Midterm Quiz: Modern Physics 301
November 5, 2002

Question 1: 12 points. Question 2: 9 points. Question 3: 9 points. Total 30 points. Individual values follow each question.

1. (a) State the Lorentz transforms. (3)

   (b) A pulse of light leaves the origin of the lab reference frame S at $t = 0$ and travels along the x-axis. At what time does it reach a detector at $x = 1$ m? (You may find that $c = 0.3$ metres per nanosecond is useful.) (2)

   Our usual "moving" inertial reference frame S' is moving along the x-axis with $v = \frac{\sqrt{3}}{2}\, c$. The origins coincide at $t = t' = 0$.

   (c) Calculate γ? (2)

   (d) Use the Lorentz transforms to give x' and t' for the light pulse reaching the detector. (numerical values in metres and nanoseconds) (3)

   (e) Based on these results show that these values of x' and t' are consistent with a constant speed of light in the two reference frames. (Numerical demonstration is fine). (2)

2. Consider a rigid O_2 molecule with mass m and moments of inertia $I_{x'}$ and $I_{y'}$ (the z'-axis is parallel to the bond between the two oxygen atoms).

   (a) Give an expression for the energy of the molecule (translational plus rotational) in terms of $x, y, z, \omega_{x'}$, and $\omega_{y'}$. (ω is the rotational velocity in radians per unit time) (2)

   (b) In the language of the kinetic theory of matter what is the general name for these variables that make up the energy expression? (2)

   (c) According to the equipartition theorem what is the thermal average value of the energy (in eV) for each molecule at $T = 1000$ K. (2)

   (d) Suppose that the average translational kinetic energy of the molecule is 0.13 eV or 2×10^{-20} J and the mass is 5.33×10^{-26} kg. What is the rms speed? (3)

3. (a) What is the energy of a photon with $\lambda = 620$ nm? (2)

   (b) For $T = 4640$ K calculate $hc/(\lambda k_B T)$ and $\exp(-\frac{hc}{\lambda k_B T})$. (3)

   (c) According to Planck's hypothesis what is $\bar{E}$, the thermal average energy for this mode? (consult your assignment or formula 3-28). (4)