Problem set 3 for ASTR 221: Stars and Planets

Due in class Thursday Sept 25

(1)(a) Assume that a spherical dust grain located 1AU from the Sun has a radius of 0.1 micron and a density of 3 g/cm3. In the absence of gravity, estimate the acceleration of that grain due to radiation**
20 **pressure. Assume that the solar radiation is completely absorbed.**
(b) What is the gravitational acceleration on the grain?

(2) Comet 1943I, which last passed through perihelion on Feb 27, 1991, has an orbital period of 512 years and an orbital eccentricity of 0.999914 (!). This is one of a class of so-called sun-grazing comets.
5 **(a) What is the comet's semi-major axis?**
5 **(b) Determine its perihelion and aphelion distances from the Sun.**
10 **(c) What is the most likely source of this object, the Oort Cloud or the Kuiper belt?**
Carroll and Ostlie (on reserve in the library) p 29, 30 may be useful here.

Kutner P26.1, P26.6 (remember, Problems, not Questions!)

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ASTR 221 Problem set 2 – solutions

21.2 (a) From Eq. (3.13),

$$F_{\rm rad} = \frac{\langle S\rangle A}{c}\cos\theta = \frac{L_\odot\,(\pi R^2)}{4\pi r^2 c} = 1.4\times10^{-14}\ \text{dyne},$$

where $R = 1000$ Å and $r = 1$ AU. Given a density of $\rho_g = 3$ g cm^{-3}, the mass of the grain is $m_g = \rho_g\left(\frac{4}{3}\pi R^3\right) = 1.3\times 10^{-14}$ g. Thus, the acceleration is $a = F_{\rm rad}/m_g = 1.1$ cm s^{-2}.

(b) $g = GM_\odot/r^2 = 0.59$ cm s^{-2}.

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21.6 (a) From Kepler's third law [Eq. (2.35) written in the form $P^2 = a^3$, where P and a are in years and AU, respectively], $a = 64$ AU. 5

(b) From Eq. (2.5), $r_p = a(1-e) = 0.0055$ AU, and from Eq. (2.6), $r_a = a(1+e) = 128$ AU. 5

(c) The Kuiper belt.

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26.1 - F(rad) = $(1/c)L_\odot\ (\pi R_E^2/(4\pi a_E^2))$
$= [(4.0 \times 10^{33}\ \text{erg/s})/(3.0 \times 10^{10}\ \text{cm/s})](6.4 \times 10^8\ \text{cm})^2/(4)(1.5 \times 10^{13}\ \text{cm})^2$
$= 6.1 \times 10^{13}$ dyne 10^5 N 10^8 N

F(grav) = $G\ M_\odot M_E / a_E^2$
$= (6.67 \times 10^{-8}\ \text{dyne-cm}^2/\text{g}^2)(2.0 \times 10^{33}\ \text{g})(5.977 \times 10^{27}\ \text{g})/(1.5 \times 10^{13}\ \text{cm})^2$
$= 3.3 \times 10^{27}$ dyne 10^{22} N

26.2 - At 1 AU, for a sail of area A, F(rad) = $(1/c)L_\odot\ (A/(4\pi a_E^2))$;
$a = F(rad)/m = (1/mc)L_\odot\ (A/(4\pi a_E^2))$; solve for $A = mac(4\pi a_E^2)/L_\odot$
$= (10^6\ \text{kg})(1\ \text{m/s}^2)\ )(3.0 \times 10^8\ \text{m/s})\ (4\pi)(1.5 \times 10^{11}\ \text{m})^2/\ (4.0 \times 10^{26}\ \text{J/s})$
$= 2 \times 10^{11}\ \text{m}^2$;
that would be 460 km on a side.

26.3 - If R is the radius of the asteroid, $\tan\theta = R/d$; since θ is small, this means
$\theta(\text{rad}) = R/d$, $R = d\ \theta(\text{rad})$

26.4 - The linear separation would be R = 100 km, and that would subtend an angle
$\theta(\text{rad}) = R/d = (100\ \text{km})(10^5\ \text{cm/km})/(3\ \text{AU})(1.5 \times 10^{13}\ \text{cm/AU})$
$= 2 \times 10^{-7}$ rad = 0.04"

26.5 - m(comet) = 10^{-9} M(Earth) ; M(Oort cloud) = 10 M(Earth); so
N = M(Oort cloud)/m(comet) = 10^{10}

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26.6 - (a)$K = (1/2)mv^2 = (1/2)[(5\ \text{g/cm}^3)(4\pi/3)(10^4\ \text{cm})^3(11 \times 10^5\ \text{cm/s})^2 = 1 \times 10^{25}$ erg. 10^{-7} J

(b) comparable to yield of nuclear weapons 10^{18} J

(c) Object leaving with vesc will reach far away with no KE, so the reverse process should produce the same speed at Earth.

26.7 - P rec by asteroid = $[L_\odot /(4\pi R^2)][4\pi r^2]$; fraction of that reflected is a; fraction of that received back at Earth is $1/(4\pi d^2)$; putting all this together
P(earth) = $[L_\odot /(4\pi R^2)][4\pi r^2][a/(4\pi d^2)]$

Chapter 27

27.1 - See problem 22.1

27.2 - M(moon) = 7.4×10^{25} g

	Mass (g)	Mass/M(moon)
Mercury	3×10^{26}	4
Venus	4.5×10^{27}	61
Earth	5.6×10^{27}	75