Name:
Student number:

Physics 157 Tutorial – week of October 28

Since out midterm is next week, you can think of this tutorial as a practice midterm (but you can still discuss it as a group). Formulae / hints are provided on the last page.

You should complete this and hand it in at the homework boxes by 5pm on Nov 4th. You can check your answers on Mastering Physics.

Problem 1: An approximately spherical, black asteroid (emissivity equal to one) of diameter 2km is orbiting the Sun at a distance from the Sun 10 times larger than the distance from the Sun to the Earth.

a) What is the temperature of this asteroid?

b) What is the wavelength of radiation it emits with maximum intensity?

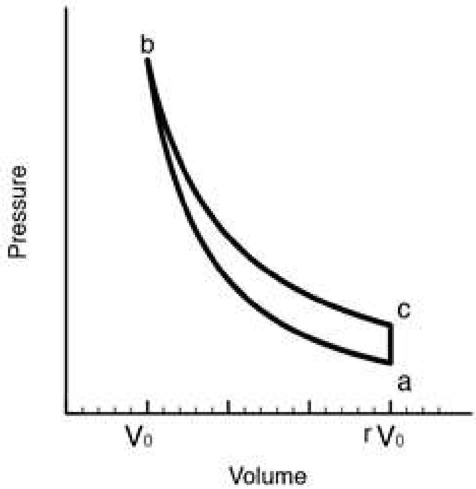
c) What radiation intensity emitted by the asteroid would be observed on Earth (when the asteroid makes its closest approach, assuming a circular orbit)?

Solar constant (solar power per unit area measured above the Earth's atmosphere is 1400 W/m^2).
Distance from the Sun to the Earth is 1.5×10^{11} m.

Problem 2

A new heat engine cycle can be described by an adiabatic compression ($a \to b$), an isothermal expansion ($b \to c$), and an isochoric cooling process ($c \to a$), as shown in the graph. The compression ratio is r. For a diatomic ideal gas: $c_V = \frac{5}{2}R$, $c_P = \frac{7}{2}R$, $\gamma = 1.4$ Assume the processes are reversible.

If point a is at room temperature (300K) and atmospheric pressure (100kPa), and the compression ratio is 4, what is the efficiency for this heat engine?



Thermodynamics formulae:

Calculating n,P,V,T:

Use ideal gas law: $\mathbf{P\ V = n\ R\ T}$ or $\mathbf{PV / T = constant}$.

For adiabatic processes, also have $\mathbf{P\ V^{\gamma} = constant}$, $\mathbf{T\ V^{\gamma-1} = constant}$ where $\gamma = C_p/C_V$

Calculating ΔU:

Have $\mathbf{\Delta U = n\ C_v\ \Delta T}$ always.

Calculating W or Q:

Work is $\mathbf{W = P\ \Delta V}$ (constant pressure) or $\mathbf{W = n\ R\ T\ ln(V_f/V_i)}$ (constant temperature)

For all other cases calculating Q or W, can use $\mathbf{Q = \Delta U + W}$ (1st Law).

This gives $\mathbf{Q = n\ C_p\ \Delta T}$ for constant pressure where $C_p = C_v + R$.

Efficiency: $\mathbf{e = W_{net}/Q_{in}}$ where Q_{in} is the sum of all positive contributions to Q

Radiation formulae:

Wien's Law: $\lambda_{max} = b/T$ $b = 2.90 \times 10^{-3}$ m K

Power in radiation: $H = A\ \sigma\ e\ T^4$

Intensity is energy per time per area.

Intensity at distance R from a spherical source: $I = H/(4\ \pi\ R^2)$

This means that $I_2/I_1 = (R_1/R_2)^2$

Hints for problem 1:

-You may first want to calculate the temperatures at each point using the tips provided above.

-The number of moles will cancel out in the end.

Hints for problem 2:

-The heat current leaving the asteroid due to radiation is equal to the heat current absorbed from the Sun. Setting this up as an equation will allow you to solve for T.

-The intensity of sunlight at the asteroid can be determined from the Solar Constant using the $1/R^2$ relationship for intensity decrease (see tipsabove).

-For absorbing sunlight, it is the cross sectional area that's important. For radiation, it is the full surface area.