PHYS 2210 Fall 2010 Homework Set 3

Due in class on **Sept 9, 2010**
Show your work!

For problem 1, use the fact that the force of air resistance on a spherical object of diameter D can be approximated using coefficients $c_1 = (1.55{\times}10^{-4})D$ and $c_2 = 0.22D^2$ (all numerical values are in SI units). The ratio of the quadratic and the linear terms of the force of air resistance can therefore be expressed as:

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

1. Consider a softball with diameter 10 cm and mass 200 g.
   (a) Using the above ratio, for what range of speeds will (i) the linear term of air resistance dominate over the quadratic term? (ii) the quadratic term dominate over the linear term?
   (b) Calculate the terminal speed of the softball taking into account both the linear and quadratic terms. Show all work.
   (c) Reflect on your results in parts a and b above. If it were desired to approximate the effect of air resistance on a falling softball with either the linear term or the quadratic term (not both), which term would you keep? Explain your reasoning.

2. The Bugatti Veyron Super Sport, the world's fastest and most expensive production car, has a maximum speed of 268 miles per hour[1]. The engine provides maximum forward force of 12,350 N on the 1900 kg car. Quadratic air resistance dominates, with a drag coefficient of .86 kg/m. On a test track, the car exits a turn with a speed of 150 mph. If there is 5 km of straight track after the

[1] James May noted on the BBC show "Top Gear" that at this top speed "the tires will only last for about 15 minutes, but it's okay because the fuel runs out in 12 minutes."

turn, can the Bugatti reach a speed of 265 mph before it runs out of straight road? (Watch your units on this one!)

3. In Taylor's book, he simplifies Eqn 2.42 for the range of a projectile by assuming that $R^2 \simeq R_{vac}^2$. Show that if you use the quadratic equation to solve for R in Eqn 2.42, and make the appropriate Taylor series expansion that you obtain the expression given in Equation 2.44.

4. Boas, 1.13.9, parts (a) and (b) Find the first few terms of the Maclaurin series for the following function. Also find the general term and write the series in summation form. $\frac{1+x}{1-x}$

5. Many relevant integrals in math and physics cannot be integrated in closed form. A good example of this is the normal function which is so important in probability and statistics. However a Taylor series can be used the expand the integrand, and the expanded terms can be integrated. Find the first 3 terms of the integral of the normal distribution, $\int_0^x e^{-x^2/2}$.

6. Recall from special relativity that for a particle moving at a relativistic speed, v, the energy E=γmc^2, where $\gamma = \frac{1}{\sqrt{(1 - \frac{v^2}{c^2})}}$. Find the first two terms of the series expansion of the energy. What is the second term? Does this make sense for a particle with v<<c?