Introduction to Modern Physics
PHYS3740
Midterm test 1
Wednesday 11th 2006

Note: the best possible score is 125/100

1) Draw a Space time diagram

A and B are at rest with respect to each other and are separated by a distance d measured in the reference frame where they are at rest. The following sequence of events occurs:

(1) A sends a light signal towards B .

(2) As soon as the signal is received by B , B sends a signal back to A .

(3) A receives the signal from B .

a) *(5 points)* Draw a space time diagram (ct, x) showing these events from the point of view of the reference frame S in which A and B are at rest (choose $x_B > x_A$). Indicate all the relevant ct intervals on your diagram.

b) *(5 points)* Draw a space time diagram from the point of view of a reference frame S' moving at speed $v = \beta c$ in the direction from A to B .

c) *(5 points)* From the point of view of S' , what is the distance d' separating A and B ? How is the relation between d and d' usually referred to?

d) *(5 points)* From the point of view of S' , what is the ct' interval between event (1) and event (3)?

e) *(5 points)* What is the ct' interval between (1) and (2)? and between (2) and (3)? (Hint: using Lorentz transform might be a good idea)

2) Here comes the muon again

A muon μ with mass $m_\mu = 105.5\, MeV/c^2$ has a kinetic energy $K_\mu = 211\, MeV$ measured in the lab reference frame.

a) *(5 points)* What is the total energy E of the muon μ ?

b) *(5 points)* What is the momentum p of the muon μ ?

c) *(5 points)* What is the speed u (in terms of the speed of light) of the muon μ ?

We now consider the same muon μ but this time from the point of view of a reference frame moving in opposite direction a speed $v = 0.8\, c$ with respect to the lab.

d) *(5 points)* What is the total energy E' of the muon μ ?

e) *(5 points)* What is the momentum p' of the muon μ ?

f) *(5 points)* What is the speed u' (in terms of the speed of light) of the muon μ ?

3) Twinkle, Tinkle, little star, how I wonder what you are!

Stars A and B are under study. It is found that the energy spectrum reaches its maximum at a wavelength λ_A that is twice λ_B that of star B. It is established that both stars are at the same distance and star B is four times as bright as A. Both stars are spherical and radiate as black bodies.

a) *(10 points)* What is the stars surface temperature ratio $\frac{T_A}{T_B}$?

b) *(10 points)* What is the two star's radii ratio $\frac{R_A}{R_B}$?

4) Photoelectric effect

When light of wavelength $450\,nm$ is shone one potassium, electrons with a stopping potential of $0.52\,V$ are emitted. If the wavelength of the incident light is changed to $300\,nm$ the stopping potential is $1.90\,V$. Using only these numbers together with the values of the speed of light $c=3\times10^{8}\,m\cdot s^{-1}$ and the electron charge $e=1.6\times10^{-19}\,C$, find

a) *(10 points)* the potassium work function and

b) *(10 points)* a value for Planck's constant

5) Bohr's Hydrogen atom

In Bohr's model of the hydrogen atom, the ionization energy is $E_0=13.6\,eV$ and successive quantum levels have energy $E_n=-\frac{E_0}{n^2}$ where n the first quantum number can take any positive integer value: $n=1,2,3,\cdots$. An hydrogen line is observed with a wavelength of $486\,nm$ ($h=6.62\times10^{-34}\,J\cdot s$).

a) *(10 points)* What is the energy of the photons in that spectral line?

b) *(10 points)* What are the quantum numbers of the states involved in the absorption and emission of that spectral line?

c) *(10 points)* Hydrogen atoms are prepared in state $n=2$. What is the longest wavelength of light that could be used to ionize these atoms?