# Physics 221 – Final Exam – Fall 2010

One-page reminder sheet allowed. *Show all work – no credit given if work not shown!* Numerical calculations should be evaluated, suggesting that you ought to have a calculator.

1. A wave has the dispersion relation $\omega = Kk^2$ where $\omega$ is the angular frequency and $k$ is the wavenumber. Is the group velocity greater than or less than the phase speed for a given wavenumber? Explain.

2. An image of a candle is projected on a screen by a positive (convex) lens. The distance from the candle to the lens is 0.5 m and the distance from the lens to the screen is 0.3 m. The candle is 0.1 m tall. (You may wish to draw a picture.)

   (a) Compute the focal length of the lens.

   (b) Calculate how tall the image of the candle is on the screen.

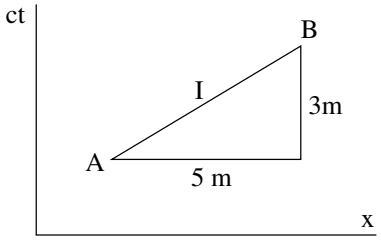
   (c) Is the image of the candle right side up or upside down? Explain.

3. Two events, A, B, in spacetime are located as shown below.

   (a) Is the separation of A and B spacelike or timelike?

   (b) Compute the invariant interval between A and B.

   (c) What velocity would a coordinate system need for A and B to appear simultaneous?




4. You (with mass $m$) are on a rocket sled accelerating along a track up a slope tilted at angle $\theta$ to the horizontal, with acceleration $a$. (Don't forget gravity!)

   (a) Make a sketch of this situation.

   (b) Identify in the sketch all force components parallel to the track acting on you and determine the total force on you in the direction of the track from the point of view of someone standing beside the track.

   (c) Identify all the force components and the total force acting on you as above, but from the point of view of the accelerated reference frame moving with the sled.

5. A mass $M$ is subject to potential energy $U(x) = Kx^4$ where $K$ is a constant.

   (a) Compute the force $F$ on the mass due to this potential energy.

(b) If the total energy of the mass is $E$, find the $x$ positions of all turning points.

(c) For total energy $E$, compute the speed of motion of the mass as a function of $x$.

6. A stationary particle of mass $m$ absorbs a photon of energy $E$, producing a single, moving particle. (Recall that a photon is massless. This is a relativistic problem.)

   (a) Compute the momentum and total energy of the new particle.

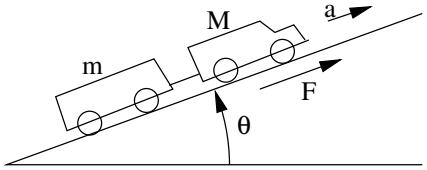
   (b) Compute the mass of the new particle.

   (c) Compute the velocity of the new particle.

7. A two element train consisting of an engine of mass $M$ and a car of mass $m$ is accelerating up a hill of slope angle $\theta$ as shown below. The car moves frictionlessly and the track exerts force $F$ on the engine. Consider only force components parallel to the track.

   (a) Compute the force $F$ needed to produce acceleration $a$. Be sure to include the effects of gravity.

   (b) Compute the force of the engine on the car.




8. You are keeping a cylinder of radius $R$ and mass $M$ from rolling under the influence of gravity down a ramp tilted at an angle $\theta$ by pulling on a rope wrapped around the cylinder as shown. Compute the force $T$ you exert on the cylinder via the rope and the force $F$ that the ramp exerts on the cylinder.