Sample Final Exam problems:

(1) [10 points] Frank is out driving his new 10.0 m-long “stretch roadster.” He approaches a tunnel, which is 5.0 m long. Harry is observing the situation from a frame that is stationary with respect to the tunnel.

(a) At what minimum speed must Frank travel relative to the tunnel in order that his car just fits into the tunnel, all at the same time, according to the reference frame of Harry? [Express the speed as a fraction of $c$.]

(b) In this situation, what will be the length of the tunnel as seen in Frank’s reference frame?

(c) Two important events in this situation would be the time that the front end of Frank’s car arrives at the far end (front) of the tunnel and the time that the back end of his car arrives at the near side (back) of the tunnel. These two events are simultaneous as seen by Harry, if the car just fits into the tunnel. What is the time difference between these two events in Frank’s frame?

(2) [10 points] Consider a doubly-ionized Li atom ($Z = 3$). Since it is doubly ionized, this ion would have one electron.

(a) What is the radius of the ion in its ground state, in the Bohr model?

(b) What are the wavelengths for the photons that would be absorbed for transitions for this ion between the ground state and the first three excited states?

(3) [10 points] Dan is traveling in a rocketship traveling at a speed of 0.7 c along the x axis, relative to Mary, who is stationary on earth. Dan aims his flare gun along the y axis (in his frame), and fires a flare which travels at at speed of 0.7 c away from him.

(a) What will be the speed of the flare in Mary’s frame?

(b) What is the angle of the flare’s trajectory, relative to the x axis, as measured according to Mary, in her frame?
(4) [10 points] Explain how the photoelectric effect demonstrates that light has particle-like properties.

(5) [10 points] An ideal black body sits at a constant temperature of 500°C.

(a) What is the energy (in eV) of photons emitted at the peak-intensity point of the emission curve?

(b) By what factor will the total radiated power increase if the temperature is increased to 750°C?

(c) For large wavelengths, show that the radiated intensity decreases with wavelength as $\lambda^4$.

(d) For what part of the spectrum does the observed radiation from this black body agree with the classical predicted spectrum? Large or small wavelengths?