Set 1

1. RP[1] 3-1
2. RP 3-4
3. RP 3-5
4. RP 3-6
5. Determine the location of points on an elliptical orbit at which the speed is equal to the circular orbit speed.

Set 2

1. RP 3-8
2. RP 3-9
3. RP 3-10
4. In the tour of the universe on the first day of class, we looked at a brief animated image of stars located close to the center of our Milky Way galaxy and moving around that center in Keplerian orbits. It was mentioned that these motions provided evidence for the presence of a massive black hole at the center of our galaxy. Since we now have discussed Kepler's laws, you should be able to do a calculation and estimate the mass of the object located at the center of the Milky Way.

   To do this, you will need to find information on the typical time it takes for stars to complete full orbits around the center of the galaxy, and at what typical distance from the galactic center. You can find this information in the abstract of the article by Eckart and Genzel published in 1997 in the journal *Monthly Notices of the Royal Astronomical Society*, volume 284, page 576. Go online to the ADS abstract service at

   `http://adsabs.harvard.edu/abstract_service.html`,

   do an author (either Eckart or Genzel) query for the year 1997, and click on the paper with the above reference. You will be able to view and download the paper. In the abstract, the authors summarize their main conclusions, including the typical speed and distance of the stars to Sgr A (the compact radio source at the center of the Milky Way). Using this speed and distance, find the numbers you need to apply Kepler III and find the mass of the object at the center of the Milky Way.
5. Compare the escape speed of a rocket launched from Earth with that of the same rocket launched at a distance of 1 AU and escaping the gravitational pull of the Sun.

[1] Ryden & Peterson

Set 3

1. RP 13-1
2. RP 13-2
3. RP 13-3
4. RP 13-4
5. RP 13-5
6. Suppose you could communicate with an astronomer on a planet orbiting a nearby star. Based on the star's parallax, you determine the star to be 2 pc away. The astronomer on the other planet claims the distance to our star (the Sun) to be only 1 pc. Explain how both you and the astronomer on the other planet can be correct. (The astronomer is native to that planet, rather than having traveled to that planet from Earth.)

Set 4

1. RP 5-8
2. An average person has $1.4\,\mathrm{m}^2$ of skin at a skin temperature of roughly 92°F. Consider the person to be an ideal radiator.
   (a) Calculate how much energy per second is radiated by the person (in watts).
   (b) Determine the peak wavelength of the radiation emitted by the person. In what region of the electromagnetic spectrum is this wavelength located?
3. Consider a model star consisting of a spherical blackbody with a surface temperature of 28,000 K and a radius of 5.16×10^9 m. The star is 180 pc from the Earth. Determine the following for the star:
   (a) its luminosity;
   (b) its absolute bolometric magnitude;
   (c) its apparent bolometric magnitude;
   (d) its distance modulus;
   (e) the flux of the star's surface;
   (f) the star's flux observed near the Earth's surface;
   (g) the peak wavelength of the radiation emitted by the star.

Set 5

1. To demonstrate the relative strengths of the electrical and gravitational forces of attraction between the electron and the proton in a Bohr atom, suppose the hydrogen atom were held together *solely* by the force of gravity. Determine the radius of the ground-state orbit (in nm and in AU), and the energy of this ground-state orbit (in eV).

2. Find the shortest-wavelength photons of the Lyman, Balmer and Paschen series (called the *series limits*). In which regions of the EM spectrum are these wavelengths found?

3. At what wavelengths will the following spectral lines be observed?

   (a) a line emitted at 500 nm by a star moving toward us at 100 km/s.

   (b) the Ca II line (undisplaced wavelength of 397.0 nm) emitted by a galaxy receding at 60,000 km/s.

4. A cloud of neutral hydrogen (H I) is moving away from us at 200 km/s. At what frequency (in MHz) will the 21-cm spectral line (produced by an electron spin flip) be observed?

5. In its rest frame, quasar Q2203+29 produces a hydrogen emission line of wavelength 121.6 nm. Astronomers on Earth measure a wavelength of 656.8 nm for this line. Determine the redshift parameter z and the apparent speed of recession of this quasar.

Set 6

1. Show that at room temperature, the thermal energy $kT \approx 1/40$ eV. At what temperature is kT equal to 1 eV, and equal to 13.6 eV?

2. Verify that Boltzman's constant $k = 8.6173 \times 10^{-5}\,\text{eV/K}$.

3. As discussed in class, each quantum state of the hydrogen atom is labeled by a set of four quantum numbers, usually denoted n, l, m_l and m_s. List the sets of quantum numbers for the hydrogen atom for the ground state $n = 1$, the first excited state $n = 2$, and the second excited state $n = 3$. Verify for these three energy levels that the degeneracy g_n of energy level n obeys $g_n = 2n^2$.

4. For a gas of neutral hydrogen atoms, at what temperature is the number of atoms in the first excited state only 1% of the number of atoms in the ground state? At what T is the number of atoms in the first excited state 10% of the number of atoms in the ground state?

5. Consider a stellar atmospheric layer consisting of a pure He gas at a temperature of 15,000 K and an electron pressure P_e of 20 Pa. Calculate the ratios HeII/HeI and HeIII/HeII. The ionization potentials of HeI and HeII are $\chi_I = 24.5$ eV and $\chi_{II} = 54.4$ eV, respectively. The partition functions are $Q_I = 1$, $Q_{II} = 2$, and $Q_{III} = 1$.

6. The star HD 215441 has an unusually strong magnetic field of 3.4 T (compare this to the average magnetic field of the Sun of 10^{-4} T). Find the wavelengths of the three components of the Hα spectral line ($\lambda_0 = 656.281$ nm) produced by the normal Zeeman effect. (See p. 127 of the book. You will also need the quantitative equation that links magnetic field B to the amount of Zeeman splitting discussed in class.)

Set 7

1. RP 13-6
2. RP 13-7
3. RP 13-8
4. RP 13-11

Set 8

1. RP 14-1
2. RP 14-5
3. RP 14-7
4. Calculate how far you could see through Earth's atmosphere if it had the opacity of the solor photosphere. Use the value for the Sun's photospheric opacity from the example given in class. The density of air is 1.2 kg/m^3.
5. RP 14-2
6. RP 5-7
7. Suppose we have a uniform-density sphere of radius R and mass absorption coefficient κ. We look through the sphere along various parallel paths, passing different distances p from the center of the sphere at their points of closest approach to the center.

   a. Find an expression for the optical depth τ as a function of p.

   b. Calculate $d\tau/dp$, the rate of change of τ with p.

   c. Use your result to discuss why on images of the Sun, the solar limb is so sharply defined.

Set 9

1. Suppose the central core of a star is made of 60% H and 35% He by mass. The central density is 50 times that of water, and the central temperature is 15×10^6 K. Calculate both the gas pressure and the radiation pressure at the center of this star. What is the ratio $P_{\mathrm{gas}}/P_{\mathrm{R}}$?
2. RP 15-2
3. RP 15-3
4. RP 15-4
5. RP 15-6

6. Estimate the hydrogen-burning lifetimes of a $0.072\,M_\odot$ star located near the lower end of the main-sequence, and that of a $85\,M_\odot$ star located near the upper end of the main-sequence. Effective temperatures and luminosities are given in the table below. For the massive star, assume that 10% of all hydrogen is available for nuclear fusion. For the low-mass star, because it will be fully convective, convective mixing will make all of its hydrogen available for fusion.

Mass ($M_\odot$)	$T_{\rm eff}$ (K)	$\log_{10}(L/L_\odot)$
0.072	1700	−4.3
85	50700	6.006

7. RP 15-10

Set 10

1. RP 17-1
2. RP 17-2
3. RP 17-4

Set 11

1. RP 18-1
2. RP 18-2
3. RP 18-4
4. RP 18-6

Set 12

1. RP 19-2
2. RP 19-8
3. RP 19-10

Set 13

1. RP 20-1
2. RP 20-2
3. RP 20-7