Homework Set #5

1. Calculate the magnitude of the centrifugal acceleration (i.e. $\omega^2 r$), due to the earth's rotation, on a particle on the surface of the earth at the Equator. Compare this result with the gravitational acceleration. Also compute the centrifugal acceleration due to the motion of the earth about the sun.

2. (F&C 5.17 and 5.14) If a projectile is fired due east with an initial speed of V_0 with an inclination angle α to the horizontal from a point in the Northern Hemisphere of latitude λ, show that the lateral deflection of the projectile when it strikes the earth is

$$d = -\frac{4\omega V_0^3}{g^2} \sin\lambda \sin^2\alpha \cos\alpha$$

   Using this result, calculate the horizontal deflection due to the coriolis force on a baseball driven due east in Yankee stadium at an elevation angle of 15° with an intial speed of 45 m/s (neglect drag). New York is at approximately 40° North latitude.

3. (F&C 5.17) A bullet is fired straight up with an initial speed V_0. Assuming that g is constant and ignoring air resistance, show that the bullet will hit the ground west of the initial point of upward motion by an amount $4\omega V_0^3 \cos\lambda/3g^2$, where λ is the latitude and ω is earth's angular velocity.

4. (F&C 5.1) A 120 lb person stands on a bathroom scale while riding in an elevator. If the elevator has an (a) upward and (b) downward acceleration of $g/4$, what is the weight indicated on the scale in each case?

5. (F&C 5.8) A cockroach crawls with constant speed in a circular path of radius b on a phonograph turntable rotating with constant angular speed ω. The circular path is concentric with the center of the turntable. If the mass of the insect is m and the coefficient of static friction with the surface of the turntable is μ_s, how fast may the bug crawl before it begins to slip if it goes (a) in the direction of rotation and (b) opposite to the direction of rotation?

6. (F&C 5.3 and 5.4) A plumb line is held steady while being carried along in a moving train. If the mass of the plumb bob is m, find the tension in the cord and the deflection from vertical if the train is accelerating forward with constant acceleration $g/10$. (Ignore the effects of the earth's rotation.) If we now allow the plumb line to oscillate as a simple pendulum, find the frequency for small oscillations.

7. F&C 5.15) Show that the thrid derivative with respect to time of the position vector(i.e. the jerk) of a particle moving in a rotating coordinate system is given by

$$\dot{\mathbf{a}} = \dot{\mathbf{a}}' + 3\dot{\omega} \times \mathbf{v}' + 3\omega \times \mathbf{a}' + \ddot{\omega} \times \mathbf{r}' + 3\omega \times (\omega \times \mathbf{v}') + \dot{\omega} \times (\omega \times \mathbf{r}') + 2\omega \times (\dot{\omega} \times \mathbf{r}') - \omega^{\mathbf{2}}(\omega \times \mathbf{r}')$$