Name: Date: Per:

The Inverse Square Law

Activity 1: Interplanetary Agriculture

With the exception of chemosynthetic bacteria, all life is dependent on sunlight. Plants are *autotrophic*, meaning they produce their own food through the process of photosynthesis. Animals, however, are *heterotrophic*, dependent on plants and other animals for their energy. All civilizations are dependent on agriculture, and therefore dependent on the light of the Sun. Many science-fiction writers have imagined the colonization of other planets, but how practical would such an endeavor be even if we could deliver people and materials to these faraway worlds?

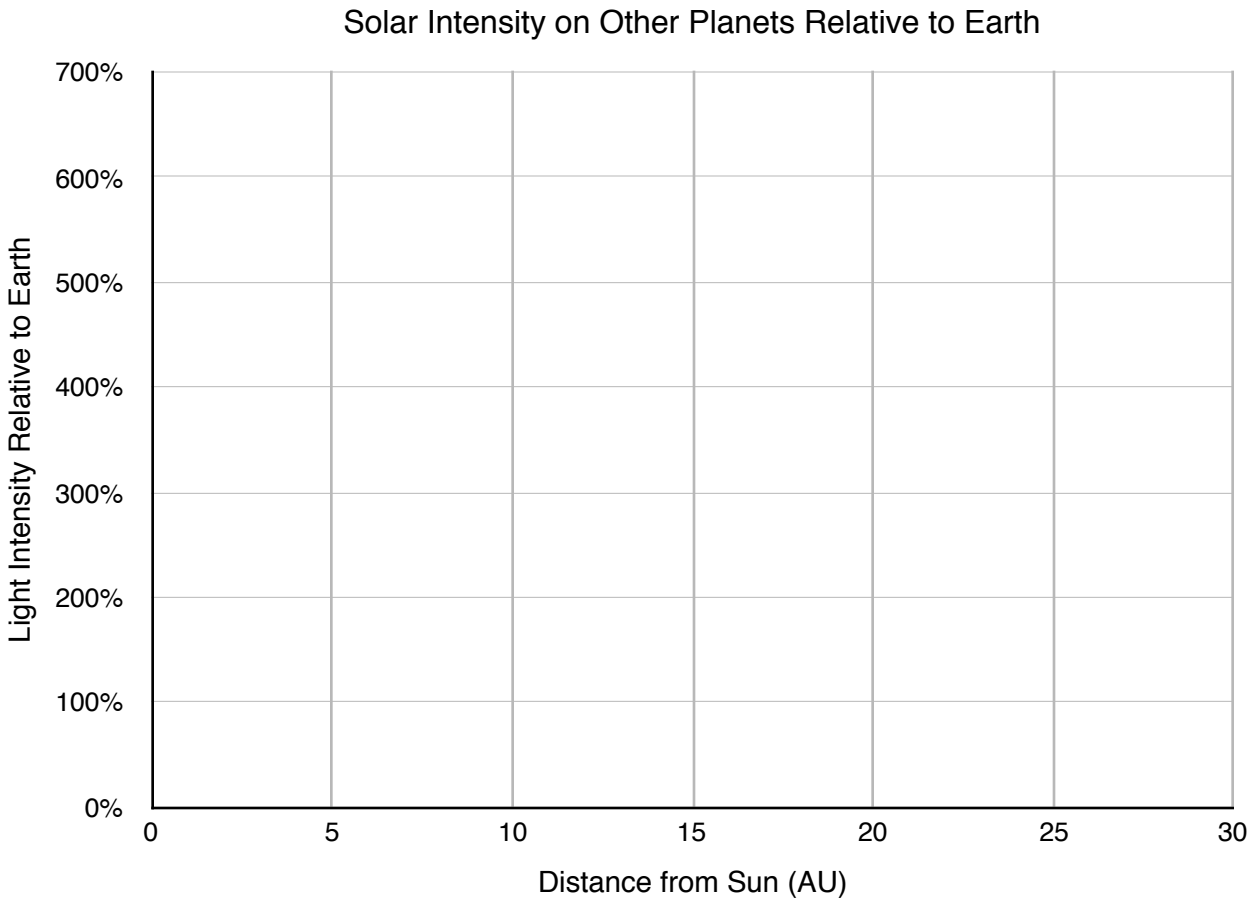
According to the inverse square law, the intensity of light decreases as the inverse of the distance from the light source. Doubling the distance from the Sun results in a fourfold reduction in light intensity. We know that the average light intensity on Earth is adequate for agriculture, but how about on distant planets? The table below shows the relative distance between the planets and the Sun.

The average distance from the Sun to Earth it 149,597,870 km (92,955,807 miles), a distance that astronomers call *1 astronomical unit*, or 1 AU. Since the average distance between the Sun and the Earth is defined as 1 AU, planets closer to the Sun have distances less than 1 AU, while planets farther from the Sun have distances greater than 1 AU.

1. How does the intensity of the light on these planets compare with the intensity of light on Earth, knowing that intensity is a function of the inverse square of the distance from the Sun? Complete the table below.

Planet	AU	I_{planet}/I_{Earth}
Mercury	0.387	
Venus	0.723	
Earth	1.000	1.000
Mars	1.523	
Jupiter	5.202	
Saturn	9.538	
Uranus	19.181	
Neptune	30.057	

2. Create a graph with distance of the planets from the Sun measured in AUs on the *x*-axis (independent variable) and the intensity of light on these planets, measured relative to the intensity on Earth (I_{planet} / I_{Earth}) on the *y*-axis (dependent variable).



3. Do you think that it would be possible to grow food in planetary greenhouses on any of the inner rocky planets: Mercury, Venus, or Mars? Justify your answer.

4. In the summer of 1989, NASA's *Voyager 2* became the first spacecraft to observe Neptune, its final planetary target during its 12 month voyage from Earth. What was the intensity of light from the Sun at this point?

Activity 2: Applications of the Inverse Square Law

The following are true statements. Explain each using the inverse square law.

1. The largest antennae in the world are radio telescopes, detecting radio waves from distant galaxies.

2. Immunotherapy is used to treat cancer. Scientists find antibodies that attack specific cancer cells, then separate the antibodies in the laboratory and derive millions of copies. The antibodies are doped with radioactive molecules and given to the patient. The radioactivity kills cancerous cells to which the antibodies cling but has little effect on surrounding tissues.

3. Pseudoscientists have warned of the dire gravitational effects associated with the alignment of Jupiter, Mars, and the Moon. Although these are massive objects, the combined force of attraction of these objects causes no noticeable effects on Earth.

4. There is no such thing as a position around the Earth in which there is zero gravity. Astronauts orbiting the Earth are simply in a continual state of free fall and therefore experience zero gravity, even though they are well within the gravitational field of the Earth.

KEY

Activity 1: Students should calculate values as shown in Table 15.8 and draw a graph such as illustrated in Figure 15.17. (1) The light intensity on Mercury and Venus is very high, and greenhouses would have to reduce the amount of light. The greater challenge would be the temperature and atmosphere of these planets, both of which are extremely hostile for life. On Mars, the light intensity is only about 43 percent that on Earth, so crops could not flourish unless the light intensity was boosted with mirrors and the atmosphere in greenhouses controlled to match that on Earth. (2) The light intensity on Neptune is approximately 0.1 percent the intensity here on Earth.

Table 15.8 Solar Intensity Relative to Earth

Planet	(AU)	$(I_{planet}/I_{Earth})\%$
Mercury	0.387	667.7%
Venus	0.723	191.3%
Earth	1.000	100.0%
Mars	1.523	43.1%
Jupiter	5.202	3.7%
Saturn	9.538	1.1%
Uranus	19.181	0.3%
Neptune	30.057	0.1%

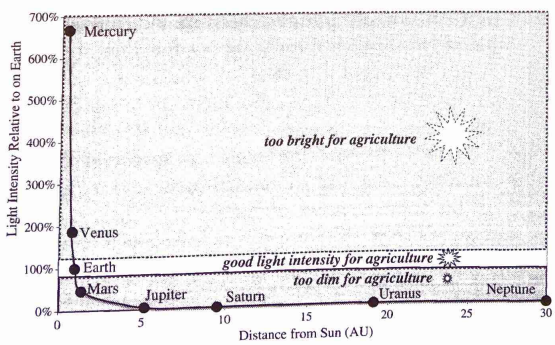


Figure 15.17 Intensity of Sunlight on Planets

Activity 2: (1) Radio signal strength drops off as the inverse square of the distance from the source. Radio waves produced in distant galaxies are extremely faint due to the inverse square law and the great distances from Earth. Large antennae are necessary to gather signals large enough to analyze. (2) The radioactively tagged antibodies selectively bind to the cancerous cells. Since radiation emanates from these uniformly in all directions, the intensity of the radiation will fall off as a function of the inverse square of distance from the antibody. The cancerous cells to which the radioactive antibodies bind are destroyed, while only minimal damage is inflicted on surrounding tissues, which receive much less radiation due to their distance from the radioactive source and the inverse square law. (3) Since gravity is a function of the inverse square of the distance from the center of mass, the attractive force of Mars and Jupiter will be extremely small in comparison with the smaller but much closer Moon. (4) The universal law of gravitation incorporates the inverse square law: $F_g = G\frac{m_1 \cdot m_2}{r^2}$. The Earth exerts gravity on the spacecraft and everything else in the universe, but its effect diminishes rapidly as distance increases. As distance, r, approaches infinity, the force of the Earth's gravity becomes negligible.