

UNIVERSITY OF FORT HARE

PHY123F

**SUPPLYMENTARY
EXAMINATIONS**

January / February 2019

Time: 3 HOURS

Subject: Oscillations, Waves and Optics

Marks: 100

This paper consists of 8 pages including cover page

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Instructions

- Answer all questions of your choice
- Read the question more than once and clearly write down your data.
- On-problem solving, specify useful definitions and draw clearly labeled diagrams.

Formula sheet (PHY123F)

$$F_s = -kx, \quad a_x = -\frac{k}{m}x, \quad \omega = \sqrt{\frac{k}{m}}, \quad x(t) = A \cos(\omega t + \phi), \quad v(t) = -A \omega \sin(\omega t + \phi),$$

$$a(t) = -A \omega^2 \cos(\omega t + \phi), \quad v_{\max} = A \omega, \quad a_{\max} = A \omega^2, \quad KE = \frac{1}{2} m v^2, \quad U = \frac{1}{2} k x^2, \quad E_{\text{tot}} = \frac{1}{2} k A^2,$$

$$v^2 = \omega^2 (A^2 - x^2), \quad \theta = \theta_{\max} \cos(\omega t + \phi), \quad \omega = \sqrt{\frac{g}{L}}, \quad T = \frac{2\pi}{\omega}, \quad R = -bv, \quad \omega = \sqrt{\omega_0^2 - \left(\frac{b}{2m}\right)^2},$$

$$x(t) = A e^{-(\frac{b}{2m})t} \cos(\omega t + \phi), \quad y(x, t) = A \cos(kx \pm \omega t + \theta), \quad \omega = 2\pi f, \quad f = \frac{1}{T}, \quad k = \frac{2\pi}{\lambda},$$

$$v = \lambda f = \frac{\omega}{k}, \quad v = \frac{\lambda}{T}, \quad v = \sqrt{\frac{F}{\mu}}, \quad K = U = \frac{1}{4} \mu \omega^2 A^2 \lambda, \quad E = \frac{1}{2} \mu \omega^2 A^2 \lambda, \quad v = \sqrt{\frac{B}{\rho}},$$

$$P = \frac{1}{2} \mu \omega^2 A^2 v, \quad \Delta P(x, t) = \Delta P_{\max} \sin(kx \pm \omega t), \quad v = \sqrt{\frac{Y}{\rho}}, \quad v = (331 \text{ m/s}) \sqrt{1 + \frac{T_c}{273^{\circ} \text{C}}},$$

$$\Delta P_{\max} = \rho v \omega s_{\max}, \quad K_{\lambda} = U_{\lambda} = \frac{1}{4} (\rho A) \omega^2 s_{\max}^2 \lambda, \quad I = \frac{P}{A}, \quad I = \frac{P}{4\pi r^2}, \quad E_{\lambda} = \frac{1}{2} (\rho A) \omega^2 s_{\max}^2 \lambda,$$

$$P = \frac{1}{2} (\rho A) v (\omega s_{\max})^2, \quad I = \frac{1}{2} \rho v (\omega s_{\max})^2, \quad I = \frac{(\Delta P_{\max})^2}{2\rho v}, \quad x = \frac{n\lambda}{2}, \quad x = \frac{n\lambda}{4}, \quad f_n = \frac{nv}{2L}, \quad n = \frac{c}{v},$$

$$f_n = \frac{nv}{4L}, \quad f_n = n f_1, \quad \beta = 10 \log\left(\frac{I}{I_0}\right), \quad f_o = \left(\frac{v+v_s}{v-v_s}\right) f_s, \quad y = y_1 + y_2 = (2A \sin kx) \cos \omega t,$$

$$y = y_1 + y_2 = 2A \cos\left(\frac{\phi}{2}\right) \sin\left(kx \pm \omega t + \frac{\phi}{2}\right), \quad n_1 \sin \theta_1 = n_2 \sin \theta_2, \quad \sin \theta_c = \frac{n_2}{n_1},$$

$$M = \frac{h'}{h} = -\frac{p}{q}, \quad \frac{1}{p} + \frac{1}{q} = \frac{2}{R}, \quad f = \frac{2}{R}, \quad \frac{1}{p} + \frac{2}{q} = \frac{2-n}{R},$$

Constants (PHY123F)

$$v_{\text{sound}} = 343.0 \text{ m/s}, \quad I_o = 1.00 \times 10^{-12} \text{ W/m}^2,$$

TABLE 35.1 *Indices of Refraction*

Substance	Index of Refraction	Substance	Index of Refraction
<i>Solids at 20°C</i>		<i>Liquids at 20°C</i>	
Cubic zirconia	2.20	Benzene	1.501
Diamond (C)	2.419	Carbon disulfide	1.628
Fluorite (CaF ₂)	1.434	Carbon tetrachloride	1.461
Fused quartz (SiO ₂)	1.458	Ethyl alcohol	1.361
Gallium phosphide	3.50	Glycerin	1.473
Glass, crown	1.52	Water	1.333
Glass, flint	1.66		
Ice (H ₂ O)	1.309	<i>Gases at 0°C, 1 atm</i>	
Polystyrene	1.49	Air	1.000 293
Sodium chloride (NaCl)	1.544	Carbon dioxide	1.000 45

Note: All values are for light having a wavelength of 589 nm in vacuum.

TABLE 14.1

Densities of Some Common Substances at Standard Temperature (0°C) and Pressure (Atmospheric)

Substance	ρ (kg/m ³)	Substance	ρ (kg/m ³)
Air	1.29	Ice	0.917×10^3
Aluminum	2.70×10^3	Iron	7.86×10^3
Benzene	0.879×10^3	Lead	11.3×10^3
Copper	8.92×10^3	Mercury	13.6×10^3
Ethyl alcohol	0.806×10^3	Oak	0.710×10^3
Fresh water	1.00×10^3	Oxygen gas	1.43
Glycerin	1.26×10^3	Pine	0.373×10^3
Gold	19.3×10^3	Platinum	21.4×10^3
Helium gas	1.79×10^{-1}	Seawater	1.03×10^3
Hydrogen gas	8.99×10^{-2}	Silver	10.5×10^3

Medium	v (m/s)	Medium	v (m/s)
Gases		Liquids at 25°C	
Hydrogen (0°C)	1 286	Glycerol	1 904
Helium (0°C)	972	Seawater	1 533
Air (20°C)	343	Water	1 493
Air (0°C)	331	Mercury	1 450
Oxygen (0°C)	317	Kerosene	1 324
		Methyl alcohol	1 143
		Carbon tetrachloride	926

Medium	v (m/s)
Solids^a	
Pyrex glass	5 640
Iron	5 950
Aluminum	6 420
Brass	4 700
Copper	5 010
Gold	3 240
Lucite	2 680
Lead	1 960
Rubber	1 600

TABLE 17.2

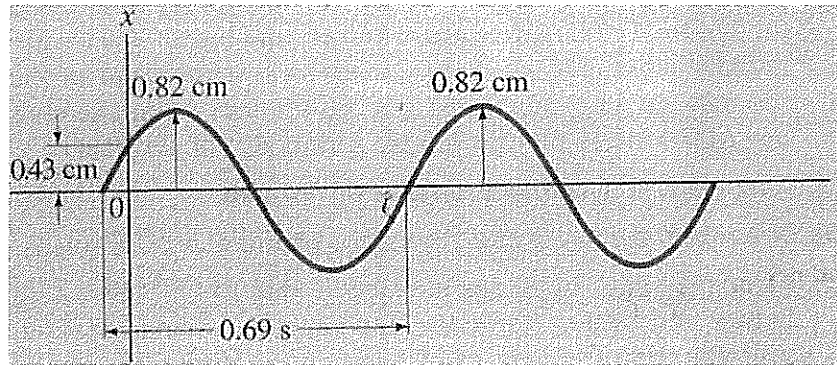
Sound Levels

Source of Sound	β (dB)
Nearby jet airplane	150
Jackhammer; machine gun	130
Siren; rock concert	120
Subway; power lawn mower	100
Busy traffic	80
Vacuum cleaner	70
Normal conversation	50
Mosquito buzzing	40
Whisper	30
Rustling leaves	10
Threshold of hearing	0

Question 1

(Oscillatory Motion)

- 1.1. The graph of displacement versus time for a small mass ($m = 0.0143 \text{ kg}$) at the end of spring is shown in figure below.



- 1.1.1. Write the equation for displacement x as a function of time t . (5)

- 1.1.2. Determine the potential (U), kinetic (KE) and mechanical (E_{tot}) energies of the system at $t = 0.173 \text{ s}$. (10)

- 1.2. A particle executes simple harmonic motion with amplitude of 3.00 cm . At what position does its speed equal one third of its maximum speed? (5)
[20]

Question 2

(Wave Motion)

- 2.1. With what tension must a rope with length 2.50 m and mass 0.120 kg be stretched for a transverse wave of frequency 40.0 Hz to have wavelength of 0.750 m ? (4)

- 2.2. Show that the wave function $y = \ln[b(x - vt)]$ is a solution of the linear wave equation

$$\frac{\partial^2 y}{\partial x^2} - \frac{1}{v^2} \frac{\partial^2 y}{\partial t^2} = 0 \quad \text{where } b \text{ is a constant} \quad (8)$$

- 2.3. A transverse wave on a string is described by the wave function

$$y = (0.120 \text{ m}) \sin\left(\frac{\pi}{8} x + 4\pi t\right)$$

- 2.3.1. Determine the transverse speed and acceleration of the string at $t = 0.200 \text{ s}$ for the point on the string located at $x = 1.60 \text{ m}$. (5)

2.3.2. What are the wavelength, period and the speed of propagation of the wave? (3)

[20]

Question 3 (Sound Waves)

3.1. A sound wave in air has a pressure amplitude equal to $4.0 \times 10^{-3} \text{ N/m}^2$. Calculate the displacement amplitude of the wave at frequency of 10 KHz. (4)

3.2.. A harmonic wave with wavelength of 0.27 m moves with speed 13 m/s. Find the wave number k and the frequency f of this wave. (4)

3.3. Standing at a crosswalk, you hear a frequency of 560 Hz from the siren of an approaching ambulance. After the ambulance passes, the observed frequency of the siren is 480 Hz. Determine the ambulance's speed from these observations. (6)

3.4. A series of noises have intensities $8.3 \times 10^{-4} \text{ W/m}^2$, and $7.2 \times 10^{-9} \text{ W/m}^2$, respectively. What is the sound level of each in decibels? (6)

[20]

Question 4

(Superposition and Standing Waves)

4.1. Two travelling sinusoidal waves are described by the wave functions $y_1 = (5.00 \text{ m})\sin[\pi(4.00x - 1200t)]$ and $y_2 = (5.00 \text{ m})\sin[\pi(4.00x - 1200t - 0.250)]$ where y_1 and y_2 are in meters and t is in seconds.

4.1.1. What is the amplitude of the resultant wave? (3)

4.1.2. What is the frequency of the resultant wave? (2)

4.2. Calculate the length of a pipe that has a fundamental frequency of 240 Hz assuming the pipe is

4.2.1 closed at one end (3)

4.2.2. open at both ends. (3)

4.3. A standing wave pattern is observed in a thin wire with a length of 3.00 m. The wave function is $y = (0.002 \text{ m})\sin(\pi x)\cos(100\pi t)$ where x is in meters and t is in seconds.

4.3.1. How many loops does this pattern exhibit? (3)

4.3.2. What is the fundamental frequency of vibration of the wire? (3)

4.3.3. If the original frequency is held constant and the tension in the wire is increased by a factor of 9, how many loops are present in the new pattern? (3)

[20]

Question 5

(Light and Optics)

5.1. Light travelling in air is incident on the surface of a block of plastic at an angle of 62.7° to the normal and is bent so that it makes a 48.1° angle with the normal in the plastic. Find the speed of light in the plastic. (5)

5.2. Light in air enters a stack of three parallel plates with indices of refraction 1.50, 1.55, and 1.60, respectively. The incident beam makes a 60.0° angle with the normal to the plate surface. At what angle does the beam emerge into the air after passing through the stack? (7)

5.3. The critical angle for total internal reflection at a liquid–air interface is 42.5° .

5.3.1. If a ray of light travelling in the liquid has an angle of incidence at the interface of 35.0° , what angle does the refracted ray in the air make with the normal? (4)

5.3.2. If a ray of light travelling in air has an angle of incidence at the interface of 35.0° , what angle does the refracted ray in the liquid make with the normal? (4)

[20]