PRELIMINARY EXAMINATION
DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part B, 12 August 2004, 14:00 - 17:00

B1. (a) (4 points) Calculate the expectation value $\langle \frac{r}{a_o} \rangle$ for the groundstate $1s$ ($n = 1$, $\ell = 0$) electron in hydrogen, where the wave function is given by

$$\Psi_{10} = \left(\frac{1}{\pi a_o^3}\right)^{1/2} \exp\left(-\frac{r}{a_o}\right) \quad ,$$

and the Bohr radius $a_o = 0.529$ Å. Show all of your work for full credit.

(b) (2 points) What is the expectation value of L^2 in the eigenstate given in part (a)?

(c) (4 points) What is the expectation value of L^2 for the hydrogen atom eigenstate with wavefunction

$$\Psi = \frac{1}{4}\left(\frac{1}{2\pi a_o^3}\right)^{1/2} (\cos\theta) \left(\frac{r}{a_o}\right) \exp\left(-\frac{r}{2a_o}\right) \quad ?$$

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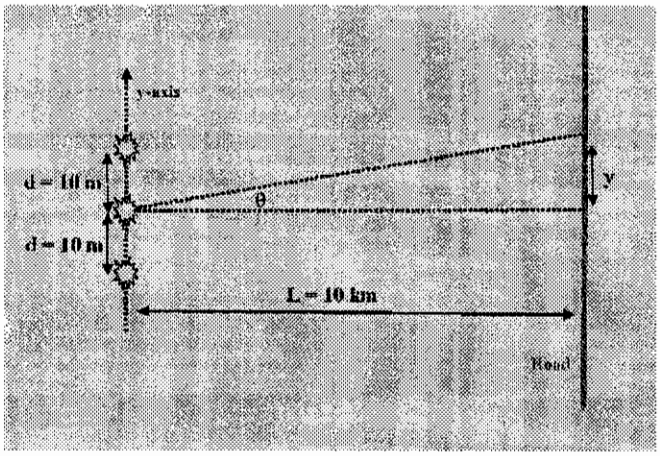
B2. Three identical radio broadcast towers lie along the y-axis and are a distance d = 10 m apart (the middle tower is at y = 0). All three towers broadcast at a frequency of 100 MHz with equal intensities and in phase. There is a road parallel to the y-axis a distance L = 10 km from the radio towers as shown in the figure. An observer walking along the road with a radio tuned to 100 MHz receives an intenstiy I_o at y = 0 (*i.e.* $I(\theta = 0) = I_o$). Use the small angle approximation when answering the questions since L $\gg$ d.

(a) (3 points) If the observer starts at y = 0 and begins walking in the positive y direction, at what distance y (in km) will the intensity of the radio signal be zero due to interference between the three towers (*i.e.* at what distance y does the first maximal destructive interference occur)?

(b) (2 points) The intensity of the radio signal received by the observer on the road at y = 1.5 km may be written as I(y = 1.5 km) = αI_o. What is α?

(c) (2 points) The intensity of the radio signal received by the observer on the road at y = 3.0 km may be written as I(y = 3.0 km) = βI_o. What is β?

(d) (3 points) Sketch the intensity of the radio signal as a function of the distance along the road. In other words, plot I(y)/I_o from y = 0 to y = 4 km.



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B3. A pendulum is constructed by attaching a mass m to an extensionless string of length l. The upper end of the string is then connected to the uppermost point on a vertical disk of radius R ($R < l/\pi$) as shown in the figure.

(a) (2 points) Find the x and y coordinates of the mass m in terms of the angle θ. (Use the coordinate axes shown in the figure).

(b) (3 points) Using θ as the generalized coordinate, find the Lagrangian for this system and hence provide the equation of motion in the form (*i.e.* you will need to provide α, β, and γ, if this general form is the correct one):

$$\alpha\,\ddot{\theta} - \beta\,\dot{\theta}^2 - \gamma\,cos\theta = 0 \quad .$$

(c) (3 points) Let $\epsilon = \theta - \theta_0$ ($\epsilon << \theta_0$). What is the frequency of small oscillations of the mass m about the angle $\theta = \theta_0$?

(d) (2 points) Find the θ_0 for which the angular motion extends equally in either direction (i.e. $\theta_1 = \theta_2$).