = 85.0 \pm 0.3$ cm and $\theta_0 = 90 \pm 1°$.

   (c) Augment your model to include air drag. Assume the mass is a sphere of radius $r = 2.05 \pm 0.05$ cm with $m = 34.7 \pm 0.2$ g.

3. A ball is rolled from rest down a circular ramp of radius $R = 27.5 \pm 0.5$ cm, beginning at rest at an angle of $45 \pm 1°$ above the bottom. Construct a simulation that will calculate the time it takes for the ball to reach the bottom of the ramp.

4. Consider a single battery that is used to charge two capacitors, as shown.
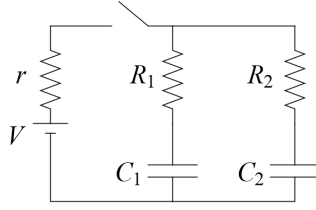
The voltage on one of the capacitors can be related to the current in that branch by differentiating the capacitor charge,

$$Q = CV_C \implies I = \frac{dQ}{dt} = \frac{d}{dt}(CV_C) = C\frac{dV_C}{dt} \equiv C\dot{V}_C$$

(a) Use this relationship, and Kirchoff's laws to show that the voltages on the two capacitors increases as

$$\dot{V}_{C1} = \frac{VR_2 - (r + R_2)V_{C1} + rV_{C2}}{[r(R_1 + R_2) + R_1 R_2]C_1}$$

$$\dot{V}_{C2} = \frac{VR_1 - (r + R_1)V_{C2} + rV_{C1}}{[r(R_1 + R_2) + R_1 R_2]C_2}$$

(b) Construct an Euler's method simulation to plot the capacitor voltages V_{C1} and V_{C2} as functions of time. Let $r = 1.8$ kΩ, $R_1 = 12$ kΩ, $R_2 = 12$ kΩ, and $C_1 = 100$ μF, $C_2 = 400$ μF, with $V = 10.0$ V. Treat uncertainty as negligible.

(c) Let each of the resistors have an uncertainty of 1%, and each capacitor have an uncertainty of 5%. Predict the voltage on each capacitor at $t = 5.0 \pm 0.2$ s.