1. Chapter 5, question 27
2. Chapter 5, question 29
3. Chapter 5, question 34
4. Chapter 5, question 37
5. The temperature of planets heated by the Sun: In this problem, you will be led through a series of steps which allow you to estimate the temperature of a given planet from first principles. Through all parts of this question, be sure to explain your reasoning carefully — a part of the grade will be given for the clarity of your explanations.

(a) The total flux of electromagnetic radiation from the Sun at a given distance \( D \) from the center of Sun is defined as the solar energy per unit time per unit surface area that passes through an area which is oriented face-on to the Sun. If we denote the total luminosity (i.e. total power output) of the Sun by \( L_\odot \), and using the fact that the Sun radiates equally in all directions, show that the total flux of e/m radiation measured at distance \( D \) from the Sun is

\[
F = \frac{L_\odot}{4\pi D^2}.
\]

[Hint — imagine surrounding the Sun by a spherical surface of radius \( D \) and consider the flow of radiation through that surface.]

(b) If the Sun radiates as a blackbody, show that the solar flux calculated in part-(a) can be expressed as

\[
F = \left(\frac{R_\odot}{D}\right)^2 \sigma T^4,
\]

where \( T \) is the temperature of the Sun’s “surface”, \( R_\odot \) is the radius of the Sun, and \( \sigma \) is the Stephan-Boltzmann constant.

(c) Consider a planet of radius \( r_p \) which is in a circular orbit about the Sun, a distance \( D \) from the center of the Sun. Electromagnetic radiation from the Sun shines onto the planet; a fraction \( A \) of that radiation is immediately reflected back into space (this fraction is called the albedo) but the rest of the energy heats the planet which starts to radiate as a black body. The planet will heat up until the power that it emits equals the power that it receives from the Sun. Assuming that the planet has a uniform surface temperature \( T_p \), derive a formula for \( T_p \) in terms of \( R_\odot \), \( T_\odot \), \( D \), \( \sigma \), \( r_p \). Note anything interesting about this formula.

(d) Use your formula to calculate the expected average temperature \( T_p \) of the Earth, given that the average albedo (due principally to clouds and ice) is \( A = 0.31 \). You will need to look up the numerical values of various quantities in order to answer this question.

(e) The actual average temperature of the Earth is 287K. What are possible reasons for why the value that you calculated in part-(d) is incorrect?

(f) The illuminated (dayside) face of the Moon has an average surface temperature of 380K. Given that the distance between the Sun and the Moon is very close to 1AU, why is this so different to your estimates in part-(d).