PY111 Midterm 1

NAME: LAST FOUR DIGITS OF SSN:

Answer in the space provided. You may use the backs of sheets if required. Box your answers on questions 2 and 3. There are 30 possible points in this midterm.

written response

[4] 1. Briefly explain the importance of *modelling* in physics.

There were two main points discussed in class: modelling makes it possible to answer problems without being encumbered with too much detail. Modelling allows one to extract generalizations.

partial credit questions

[6] 2. A string is held under tension by passing one end over a massless pulley and attaching it to a weight of mass $M = 2.5$ kg. (a) If M is doubled, what happens to the fundamental frequency of the string? (b) The weight is now charged to a value $+Q$ and another charge $+Q$ is placed 50 cm below the mass. Determine the charge Q such that the fundamental frequency is halved. You may use Coulomb's Law.

(a) Common experience tells us that a string under higher tension has a higher frequency of vibration. The formulas below show that $v \propto \sqrt{T}$ *where* T *is the tension. Since* M *is doubled,* T *is doubled,* v *goes up by* $\sqrt{2}$*, and finally* $f_1 = v/2L$ *goes up by* $\sqrt{2}$.

(b) In this case there is an extra repulsive force (given by Coulombs Law) on the mass, lowering the tension, and hence f_1*. Since* $T + F_{coulomb} = Mg$ *we have* $T_{new} = Mg - F_c$ *which we want to be* $T_{old}/4$ *to make* f_1 *half of what it was. Since* $T_{old} = Mg$ *we have* $F_c = 3/4Mg$*. Finally, solving for* Q *gives* $Q = 2.26 \cdot 10^{-5}$ *C.*

[5] 3. Three charges are placed as follows: $q_1 = +5\mu C$ at $r_1 = (0, 4cm)$; $q_2 = -5\mu C$ at $r_2 = (0, -4cm)$, and $q_3 = -8\mu C$ at $r_3 = (6cm, 0)$. Determine the magnitude and direction of the total force on q_3.

The x *components of the forces cancel, leaving a total force vector pointing in the* $+\hat{y}$ *direction. Its magnitude is given by* $2 \cdot F_{13} \sin(\theta)$ *where* $\tan\theta = 4/6$ *and* F_{13} *= 69.1 N by Coulomb's Law. The final result is* $F_{total} = 76.6$ *N up.*

multiple choice questions

[3] 4. A siren approaches you at 30 m/s. Assuming that the speed of sound is 343 m/s and that the siren emits sound with a wavelength of 10 cm, what frequency sound do you hear?

The frequency sound you hear is given by the Doppler shift formula: $f_o = f_s/(1 - v_s/v)$. *Using* $v = \lambda f$ *we get* $f_s = 3430$ *Hz and hence* $f_o = 3758$ *Hz.*

a. 3154 Hz
b. 3730 Hz
c. 3760 Hz
d. 3800 Hz

[3] 5. A sound is emitted uniformly in all directions by a speaker. The intensity of the sound at 22 m from the speaker is $3.0 \cdot 10^{-4} W/m^2$. What is the intensity at a spot 78 m from the speaker?

The sound intensity is defined to be $I = P/A$, *since* $A = 4\pi r^2$ *we see that* $I(78) = I(22) \cdot (22/78)^2 = 2.38 \cdot 10^{-5}$ W/m^2.

a. $1.2 \cdot 10^{-5} W/m^2$
b. $2.4 \cdot 10^{-5} W/m^2$
c. $8.5 \cdot 10^{-5} W/m^2$
d. $1.1 \cdot 10^{-3} W/m^2$

[3] 6. Use Gauss's Law to determine the electric field at a radius r from the center of an insulating sphere of radius a. Assume that the total charge of the sphere is Q and that this charge is uniformly distributed throughout the sphere. Take $r < a$.

Surround the charge with a Gaussian sphere of radius $r < a$. *Since the field is perpendicular to the surface and constant over the surfaces (rules 2 and 3) we get the simple form of Gauss's Law:*

$E(r) \cdot 4\pi r^2 = Q_{inc}/\epsilon_0 = Qr^3/a^3\epsilon_0$ *giving (d) below.*

a. $\frac{Q}{4\pi\epsilon_0 r^2}$
b. $\frac{Q}{2\pi\epsilon_0 r}$
c. $\frac{\lambda}{\epsilon_0}$
d. $\frac{Qr}{4\pi\epsilon_0 a^3}$

[3] 7. What is the magnitude of the electric field at the origin if four charges are placed at the corners of a square which is centered on the origin. Take the charges to all have $q = 4nC$ and the length of one side of the square to be $1cm$.

The fields of all the charges cancel at the origin so the answer is (a).

a. $E = 0N/C$
b. $E = 20.3N/C$
c. $E = 20.3kN/C$
d. $E = 5kN/C$

[3] 8. Two identical speakers are placed at the origin and at $r = (0, -1.2m)$. A microphone picks up the sound they create at the point $r = (-4m, 0)$. Determine the lowest frequency required for the sound to be in phase at the microphone. Take the speed of sound to be $v = 343$ m/s.

The distance travelled by the two waves must differ by a multiple of a wavelength for the waves to be in phase. Thus $L_2 - L_1 = n\lambda = nv/f$. *Or* $f = nv/(L_2 - L_1) = 343/0.176 = 1950$ *Hz.*

Note typo is answers! Everyone gets 100 on this problem...

a. 2330 Hz
b. 2500 Hz
c. 4660 Hz
d. 1.2 kHz

equations

$v = \lambda f \qquad v = \sqrt{TL/m} \qquad v = \sqrt{B_{ad}/\rho} \qquad v = \sqrt{Y/\rho}$

$y = A\sin(2\pi ft \pm 2\pi x/\lambda) \qquad I = P/A \qquad \beta = (10db)\log(I/I_0)$

$f_o = f_s\frac{v \pm v_o}{v \mp v_s} \qquad \sin\theta = \lambda/D \qquad \sin\theta = 1.22\lambda/D \qquad f_n = \frac{nv}{2L}$

$F = \frac{|q_1||q_2|}{4\pi\epsilon_0 r^2} \qquad \epsilon_0 = 8.85 \cdot 10^{-12} \qquad |q_e| = 1.6 \cdot 10^{-19}\text{C}$

$E = F/q_0 \qquad E = \sigma/\epsilon_0 \qquad \Phi_E = \int E\cos\phi dA = Q/\epsilon_0$

$V = \frac{4}{3}\pi r^3 \qquad A = 4\pi r^2 \qquad A = 2\pi rL \qquad V = \pi r^2 L$