**PHY 201 Homework 3**
**Due Friday, Sept. 20 at SE 316 at noon.**

You will need graph paper for problems 4, 7, and 9.

1. According to your lecture notes, what did Galileo say about gravity? Can you perform an experiment which seems to contradict his assertion? Explain briefly.

2. What picture of gravity have we been using so far in this class, Newton's or Einstein's? Explain why.

3. Vector $\mathbf{A}$, expressed in polar coordinates, has length and direction $(r, \theta) = (a, \alpha)$. Vector $\mathbf{B}$, expressed in polar coordinates, has length and direction $(r, \theta) = (b, \pi/2)$. Express $\mathbf{A}$ and $\mathbf{B}$ in Cartesian coordinates (using $\hat{\mathbf{x}}$ and $\hat{\mathbf{y}}$). Calculate their dot product $\mathbf{A} \cdot \mathbf{B}$. For what values of $\alpha$ is $\mathbf{A} \cdot \mathbf{B}$ equal to zero?

4. Given the vectors $\mathbf{A} = 3\hat{\mathbf{x}} + 4\hat{\mathbf{y}}$ and $\mathbf{B} = 2\hat{\mathbf{x}} - 2\hat{\mathbf{y}}$, find $\mathbf{C} = \mathbf{A} + \mathbf{B}$ and $\mathbf{D} = \mathbf{A} - \mathbf{B}$ graphically (using graph paper) and analytically.

5. I use a slingshot to shoot a stone off a cliff. The coordinates of the stone are:

$$x(t) = (12\,\mathrm{m/s})\,t \quad \text{and} \quad y(t) = (4\,\mathrm{m/s})\,t - \left(4.9\,\mathrm{m/s^2}\right) t^2$$

   (a) Write down the position vector $\mathbf{R}(t)$ in terms of $\hat{x}$ and $\hat{y}$.
   (b) Likewise, find the velocity vector $\mathbf{v}(t)$.
   (c) Find the acceleration vector $\mathbf{a}(t)$.
   (d) What is the velocity vector at $t = 3$ seconds?

6. Just North of Heidelberg is a hill called the Heiligenberg. On top of this hill is a well that was dug by the Celts over 2000 years ago. Why might one want to dig a well on the top of a hill? I drop a stone into the well and hear a splashing sound $t_s$ seconds later. If the speed of sound is $c_s$, express the depth of the well as a function of $t_s$, $c_s$, and the acceleration of gravity $g$. You can assume that the acceleration of the stone is due entirely to gravity. What is the depth of the well if $t_s = 3.45\,\mathrm{s}$, $c_s = 336\,\mathrm{m/s}$, and $g = 9.807\,\mathrm{m/s^2}$?

7. At kickoff time, I kick the football and it flies (hopefully) toward the end zone. The initial speed of the football is $v_0$ and the initial angle of the trajectory is $\theta$ above the field, $0 < \theta < \pi/2$. Express the position $\mathbf{X}(t)$ of the football as a function of time $t$. Draw a sketch to show how your coordinates are defined. Let $R$ be the horizontal distance the football travels before it hits the ground. Find $R$ as a function of $v_0$, $\theta$, and $g$. You can use the identity $2\sin(a)\cos(a) = \sin(2a)$ to simplify your answer. Draw a graph of $R$ versus $\theta$. At what angle $\theta$ is $R$ maximized? If the ball travels 50 m before hitting the ground, what is the smallest possible initial speed of the ball.

8. Calculate the centripetal acceleration at the equator due to earth's rotation about its axis. Calculate the centripetal acceleration of the earth as it orbits around the sun.

9. Rufus likes to fly in a straight line at a velocity of 5 m/s. However, Rufus is tied to a 2 m long rope and must fly in a circle. What is the centripetal acceleration that Rufus feels? Rufus now tries to increase his speed, resulting in a tangential acceleration of $1.2\,\mathrm{m/s^2}$. Find his acceleration *vector*. Draw a nice picture, define a coordinate system and illustrate the direction of this vector.