Physics 221 – Test 3 – Fall 2010

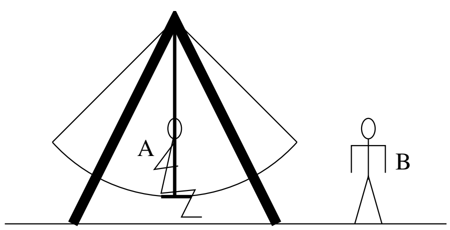
One-page reminder sheet allowed. *Show all work – no credit given if work not shown!* Values of constants: $c = 3 \times 10^8$ m s^{-1}; $\hbar = 1.06 \times 10^{-34}$ J s. Numerical calculations should be evaluated, suggesting that you ought to have a calculator.

1. You (person A) are swinging on a playground swing as shown below.

   (a) From the point of view of your buddy (person B) standing next to the swing, sketch the forces acting on you as well as your acceleration as you pass through the bottom of the swing arc. Ignore general relativity.

   (b) Do the same as above from your point of view on the swing.

   (c) Taking into account general relativity (in particular, the equivalence principle), explain how your acceleration at the bottom of the arc, reckoned from an inertial reference frame, is different from your answer in part (a).

   (d) 

2. For a given total energy, determine whether the momentum of a photon (massless particle) is greater than or less than that of a proton (massive particle) moving at any speed $v < c$.

3. In quantum world B ($\hbar = 10^{-2}$ J s) baseball becomes a very interesting game. When the pitcher throws the ball (mass 0.15 kg), its initial position uncertainty is of order the size of his hand (say, 8 cm).

   (a) Compute the uncertainty in the velocity of the ball (both longitudinal and transverse components) when he throws it.

   (b) Roughly how fast would the pitcher have to pitch the ball to give reasonable assurance that it goes over the home plate (≈ 0.5 m wide)? The pitcher's mound is about 30 m from home plate.
   (CONTINUE ON OTHER SIDE.)

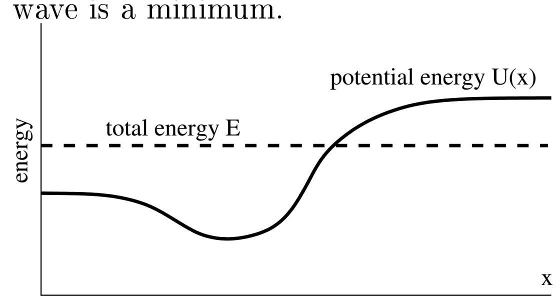
4. Suppose an unknown source of X-rays is impingent on a crystal with crystal plane separation 5×10^{-10} m. A Bragg diffraction peak occurs for a Bragg angle $\theta = 45°$. (There may be other peaks as well.) Compute the possible wavelengths for the X-rays.

5. The potential and total energy for a particle vary as a function of x as shown below. You should re-draw this plot on your test paper

   (a) Sketch a plot of the force acting on the particle as a function of x.

   (b) Indicate any turning points in the plot as well as corresponding regions inaccessible to the particle for the given total energy.

   (c) Indicate at what value of x in the plot the wavelength of the associated matter wave is a minimum.



6. The potential energy of a particle moving in the $x - y$ plane is $U(x, y) = Axy$ where A is a positive constant. This represents the only force acting on the particle.

   (a) Compute the x and y components of the force and sketch a sample of force vectors in the $x - y$ plane sufficient to demonstrate how the force varies with position.

   (b) If the total energy of the particle is zero, sketch the regions in the $x - y$ plane where the particle can go.

   (c) If the particle moves from point $(a, -a)$ to point (a, a), compute the change in its kinetic energy. Hint: Does its total energy change?