# Question 1

(a):

$$m\frac{dv}{dt} = -mg + c_1 v$$

If $v$ is positive, (moving up), the drag term $c_1 v$ would be positive and thus accelerating, this cannot be a drag force. If $v$ is negative(moving down), the drag term $c_1 v$ would also be negative and again, be causing an acceleration, and not a drag, (a) represents neither situation.
(b):

$$m\frac{dv}{dt} = -mg - c_1 v$$

If $v$ is positive, the drag term would be negative, thus it would be resisting the direction of motion, and thus be a drag force. If $v$ is negative, the drag term would be positive, thus also resisting the direction of motion. (b) Represents a ball that could be traveling up or down.
(c):

$$m\frac{dv}{dt} = -mg + c_2 v^2$$

No matter if the ball is moving up or down, the drag term is positive. The only time this can represent a drag force is if the ball is moving down, and the positive value would be resisting the motion. Down only.
(d):

$$m\frac{dv}{dt} = -mg - c_2 v^2$$

No matter if the ball is moving up or down, the drag term is negative. The only time this can represent a drag force is if the ball is moving up, and the negative value would be resisting the motion. Up only.

# Question 2

(a): The terminal velocity of an object occurs when the sum of the forces from gravity and drag = 0:

$$0 = mg - c_2 v^2$$
$$mg = c_2 v^2$$

Solving for $v$ gives:

$$\frac{mg}{c_2} = v^2$$
$$v_{term} = \sqrt{\frac{mg}{c_2}}$$

(b): Terminal velocity for an object subject to both drag forces is a bit more complicated. The same holds true however, that terminal velocity occurs when the sum of the gravity force and drag forces equals 0:

$$0 = mg - c_1 v - c_2 v^2 qw$$

Defining a few terms to make this cleaner:

$$k_1 = \frac{c_1}{m},\ k_2 = \frac{c_2}{m}$$
$$k_2 v^2 + k_1 v - g = 0$$

Quadratic:

$$a = k_2,\ b = k_1,\ c = g$$
$$v_{term} = \frac{-k_1 \pm \sqrt{(k_1)^2 + 4k_2 g}}{2k_2}$$

# Question 3

$$\left|\frac{c_2v^2}{c_1v}\right| = \frac{0.22v\,|v|\,D^2}{(1.55*10^{-4})vD} = (1.4*10^3)\,|v|\,D$$

Ball: $D = 10cm = 0.1m$, $m = 200g = 0.2kg$

(a): I will assume that the quadratic term dominates over the linear term when the ratio is 20 or higher. Solving for v:

$$20 = (1.4*10^3)\,|v|\,D$$
$$|v| = \frac{20}{(1.4*10^3)D} \approx 0.14\frac{m}{s}$$

The Quadratic term dominates at velocities above $0.14\frac{m}{s}$.

I will assume the linear term dominates when the inverse ratio is 20 or higher:

$$\frac{1}{20} = (1.4*10^3)|v|D$$
$$|v| = \frac{1}{20(1.4*10^3)D} \approx 3.6*10^{-4}\frac{m}{s}$$

The linear term dominates at speeds below $3.6*10^{-4}\frac{m}{s}$.

(b): The terminal speed occurs when the sum of the forces acting on the ball equals 0:

$$\sum F = 0 = -mg - c_1v + c_2v^2$$
$$v_{term} = \frac{c_1 \pm \sqrt{(c_1)^2 + 4mgc_2}}{2c_2}$$
$$v_{term} = \frac{1.55*10^{-4}*.1 \pm \sqrt{(1.55*10^{-4}*.1)^2 + 4*.2*9.8*.22*.1^2}}{2*.22*.1^2}$$
$$v_{term} = \frac{1.55*10^{-5} \pm \sqrt{2.4025*10^{-10} + .017248}}{.0044}$$
$$v_{term} \approx \frac{1.55*10^{-5} \pm \sqrt{.017248}}{.0044}$$
$$v_{term} \approx \frac{1.55*10^{-5} \pm .131332}{.0044}$$
$$v_{term} \approx \frac{.13135}{.0044} = 29.9\frac{m}{s}(plus)$$
$$v_{term} \approx \frac{-.13132}{.0044} = -29.8\frac{m}{s}(minus)$$

The terminal velocity for the ball is approximately $29.9\frac{m}{s}$.

(c): For the ball, the terminal velocity is in the range of speeds dominated by the quadratic drag term. If I had to choose one to keep, the quadratic drag would be more accurate, as the linear drag is negligible.

# Question 4

$$\left|\frac{c_2 v^2}{c_1 v}\right| = \frac{0.22 v\,|v|\,D^2}{(1.55 * 10^{-4}) v D} = (1.4 * 10^3)\,|v|\,D$$

Oil-Drop: $D = 10^{-4} cm = 10^{-6} m$, $m = 10^{-12} g = 10^{-15} kg$

(a): Again assuming the quadratic term dominates when the ratio is 20 or higher. Solving for v:

$$20 = (1.4 * 10^3)\,|v|\,D$$
$$|v| = \frac{20}{(1.4 * 10^3) D} \approx 1.4 * 10^3 \frac{m}{s}$$

The Quadratic term dominates at velocities above $1.4 * 10^3 \frac{m}{s}$.

I will assume the linear term dominates when the inverse ratio is 20 or higher:

$$\frac{1}{20} = (1.4 * 10^3)|v|D$$
$$|v| = \frac{1}{20(1.4 * 10^3) D} \approx 3.6 * 10^{-4} \frac{m}{s}$$

The linear term dominates at speeds below $3.6\frac{m}{s}$.

(b): The terminal speed occurs when the sum of the forces acting on the deop equals 0:

$$\sum F = 0 = -mg - c_1 v + c_2 v^2$$

$$v_{term} = \frac{c_1 \pm \sqrt{(c_1)^2 + 4mgc_2}}{2c_2}$$

$$v_{term} = \frac{1.55 * 10^{-4} * .1 \pm \sqrt{(1.55 * 10^{-4} * 10^{-6})^2 + 4 * .2 * 9.8 * .22 * .1^2}}{2 * .22 * .1^2}$$

$$v_{term} = \frac{1.55 * 10^{-5} \pm \sqrt{2.4025 * 10^{-10} + .017248}}{.0044}$$

$$v_{term} \approx \frac{1.55 * 10^{-5} \pm \sqrt{.017248}}{.0044}$$

$$v_{term} \approx \frac{1.55 * 10^{-5} \pm .131332}{.0044}$$

$$v_{term} \approx \frac{.13135}{.0044} = 29.9\frac{m}{s}(plus)$$

$$v_{term} \approx \frac{-.13132}{.0044} = -29.8\frac{m}{s}(minus)$$

The terminal velocity for the ball is approximately $29.9\frac{m}{s}$.