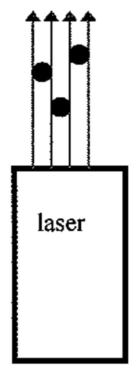
PHYC 463 Advanced Optics I
Fall 2007
Homework #2, Due Wednesday Sept. 5

1- Consider an astronaut floating in free space with only a 10 W lantern. How long will it take to reach a speed of 10 m/sec using the radiation as propulsion? The astronaut's total mass is 100 kg.

2-Problem 2.8 (K&F)

3-Problem 2.9 (K&F)



4-Suppose we want to suspend spherical particles of radius r and density ρ (gr./cm^3) in vacuum using radiation pressure.

a- Assuming the particles are highly reflecting ($R \approx 1$), what is the irradiance required to suspend these particle against earth's gravitational force?

b- For aluminum particles having ρ=2.7 gr/cm^3 and r=100 μm, calculate the suspension irradiance I_S. (Note: g=980 cm/sec^2)

Have a Safe Labor Day Weekend!

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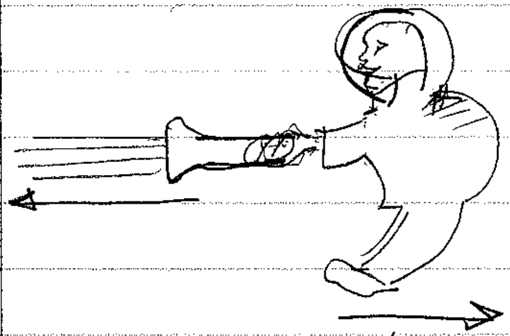
(1)

$$P = \frac{F}{A} = \frac{I}{c} \Rightarrow F = \frac{IA}{c} = \frac{P}{c}$$



$$F = m\frac{dv}{dt}$$

$$\Delta t = \frac{m\,\Delta V}{F} = \frac{mc\,\Delta V}{P}$$

$$\Delta t = \frac{100\times 3\times 10^{8}\times 10}{100} \simeq 3\times 10^{10}\ \text{sec.}$$

$$\simeq 1000\ \text{years}$$

(2)

$$I = I_0\, e^{-\alpha d} = I_0\, e^{-1} \Rightarrow \alpha = \frac{1}{d} = \frac{1}{20\times 10^{-7}} = 5\times 10^{5}\ \text{cm}^{-1}$$

$$\alpha = \frac{4\pi k}{\lambda} \Rightarrow k = \frac{\lambda\alpha}{4\pi} = \frac{4.5\times 10^{-7}\times 5\times 10^{5}}{4\pi}$$

$$k \simeq 2.05$$

3. $\tilde{n} = 4 - i2 = n - ik$

$$\epsilon = \epsilon_0 (4 - i2)^2 = 12 - 16i$$

$$e^{-\frac{z}{\delta}} = e^{-\frac{2\pi k}{\lambda} z} = e^{-\frac{\alpha}{2} z}$$

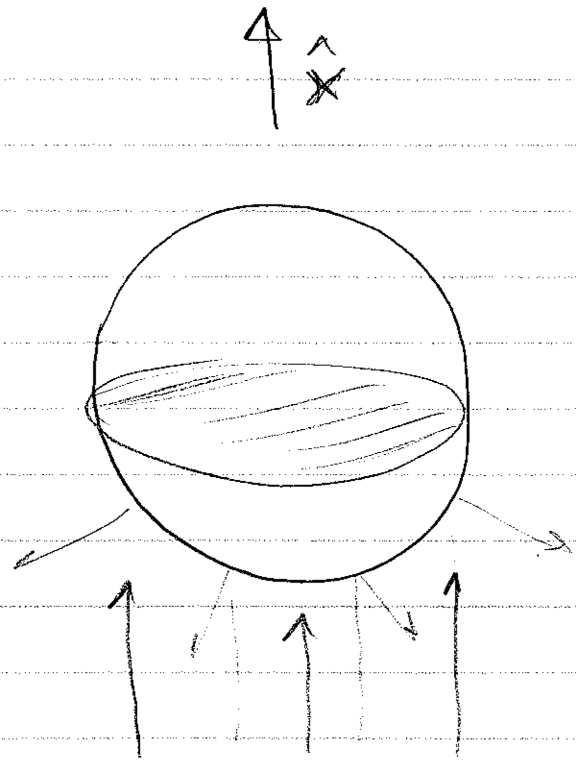
$$\delta = \frac{\lambda}{2\pi k} = \left(\frac{1}{8\pi}\right) \lambda$$

$$B = \frac{\tilde{n}}{c} \hat{s} \times \underline{E} = \frac{|\tilde{n}|}{c} \hat{s} \times E_0 \, e^{-\frac{z}{\delta}} e^{-i\varphi_{EB} + i\varphi}$$

if $E = E_0 e^{i\varphi}$

$$\varphi_{EB} = \text{Phase}(\tilde{n}) = \tan^{-1} \frac{k}{n} = \tan^{-1} \frac{2}{4} \approx 26.5^\circ$$

4.0



(a) $$F_x = \frac{I \times A_x \times 2R}{c} = mg$$

A_x = projected area (cross section) normal to $\hat{x}$

$A_x = \pi r^2$, R (reflectivity) = 1

$$F_x = \frac{I \times \pi r^2 \times 2}{c} = mg.$$

but $m = \rho V = \rho \times \frac{4\pi}{3} r^3$

Thus $$\boxed{I_s = \frac{2}{3} r \rho g c}$$

(b) $$I_s = \frac{2}{3} \times 10^{-4} \times 2.7 \times 10^{3} \times 9.8 \times 3 \times 10^{8} = 53 \ \frac{kW}{m^2}$$