Physics 131 – Final Exam – Fall 2007

One-page reminder sheet allowed. Note that $\hbar = 1.06 \times 10^{-34}$ J s, $c = 3 \times 10^{8}$ m s^{-1}. *Show all work – no credit given if work not shown!*

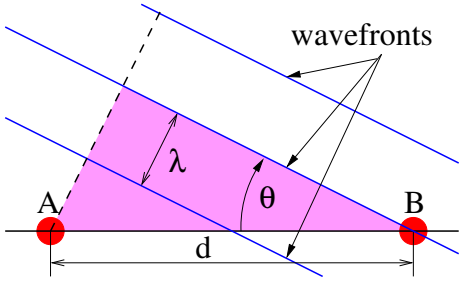
1. Make sketches of one-dimensional dispersion relations $\omega = \omega(k)$ which satisfy the following conditions:

   (a) The group velocity is the same as the phase speed for all $k > 0$.

   (b) The group velocity is greater than the phase speed for all $k > 0$.

   (c) The phase speed is positive and the group velocity is zero for all $k > 0$.

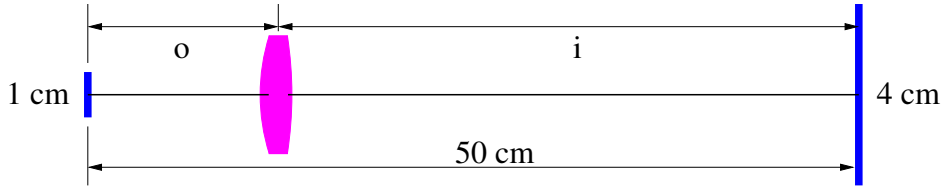
2. A plane wave of wavelength λ impinges on two wave receivers A and B separated by a distance d. For what values of the illustrated angle θ are the received wave signals in phase? Hint: Compute the extra path length for waves hitting B compared to A in terms of θ and d.



3. For an object 1 cm high, you wish to project an image of it 4 cm high and 50 cm distant.

   (a) Where along the line between the object and the image should you place the lens?

   (b) What should the focal length of the lens be?



4. Given the potential energy $U = Ax^2 - By$ of a particle of mass M moving in the $x - y$ plane, where A and B are positive constants:

   (a) Compute the force on the particle.

   (b) Determine the region of the $x - y$ plane classically accessible to the particle if its total energy is E.

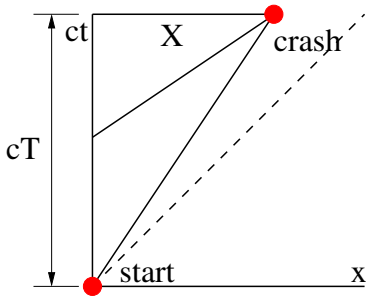
   (c) Determine the work done on the particle in moving from $(0, 0)$ to $(0, a)$.

5. A driver in a very fast car moves to the right, passing the origin in the rest frame of the earth at time $t = 0$. The car crashes at time $t = T = 2 \times 10^{-5}$ s a distance $X = 2cT/3$ to the right of the origin in the earth's frame.

   (a) How fast was the car going in the earth frame?

   (b) How much time elapsed between passing the origin and crashing according to the driver?

   (c) What was the distance from the origin to the crash site according to the driver?



6. The energy levels of a particle in a box are given by $E = 2E_R, 8E_R, 18E_R, ...$ where E_R is a constant.

   (a) What can you infer about the particle?

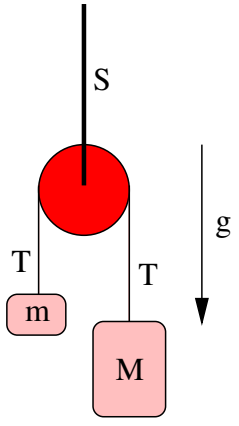
   (b) If the particle has mass M and E_R is known, derive an equation for the size of the box.

7. A string going over a pulley has masses m and $M > m$ attached to each end as shown below. The pulley rotates without friction and has negligible mass and moment of inertia.

   (a) How fast does M accelerate downward (and m upward)?

   (b) Derive an equation for the tension T in the string.

   (c) Derive an equation for the support force S holding up the pulley.



8. A mass M is attached to a wall with a spring of spring constant $3k$, where k is a constant. Compute the oscillation frequency of the mass.