

**Midterm Quiz: Modern Physics 201**  
**Feb. 23, 2006**

Textbook and 2-sided formula sheet. Total 40 + 2 bonus points. Individual values follow each question. Usual conventions for frames  $S$  and  $S'$  apply.

1. Consider two train cars. One is at rest in the frame of the station, a frame we will call  $S$ . At time  $t = 0$  lightning strikes both ends of both cars simultaneously, leaving a mark at the ends of both cars (a situation similar to what we described in class, ask me if you have further questions). The car at rest in the station has a length of 10 m. When the moving car is later stopped and inspected, it is found to be 15 m long.
  - (a) What is the name of phenomenon that is causing this discrepancy in length measurements? How fast was the car moving in frame  $S'$ ? (3)
  - (b) Assuming the usual conventions for the synchronization of the frames ( $x = t = x' = t' = 0$  for the one lightning strike) what are the  $x'$  and  $t'$  coordinates for the other lightning strike? Does this agree with the measurement you made of the length of the car once it came to rest? (4)
  - (c) Suppose you are in frame  $S'$  and sitting at the back end of the train car. When do you see the lightning strike the front of the car i.e. when does the light from the flash get to you? Does this happen before or after lightning strikes your position? (3)
2. Suppose that an object is moving at speed  $c$  along the  $y$ -axis. An inertial frame is going by with speed  $0.6c$  along the  $x$ -axis. Without any calculations: what is the speed of the object as measured in  $S'$ ? Write down but don't calculate the expressions for  $V'_x$  and  $V'_y$ . (4)
3. Monochromatic light with  $\lambda = 405$  nm is incident on a photocathode. The work function of the cathode is 0.9 eV. (This is the energy required to liberate electrons from the cathode.) What reverse bias is necessary to cut off the photocurrent? What is the intensity dependence of this value? Highlight Einstein's postulate concerning the photoelectric effect. (6)
4.
  - (a) Give the relativistic definition of momentum and energy in terms of  $\vec{V}$  the velocity of the particle measured in that frame. (2)
  - (b) Calculate  $E$ ,  $p_x$ ,  $p_y$ , and  $p_z$  in "MeV" style units for an electron moving at  $0.95c$  along the  $x$ -axis.  $m_e = 0.511$  MeV/ $c^2$  (2)
  - (c) Numerically show that  $E^2 - p^2c^2 = m^2c^4$  is satisfied for the above example. (2)
5. What experiment is given credit for discovering the electron? Give a schematic of the experiment. (no need for formulas) What property of the electrons was actually measured? What step was used to directly determine the velocity of the electrons? (please include a formula here) (7)
6. Use a sketch to describe the spectral energy density (either  $u(\lambda)$  or  $R(\lambda)$ ) of a blackbody radiator as a function of temperature and wavelength. Give one of the formulas related to blackbody radiation along with its name. What is the ultraviolet catastrophe? How was it resolved? (7)
7. Bonus: the cosmic microwave background is strong evidence for what theory of the universe? (2)