12. (II) When our Sun becomes a white dwarf, it is expected to be about the size of the Moon. What angular width will it subtend from the present distance to Earth?

13. (II) Calculate the density of a white dwarf whose mass is equal to the Sun's and whose radius is equal to the Earth's. How many times larger than Earth's density is this?

14. (II) A neutron star whose mass is 1.5 solar masses has a radius of about 11 km. Calculate its average density and compare to that for a white dwarf (Problem 13) and to that of nuclear matter.

15. (II) Calculate the Q-values for the He burning reactions of Eq. 33–2. (The mass of the very unstable ${}^{8}_{4}\mathrm{Be}$ is 8.005305 u.)

16. (II) Suppose two stars of the same apparent brightness l are also believed to be the same size. The spectrum of one star peaks at 800 nm whereas that of the other peaks at 400 nm. Use Wien's law (Section 27–2) and the Stefan-Boltzmann equation (Eq. 14–5) to estimate their relative distances from us. [*Hint*: see Examples 33–4 and 33–5.]

17. (III) Stars located in a certain cluster are assumed to be about the same distance from us. Two such stars have spectra that peak at $\lambda_1 = 500\,\mathrm{nm}$ and $\lambda_2 = 700\,\mathrm{nm}$, and the ratio of their apparent brightness is $l_1/l_2 = 0.091$. Estimate their relative sizes (give ratio of their diameters). [*Hint*: use the Stefan-Boltzmann equation, Eq. 14–5.]

33–4 General Relativity, Gravity and Curved Space

18. (I) Show that the Schwarzschild radius for a star with mass equal to that (*a*) of our Sun is 2.95 km, and (*b*) of Earth is 8.9 mm.

19. (II) What is the Schwarzschild radius for a typical galaxy (like ours)?

20. (II) Describe a triangle, drawn on the surface of a sphere, for which the sum of the angles is (*a*) 359°, and (*b*) 180°.

21. (II) What is the maximum sum-of-the-angles for a triangle on a sphere?

33–5 Redshift, Hubble's Law

22. (I) If a galaxy is traveling away from us at 1.0% of the speed of light, roughly how far away is it?

23. (I) The redshift of a galaxy indicates a velocity of 3500 km/s. How far away is it?

24. (I) Estimate the speed of a galaxy (relative to us) that is near the observable "edge" of the universe, say 12 billion light-years away.

25. (II) Estimate the observed wavelength for the 656-nm line in the Balmer series of hydrogen in the spectrum of a galaxy whose distance from us is (*a*) 1.0×10^6 ly, (*b*) 1.0×10^8 ly, (*c*) 1.0×10^{10} ly.

26. (II) Estimate the speed of a galaxy, and its distance from us, if the wavelength for the hydrogen line at 434 nm is measured on Earth as being 610 nm.

27. (II) What is the speed of a galaxy with $z = 0.60$?

28. (II) What would be the redshift parameter z for a galaxy traveling away from us at $v = 0.50c$?

29. (II) Starting from Eq. 33–3, show that the Doppler shift in wavelength is $\Delta\lambda/\lambda_0 \approx v/c$ (Eq. 33–5b) for $v \ll c$. [*Hint*: use the binomial expansion.]

33–6 to 33–8 The Big Bang, CMB, Universe Expansion

30. (I) Calculate the wavelength at the peak of the blackbody radiation distribution at 2.7 K using Wien's law.

31. (II) The critical density for closure of the universe is $\rho_c \approx 10^{-26}\,\mathrm{kg/m^3}$. State ρ_c in terms of the average number of nucleons per cubic meter.

32. (II) The scale of the universe (the average distance between galaxies) at any one moment is believed to have been inversely proportional to the absolute temperature. Estimate the size of the universe, compared to today, at (*a*) $t = 10^6\,\mathrm{yr}$, (*b*) $t = 1\,\mathrm{s}$, (*c*) $t = 10^{-6}\,\mathrm{s}$, and (*d*) $t = 10^{-35}\,\mathrm{s}$.

33. (II) At approximately what time had the universe cooled below the threshold temperature for producing (*a*) kaons $(M \approx 500\,\mathrm{MeV}/c^2)$, (*b*) Υ $(M \approx 9500\,\mathrm{MeV}/c^2)$, and (*c*) muons $(M \approx 100\,\mathrm{MeV}/c^2)$?

General Problems

34. Suppose that three main-sequence stars could undergo the three changes represented by the three arrows, A, B, and C, in the H–R diagram of Fig. 33–28. For each case, describe the changes in temperature, luminosity, and size.

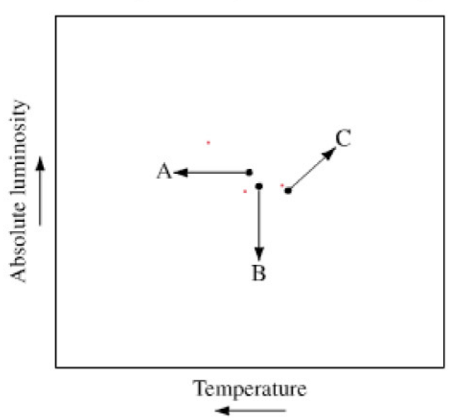

FIGURE 33–28 Problem 34.

35. Assume that the nearest stars to us have an absolute luminosity about the same as the Sun's. Their apparent brightness, however, is about 10^{11} times fainter than the Sun. From this, estimate the distance to the nearest stars. (Newton did this calculation, although he made a numerical error of a factor of 100.)

36. Use conservation of angular momentum to estimate the angular velocity of a neutron star which has collapsed to a diameter of 20 km, from a star whose radius was equal to that of our Sun (7×10^8 m), of mass 1.5 times that of the Sun, and which rotated (like our Sun) about once a month.

37. By what factor does the rotational kinetic energy change when the star in Problem 36 collapses to a neutron star?

38. A certain pulsar, believed to be a neutron star of mass 1.5 times that of the Sun, with diameter 20 km, is observed to have a rotation speed of 1.0 rev/s. If it loses rotational kinetic energy at the rate of 1 part in 10^9 per day, which is all transformed into radiation, what is the power output of the star?