REAL TEST 2 AU '13 Test 2 solutions

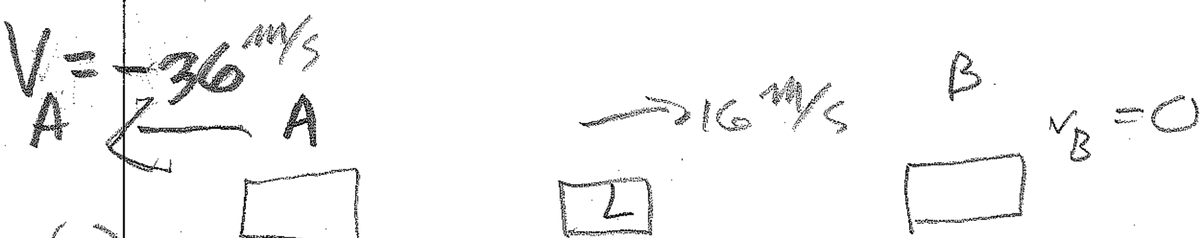
1. (40 POINTS) Two train whistles A and B, have a frequency of 390 Hz. B is stationary and A moves left away from B with speed 36.0 m/s. A listener is between the two trains and moving rightward toward the stationary train B with speed 16.0 m/s. No wind is blowing.

speed of sound = 340 m/s

(a) (15 points) What is the frequency from A as heard by the listener?

(b) (15 points) What is the frequency from B as heard by listener ?

(c) (10 points) What is the beat frequency from the two whistles that the listener picks up with an electronic detector? Can the listener detect the frequency with her own ears? Explain.



a. $390\cdot\left(\frac{V}{V+V_S}\right)\cdot\left(\frac{V-V_L}{V}\right) = (390)\left(\frac{V-V_L}{V+V_S}\right)$

$= (390)\left(\frac{340-16}{340+36}\right) = 336.06\ Hz$

b. $(390)\left(\frac{V+V_L}{V}\right) = (390)\left(\frac{340+16}{340}\right) = 408.35\ Hz$

c. $408.35 - 336.06 = 72.29\ Hz$

2. (20 POINTS)

A beaker with negligible mass contains 0. 275 kg of water at temperature 80.0 °C. Suppose 62.0 g of ice at a temperature of -16.0 °C is dropped into the water. $C_i = 0.50 \frac{cal}{g°C}$ $L_f = 80 \frac{cal}{g}$ $C_w = 1.0 \frac{cal}{g°C}$

(a) (2) How would you describe the *final* system after it comes to equilibrium? (i) pure ice (ii) a mixture of ice an water or (iii) pure water. Please circle one. NOTE: [redacted] ANSWER SHOULD BE CONSISTENT WITH YOUR ANSWER TO PART (b)

(b) (16) What is the final temperature of the system?

(c) (4 points) What mass of ice would be needed to cause to system to be pure ice at 0 °C? Does your answer seem reasonable? Explain.

(a) PURE WATER m_i

(b) $(62)(0.50)(16) + (62)(80) + (62)(1)(T_f - 0)$

$= (275)(1)(80 - T_f)$

$496 + 4960 + 62T_f$

$= 22000 - 275T_f$

$(62+275)T_f = 16544$

$337T_f = 16544$

$T_f = 49.1\,°C$

(c) $m_i(0.50)(16) = (275)(1)\cdot 80 + (275)(80)$

$m_i = \dfrac{22000 + 22000}{8}$

$= 5500\,g$
$= 5.5\,kg$

3. (40 POINTS) The outer diameter of a glass jar and the inner diameter of its iron lid are both 722 mm at room temperature 21.0 °C.

$\alpha_g = 0.50\times10^{-5}\,(^\circ C)^{-1}$ and $\alpha_{Fe} = 1.2\times10^{-5}\,/(^\circ C)^{-1}$

(a) (30 points) What will be the size of the *difference* in these diameters if the lid and glass are *both* held under hot water until they *both* reach the temperature of 51.0 ° C?

(b) (10 points) What rise in temperature for both the glass and the lid would be required if the difference in the diameters was 1 mm? Does your answer seem reasonable ? Explain.

(a) $\Delta D = (\alpha_{Fe} - \alpha_g)(0.722\text{ m})(30^\circ C)$

$= (0.70\times10^{-5})\underbrace{(0.722)(30)}$

$(0.0000070)(21.66)$

$= 1.51\times10^{-4}$

$= 0.151\times10^{-3}$

$= 0.151$ mm

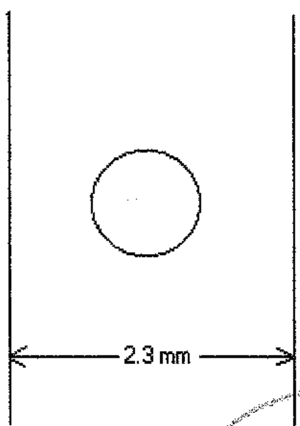
(b) $1\times10^{-3} = (0.70\times10^{-5})(0.722)\cdot\Delta T$

$\dfrac{1.4\times10^{2}}{0.722} = 1.97\times10^{2} = \Delta T$

$= \boxed{197\,^\circ C = \Delta T}$

4. (40 POINTS) In the figure below, a laser beam of power 4.1 x10^2 W and diameter 2.3 mm is directed upward at a solid spherical bead (of diameter < 2.3 mm) . The radiation pressure exerted by the beam causes the bead to float in space with zero acceleration. The bead reflects ~~90 %~~ of the radiation and absorbs the rest of it. The density of the bead is 0.20 x10^4 kg/m^3.

0 → 70%



$$\frac{1.7I}{c}\cdot\pi r^2 = \frac{4}{3}\pi r^3\cdot\rho\cdot g$$

(8) $$\frac{1.7\cdot I}{c} = \frac{4}{3}r\cdot\rho\cdot g$$

$$r = \frac{3\cdot(1.7)I}{4\rho g c}$$

$$I = \frac{4.1\times10^2}{\pi d^2/4} = \frac{4.1\times10^2}{\pi\frac{(2.3\times10^{-3})^2}{4}}$$

(a) (18 points) What is the radius r of the bead ?
(b) (10 points) Suppose the magnetic field equations for the plane electromagnetic wave of the incident beam are:

$$I = \frac{4.1\times10^2\cdot4}{\pi\cdot(2.3\times10^{-3})^2}$$

$B_x = 0$
$B_y = B_m\cos(kx-\omega t)$
$B_z = 0$

See the axes on next page.

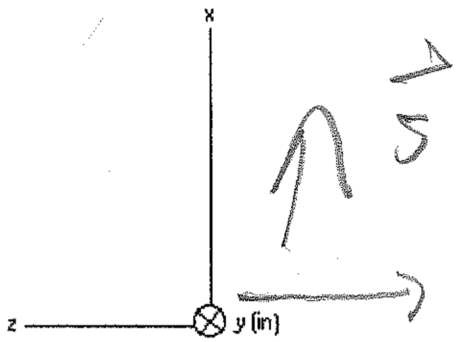
$$\frac{(4.1)(4)\times10^2}{(3.14)(5.29)\times10^{-6}}$$

$$\frac{16.4\times10^8}{(3.14)(5.29)} = 0.9873\times10^8\ \frac{W}{m^2}$$

$$r = \frac{(3)(1.7)(0.987\times10^8)}{(4)(2000)(9.8)(3\times10^8)}$$

$= 2.14\times10^{-5}$ m

$= 0.0214^{-3}$ mm



Write the electric field equations in the blanks below for the incident beam.(Use symbols.)

E_X = 0 **E_Y =** 0 **E_Z =** $-cB_m \cdot \cos(kx-\omega t)$

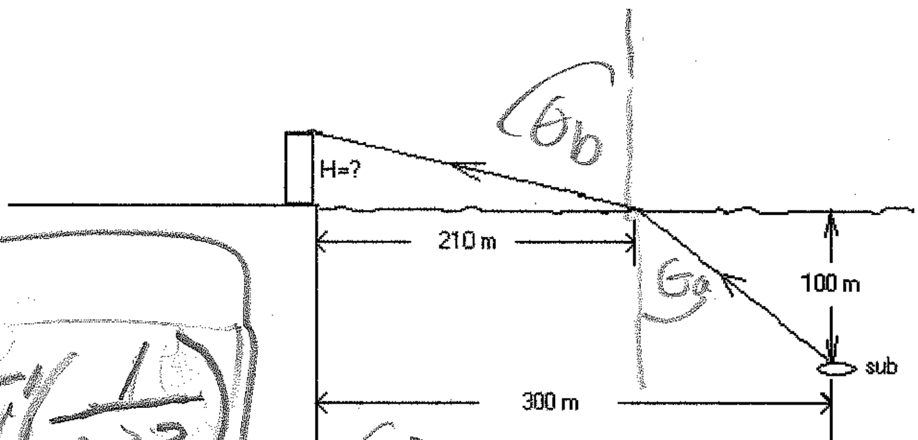
(c) (2 points) What is the numerical value E_m of the electric field amplitude ?

$I = \frac{E_m^2}{2\mu_0 c} \rightarrow E_m = 2.73\times10^5 \frac{V}{m}$

[redacted]

5. (20 points) A submarine (aka sub) is 300 m horizontally out from the shore and 100 m <u>beneath the surface of the water.</u> Please see the diagram below. A laser beam is sent from the sub so that it strikes the surface of the water at a point 210 m from the shore.

(a) (8) If the beam just strikes the top of a building standing directly at the water's edge, find the height H of the building. Assume that $n_{AIR} = 1$ and $n_{WATER} = 1.33$.
(b) (12) What would be the maximum vertical depth d of the submarine below the water surface in order for *total internal refection* to occur where light leaving the sub strikes the surface?



(b)

$\theta_c = \sin^{-1}\left(\frac{1}{1.33}\right)$

$= 48.75$

$\tan 48.75 = \frac{90}{d}$

$\to d = \frac{90}{\tan 48.75} = 78.9$ (m)

(a)

$\tan\theta_a = \frac{90}{100} \Rightarrow \theta_a = 41.98°$

$1.33 \cdot \sin 41.98 = (1)\sin\theta_b$

$\sin\theta_b = 0.8896$

$\Rightarrow \theta_b = 62.8°$

$\tan 62.8° = \frac{210}{H} \to H = 107.9$ (m)