1. (25 points)

   a.) (6 pts) Explain in general terms what electromagnetic radiation is.
   
   Waves of energy

   b.) (6 pts) Give a specific example of electromagnetic radiation.
   
   Light
   X-rays
   Gamma rays
   Heat
   Radio waves
   Microwaves
   Radar

   c.) (6 pts) Why are astronauts, even in low altitude orbits, at greater risk from exposure to high-energy radiation than we are on Earth’s surface?
   
   Earth’s atmosphere absorbs most of the electromagnetic radiation before it reaches the ground.

   d.) (4 pts) What constitutes the Van Allen radiation belts?
   
   Charged particles (electrons and protons)

   e.) (3 pts) What is the potential effect of the Van Allen belts on satellites in high orbits?
   
   Radiation in the belts can damage onboard electronics.
2. (25 points) The two graphs below show spectrographic data. The unshifted spectrum is from hydrogen that is not moving relative to the spectrograph; the shifted spectrum is from a distant star.

![Unshifted spectrum](image1.png) ![Shifted spectrum](image2.png)

a.) (4 pts) Is the star moving toward Earth or away from us? \[\text{away}\]

b.) (7 pts) Calculate the star's speed relative to Earth (using the highest peak in the data).

\[V = c \left(\frac{\Delta \lambda}{\lambda}\right)\]

\[\Delta \lambda = \lambda_{\text{shifted}} - \lambda_{\text{unshifted}}\]

\[= 6 \text{ microns} - 5.6 \text{ microns}\]

\[= 0.4 \text{ microns}\]

\[\lambda = \frac{\lambda_{\text{unshifted}}}{5.6 \text{ microns}} = 5.6 \text{ microns}\]

\[V = (3 \times 10^8 \text{ m/s}) \left(\frac{0.4 \text{ microns}}{5.6 \text{ microns}}\right) = 2.143 \times 10^7 \text{ m/s}\]

c.) (7 pts) Calculate the star's distance from Earth.

\[d = \frac{V}{H} = \frac{2.143 \times 10^7 \text{ m/s}}{2.2 \times 10^{-18} \text{ s}} = 9.74 \times 10^{24} \text{ m}\]

d.) (7 pts) State one reason that these spectrographic measurements can be made more accurately by scientific instruments onboard a satellite (as compared to an identical set of instruments on Earth).

\[\text{Reduced or eliminated problems from atmospheric blurring, atmospheric absorption, light pollution, and gravitational}\]

\[\text{effects.}\]
3. (25 points)

a.) (3 points each) Match each satellite subsystem on the left with the corresponding function or device on the right. Write your answers in the blank spaces next to the subsystem name on the left.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Function or device</th>
</tr>
</thead>
<tbody>
<tr>
<td>thermal control</td>
<td>d. multi-layer insulation blankets</td>
</tr>
<tr>
<td>attitude control</td>
<td>c. gyroscope</td>
</tr>
<tr>
<td>communications</td>
<td>a. antenna</td>
</tr>
<tr>
<td>propulsion</td>
<td>b. protective covering to shield against meteors</td>
</tr>
<tr>
<td>structure</td>
<td>e. handles commands sent from ground control</td>
</tr>
</tbody>
</table>

b.) (10 pts) A GPS receiver is discovered to be showing its position incorrectly. If the position has an error of 90 meters, then what is the clock error on the GPS satellite?

\[ d_{err} = c \Delta t_{err} \]

\[ 90 \text{ m} = (3 \times 10^8 \text{ m/s}) \Delta t_{err} \]

\[ \Delta t_{err} = \frac{90 \text{ m}}{3 \times 10^8 \text{ m/s}} = 3 \times 10^{-7} \text{ s}. \]
4. (25 points)

a.) (5 pts) In remote sensing applications, which type of sensor uses a single sensor cell and uses a pivoting mirror to reflect into that cell?

*Side-scanning sensor*

b.) (15 pts) A remote sensing satellite is flying over a wild-fire. In the graph below, carefully sketch the spectrum that results if the fire has a temperature of 2000 °K. Your sketch should be accurate enough to allow someone to use it to determine the fire’s temperature.

\[
L = \frac{2900 \text{ microns} \cdot ^\circ \text{K}}{2000 \ ^\circ \text{K}} = 1.45 \text{ microns}
\]

![Graph of intensity vs. wavelength](image)

- Reduced intensity of e/m radiation
- Reduced resolution (cannot see as much detail)