March 23, 2012.

SOLUTIONS

Name (please print):
Signature:
Student number:

PHYS 1420 06 – Physics with Applications to Life Sciences
Test 4A

Answer all questions in the space provided on this test paper. Use pen to write.
Formulae are provided on the last page.

1. (6 marks)

A noisy machine in a factory produces a sound intensity of 1.00×10^{-5} W/m^2.

a. Calculate the sound intensity level of the machine.

$$\beta_1 = 10 \log \frac{I_1}{I_0} = 10 \log \frac{1.00 \times 10^{-5}\ W/m^2}{10^{-12}\ W/m^2} = 10 \log 10^7 = 70\ dB$$

b. An average person perceives sound as twice as loud if the sound intensity level increases by 10 dB. How many machines would have to work at the same time to produce sound twice as loud as one machine? Show calculations!

$$\beta_n = 10 \log \frac{I_n}{I_0} \quad , \quad \beta_n = 70\ dB + 10\ dB = 80\ dB$$

$$80\ dB = (10\ dB) \log \frac{I_n}{10^{-12}}$$

$$8 = \log \frac{I_n}{10^{-12}}$$

$$\frac{I_n}{10^{-12}} = 10^8 \Rightarrow I_n = 10^{-4}\ W/m^2$$

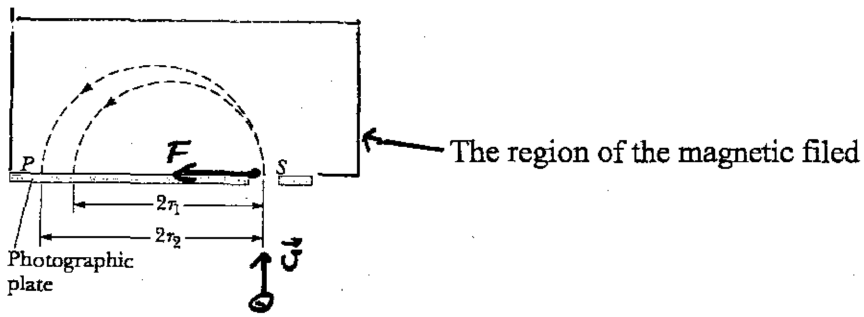
$$n = \frac{I_n}{I_1} = \frac{10^{-4}\ W/m^2}{1.00 \times 10^{-5}\ W/m^2} = 10\ \text{MACHINES}$$

c. Hair cells located in the cochlea start to be permanently damaged when the sound intensity level exceeds

1. 150 dB
2. 120 dB
3. 100 dB
4. 90 dB
5. 85 db (circled)

2. (7 marks).

Two singly ionized isotopes of uranium: uranium-235 (mass 3.90×10^{-25} kg, charge $q = -1.6 \times 10^{-19}$ C) and unranium-238 (mass 3.95×10^{-25} kg, $q = -1.6 \times 10^{-19}$ C), each having speed $v = 3.00 \times 10^{5}$ m/s, enter a uniform magnetic field B = 0.6000 T through the slit S. In the magnetic field both ions moves along a semi-circular path before they are detected using the photographic plate (see figure below).



a. What is the direction of the magnetic field?

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b. What is the magnitude and direction of the magnetic force acting on each isotope at the moment when they enter the magnetic filed?

$$\vec{F} = q\vec{v} \times \vec{B}$$

$$F = qvB \sin 90^\circ = |(1.6 \times 10^{-19} C)(3.00 \times 10^{5} m/s)(0.600 T)| \sin 90^\circ = 2.9 \times 10^{-14} N$$

$F = 2.9 \times 10^{-14}$ N, DIRECTION: TO THE LEFT, AS SHOWN ABOVE.

c. Show that the radius of the semi-circular path is given by the following formula: r = mv/qB.

$$F = ma \qquad a_c = \frac{v^2}{r}$$

$$qvB = m\frac{v^2}{r}$$

$$r = \frac{mv}{qB}$$

d. Which of the two isotopes strikes the photographic plate first?

URANIUM-235 (SMALLER MASS, SMALLER RADIUS)

e. How much time does it take uranium-235 to travel from the slit S to the photographic plate?

$$v = \frac{\text{DISTANCE}}{\text{TIME}} = \frac{\pi r}{t}$$

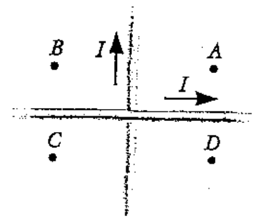
$$t = \frac{\pi r}{v} = \frac{\pi\left(\frac{mv}{qB}\right)}{v} = \frac{\pi m}{qB} = \frac{\pi(3.90 \times 10^{-25} kg)}{(1.6 \times 10^{-19} C)(0.600 T)} = 1.3 \times 10^{-5} s$$

3. (8 marks).

Answer the following four multiple-choice questions.

a. Two long, straight wires cross each other at right angles, each carries the same current, as shown below. The magnetic field produced by both wires is strongest at the following point(s).

1. A
2. B
3. C
4. D
5. B and D
6. A and C



b. A techniques called magnetoencephalography (MEG) is used to study electrical activity in the brain. This technique is capable of detecting magnetic fields as weak as 1.0×10^{-15} T. What current a neuron must carry to produce the magnetic field that can be detected by the MEG technique at a distance of 4.0 cm? The neuron can be modelled as a long wire carrying a current.

1. 4.0×10^{-5} A
2. 2.0×10^{-2} A
3. 1.6×10^{-19} A
4. 8.0×10^{-5} A
5. 2.0×10^{-10} A

$B = \frac{\mu_0 I}{2\pi r} \Rightarrow I = \frac{(2\pi r)(B)}{\mu_0} = \frac{2\pi(0.04\,m)(1.0\times10^{-15}\,T)}{4\pi\times10^{-7}\,Tm/A}$

$I = 2.0\times10^{-10}\,A$

c. The following statement is true regarding a plane electromagnetic wave.

1. The electric field is always larger than the magnetic field.
2. The electric field and the magnetic field reach their maximum magnitudes at the same time and at the same point in space.
3. The electric field reaches its maximum value when the magnetic field is equal to zero.
4. The electric field is parallel to the magnetic field.
5. Electromagnetic waves can not form standing waves.

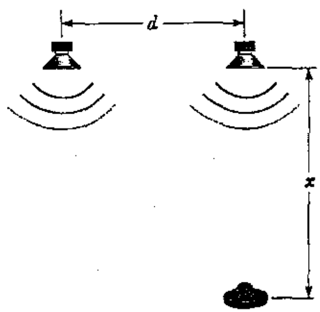
d. The longest wavelengths that an average person can hear is approximately equal to:

1. 0.017 m
2. 0.058 m
3. 17 m
4. 58 m
5. 6860 m

$v = \lambda f$ or $\lambda = \frac{v}{f} = \frac{343\,m/s}{20\,Hz} \approx 17\,m$

4. (4 marks).

A pair of speakers separated by a distance d = 0.90 m are driven by the same signal generator. An observer originally positioned at one of the speakers begins to walk along a line perpendicular to the line joining the speakers and detects the first constructive interference of sound at x = 2.50 m. What is the frequency of sound produced by the two speakers? Speed of sound in air v = 343 m/s.



$$r_2 - r_1 = n\lambda, \quad n = 1$$

$$\lambda = \frac{v}{f} = \frac{343\ m/s}{f}$$

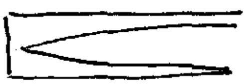
$$\sqrt{d^2 + x^2} - x = \frac{343\ m/s}{f}$$

$$\sqrt{(0.90m)^2 + (2.50m)^2} - 2.50m = \frac{343\ m/s}{f}$$

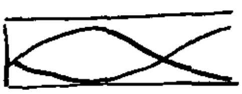
$$f = 2180\ Hz.$$

5. (6 marks).

a. A human ear canal can be thought of as a pipe L = 2.8 cm long open at one end and closed at the other end by the eardrum. Calculate frequencies of first two harmonics (standing waves) that can be created in the ear canal. Draw the wave envelopes for these two standing waves. Speed of sound in air v = 343 m/s.

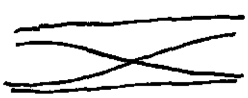


$f_1 = \frac{v}{\lambda_1}$, $L = \frac{\lambda_1}{4} \Rightarrow \lambda_1 = 4L$, $f_1 = \frac{v}{4L} = \frac{343\ m/s}{(4)(0.028\ m)} = 3062\ Hz$



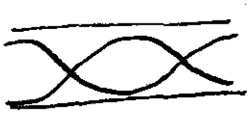
$f_2 = \frac{v}{\lambda_2}$, $L = \frac{3}{4}\lambda_2 \Rightarrow \lambda_2 = \frac{4L}{3}$, $f_2 = \frac{3v}{4L} = \frac{(3)(343\ m/s)}{(4)(0.028\ m)} = 9187\ Hz$

a. Some organ pipes are tubes open at both ends. If this type of organ pipe is 60.0 cm long, what are the wavelengths of the lowest two harmonics (standing waves) that can be created in the pipe? Draw wave envelopes for these two standing waves.



$f_1 = \frac{v}{\lambda_1}$ $L = \frac{\lambda_1}{2} \Rightarrow \lambda_1 = 2L$,

$\lambda_1 = 1.2\ m$



$f_2 = \frac{v}{\lambda_2}$ $L = \lambda_2$,

$\lambda_2 = 60\ cm$

$B = \frac{\mu_0 I}{2\pi r}$, $B = \frac{\mu_0 N I}{L}$, $B = \frac{\mu_0 N I}{2R}$, $\mu_0 = 4\pi \times 10^{-7}\ \frac{Tm}{A}$

$\vec{F} = q\vec{v}\times\vec{B}$, $F = qvB\sin\theta$, $1T = 10^4 Gs$

$v = \lambda f$, $f = \frac{1}{T}$, $v = \sqrt{\frac{T}{\mu}}$, $\mu = \frac{m}{L}$, $v = \sqrt{\frac{B}{\rho}}$

$I = \frac{P}{A}$, $I = \frac{P}{4\pi r^2}$, $\beta = 10 \log \frac{I}{I_0}$, $I_0 = 10^{-12}\ W/m^2$

$r_2 - r_1 = n\lambda$, $r_2 - r_1 = (n + \frac{1}{2})\lambda$, $\sin\theta = \frac{n\lambda}{d}$, $\sin\theta = \frac{(n+\frac{1}{2})\lambda}{d}$

$I = I_0 \cos^2\theta$, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, $n = \tan\theta_B$