1.) Problem 1.1 in Rybicki & Lightman (pinhole camera)
2.) Problem 1.6 in Rybicki & Lightman (entropy of thermal radiation)
   (Hint: Apply the first law of thermodynamics to a Black Body radiation field at constant volume.)

3.) In class we demonstrated from an elementary energy argument that light intensity or, equivalently, apparent surface brightness is a spatially invariant property of a light beam, provided one can ignore additions or reductions from emission or absorption. Here, establish this result by thinking of light as a gas of (almost) noninteracting photons. To do this apply Liouville’s theorem from statistical mechanics, which states that the phase space density, $n$, of particles in such a gas is invariant in their motion. That is, for such a gas $dN/dx^3/dp^3$ is invariant if one follows a set of such particles from point A to point B. Note that the direction of $p$ (a momentum vector) is the unit vector, $\hat{k}$, while $p\cdot \mathbf{\eta} = 0$, so $dk_kd^2x$ represents a phase space volume for photons propagating close to the direction $\hat{k}$.

4.) Imagine a transparent (“optically thin”) cosmic object (its optical depth, $\tau << 1$, but not exactly zero—why not?--) that has a constant and homogeneous volume emissivity, $j$. Assuming the object is a sphere of radius, $R$, and there is no incident radiation from outside, show using relations developed in class that:

a) The mean intensity, $J$, at the center of the object is $J = jR$.
b) The radiant energy density at the center of the object is $u = (4\pi/c) jR$.
c) The luminosity of the object is $L = (16\pi^2/3) jR^3$. (Note: luminosity is the total power emitted from the surface in erg/sec.)
d) The flux per unit area emitted from the surface of the object is $F_s = (4\pi/3) jR = (c/3)u$. (Note: here and below, do not derive the first equality from the second. Show equivalency of the second equality to the first after establishing the first.)
e) The mean surface brightness of the object when seen from large distance is $B = (4/3) j R = F_s / \pi$. (Note: Typically, “large distance” in this course means far enough that small angle formulas apply, e.g., $\sin \theta \approx \theta$. Note, also that in this context “mean” refers to the average over the solid angle subtended by the object at the observer, $d\Omega_s$.)
f) The flux of the object, $F$, when observed at a large distance, $D$, [so that $(R/D)^2 << 1$] is
   i) $F = (4/3) J d\Omega_s$, where $J$ is the mean intensity from part a,
   ii) $F = L/(4\pi D^2)$
   iii) $F = F_s (R/D)^2$ (Note: How could you have written this form immediately by applying the inverse-square law for radiation.)