This worksheet has been created to fit the SL Physics curriculum for the IB curriculum and probably has limited use elsewhere.

It is a practice exercise in:

1. Using Wein's Law to estimate temperature through color of an object of known temperature.
2. Calculating an approximation for the solar constant.
3. Calculating an approximation for the temperature of the earth ignoring the atmosphere and earth's rotation.
4. Finding the change in temperature of the earth's surface using an approximated surface heat capacity and an erroneous estimate for difference in incoming radiation intensity and outgoing radiation intensity.

Worksheet generated by Kristy Bibbey

Name___________________

Climate Change

1. Assume that the temperature of a 75-Watt light bulb filament is the same as the surface of the sun (5800 K). Calculate the surface area of the filament. ($\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$)

_____ m^2 2pts

_____ mm^2 1pt

Why do we assume that the filament is the same temperature as the surface of the sun?

1pt

2. Show the formula and calculation (including units) to determine the total power radiated by the sun. $r_{sun} = 6.96 \times 10^8 m$.

3pts

3. Calculate the power per area in Wm^{-2} that is radiated at a distance of $1.5 \times 10^{11}m$. ($1.5 \times 10^{11}m$ is the average radius of the earth's orbit.) This is referred to as the solar constant.

2pts

4. Let the solar constant be S_o in Wm^{-2}. Let the radius of the earth be r_E in m. Show that the average intensity at the surface of the earth is $\frac{S_o}{4}$.

2pts

5. $0.30 = \alpha$ = albedo: ratio of power reflected
$0.77 = e$ = emissivity: ratio of power radiated

Total Power Absorbed = Total Power Radiated

$$S_o (1-\alpha)\pi r_E^2 = e\sigma 4\pi r_E^2 T^4$$

a) Why is the area πr_E^2 for power absorbed and $4\pi r_E^2$ for power radiated?

2pts

b) Solve the equation for T using only variables.

1pt

c) Solve for T. 1pt

6. a) Define surface heat capacity. (include suggested units)

3pts

b) Write a word equation for surface heat capacity. Let C_s represent surface heat capacity.

C_s = ____

1pt

7. Temperature change $= \frac{\text{(incoming radiation intensity-outgoing radiation intensity) x time}}{\text{surface heat capacity}}$

Use $C_s = 2.8 \times 10^8 \ Jm^{-2}K^{-1}$

Assume the incoming radiation intensity exceeds the outgoing radiation intensity by $11Wm^{-2}$.

a) Calculate ΔT for a time of 36 days. 1pt

b) Calculate ΔT for a time of 2 years. 1pt

c) Calculate ΔT for a decade. 1pt

d) Is the assumption of $11Wm^{-2}$ is an accurate assumption? Justify your answer.

2pts

Name___________________

Climate Change

1. Assume that the temperature of a 75-Watt light bulb filament is the same as the surface of the sun (5800 K). Calculate the surface area of the filament. ($\sigma = 5.67 \times 10^{-8}$ $Wm^{-2}K^{-4}$)

$P = \sigma A T^4$ $\quad A = \frac{P}{\sigma T^4} = \frac{75W}{(5.67 \times 10^{-8}\ Wm^{-2}K^{-4})(5800K)^4}$

1.2×10^{-6} m^2 2pts

__12__mm^2 1pt

Why do we assume that the filament is the same temperature as the surface of the sun?

Same color – same temp (Wein's Law)

1pt

2. Show the formula and calculation (including units) to determine the total power radiated by the sun. $r_{sun} = 6.96 \times 10^8 m$.

$A = 4\pi r^2 = 4\pi(6.96 \times 10^8 m)^2 = 6.08 \times 10^{18} m^2$

$P = \sigma A T^4$

$P = (5.67 \times 10^{-8}\ Wm^{-2}K^{-4})(6.08 \times 10^{18} m^2)(5800K)^4 = 3.9 \times 10^{26} W$

3pts

3. Calculate the power per area in Wm^{-2} that is radiated at a distance of 1.5×10^{11}m. (1.5×10^{11}m is the average radius of the earth's orbit.) This is referred to as the solar constant.

$\frac{P}{A} = \frac{3.9 \times 10^{26} W}{4\pi(1.5 \times 10^{11} m)^2} = 1400\ Wm^{-2}$

2pts

4. Let the solar constant be S_o in Wm^{-2}. Let the radius of the earth be r_E in m. Show that the average intensity at the surface of the earth is $\frac{S_o}{4}$.

$\frac{S_o(\text{cross-sectional area of earth})}{\text{surface area of earth}} = \frac{S_o \pi r_E^2}{4\pi r_E^2} = \frac{S_o}{4}$

2pts

5. $0.30 = \alpha$ = albedo: ratio of power reflected
$0.77 = e$ = emissivity: ratio of power radiated

Total Power Absorbed = Total Power Radiated

$$S_o (1-\alpha)\pi r_E^2 = e\sigma 4\pi r_E^2 T^4$$

a) Why is the area πr_E^2 for power absorbed and $4\pi r_E^2$ for power radiated?

The sun radiates a cross-sectional area (disk) of the earth. The earth's entire surface area re-radiates the heat back out.

2pts

b) Solve the equation for T using only variables.

$T^4 = \frac{S_o (1-\alpha)\pi r_E^2}{e\sigma 4\pi r_E^2}$ $\quad T =$ fourth root of $\frac{S_o (1-\alpha)}{e\sigma 4\pi r_E^2}$

1pt

c) Solve for T. 1pt

$$T = \text{fourth root of } \frac{1400\ Wm^{-2}(1 - 0.3)}{4(.77)(5.67 \times 10^{-8}\ Wm^{-2}K^{-4})} \qquad T = 274\ K$$

6. a) Define surface heat capacity. (include suggested units)

The surface heat capacity is the amount of energy to raise a standard surface area by 1K.
Units: $Jm^{-2}K^{-1}$

3pts

b) Write a word equation for surface heat capacity. Let C_s represent surface heat capacity.

$$C_s = \frac{\text{Energy}}{(\text{change in surface temp})(\text{surface area})}$$

1pt

7. Temperature change $= \frac{(\text{incoming radiation intensity-outgoing radiation intensity}) \times \text{time}}{\text{surface heat capacity}}$

Use $C_s = 2.8 \times 10^8\ Jm^{-2}K^{-1}$
Assume the incoming radiation intensity exceeds the outgoing radiation intensity by $11Wm^{-2}$.

a) Calculate ΔT for a time of 36 days. 1pt

$$\Delta T = \frac{(11Wm^{-2})(36\text{ days})\frac{(24\text{ hr})(3600\text{ sec})}{(1\text{ day})\ (1\text{ hour})}}{2.8 \times 10^8\ Jm^{-2}K^{-1}} = 0.12K$$

(Remember that $1W = 1Js^{-1}$ for unit conversion.)

b) Calculate ΔT for a time of 2 years. 1pt

$$\Delta T = \frac{(11Wm^{-2})(2\text{ years})\ \frac{(365\text{ days})(24\text{ hrs})(3600\text{ sec})}{(1\text{ yr})\ \ (1\text{ day})\ \ (1\text{ hr})}}{2.8 \times 10^8\ Jm^{-2}K^{-1}} = 2K$$

c) Calculate ΔT for a decade. 1pt

$$\Delta T = \frac{(11Wm^{-2})(10\text{ years})\ \frac{(365\text{ days})(24\text{ hrs})(3600\text{ sec})}{(1\text{ yr})\ \ (1\text{ day})\ \ (1\text{ hr})}}{2.8 \times 10^8\ Jm^{-2}K^{-1}} = 12K \sim 10K$$

d) Is the assumption of $11Wm^{-2}$ is an accurate assumption? Justify your answer.

$11Wm^{-2}$ does not seeam like a good assumption because at that rate the earth's temp would increase about 1K each year.

2pts