MIDTERM EXAM #1 (FORM A)

PHYSICS 1B LECTURE 4

INSTRUCTOR: HECTOR GARCIA VASQUEZ

Tuesday, April 23rd, 2019

10:00 AM – 10:50 AM

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DO NOT TURN PAGE UNTIL INSTRUCTED

You will have 50 minutes to complete this exam. One standard 3" x 5" index note card is permitted. Books and all other notes are not allowed. Scientific and graphing calculators are allowed. All other electronics are not allowed and must be put away. Both pen and pencil are allowed.

Please write your answer in the space below the problem. Scratch paper will be provided. **You must write legibly and demonstrate your reasoning to get full credit.** For clarity, please draw a box around your final answer.

Q1	17
Q2	20
Q3	16
Q4	20
Q5	20
TOTAL	93

Trig Identities

$$\cos\left(\theta \pm \frac{\pi}{2}\right) = \mp\sin(\theta)$$

$$\cos(\pi \pm \theta) = -\cos(\theta)$$

$$\cos(\alpha \pm \beta) = \cos(\alpha)\cos(\beta) \mp \sin(\alpha)\sin(\beta)$$

$$\cos(\alpha) + \cos(\beta) = 2\cos\left(\frac{\alpha+\beta}{2}\right) + \cos\left(\frac{\alpha-\beta}{2}\right)$$

$$\cos(\alpha) - \cos(\beta) = -2\sin\left(\frac{\alpha+\beta}{2}\right) + \sin\left(\frac{\alpha-\beta}{2}\right)$$

$$\sin\left(\theta \pm \frac{\pi}{2}\right) = \pm\cos(\theta)$$

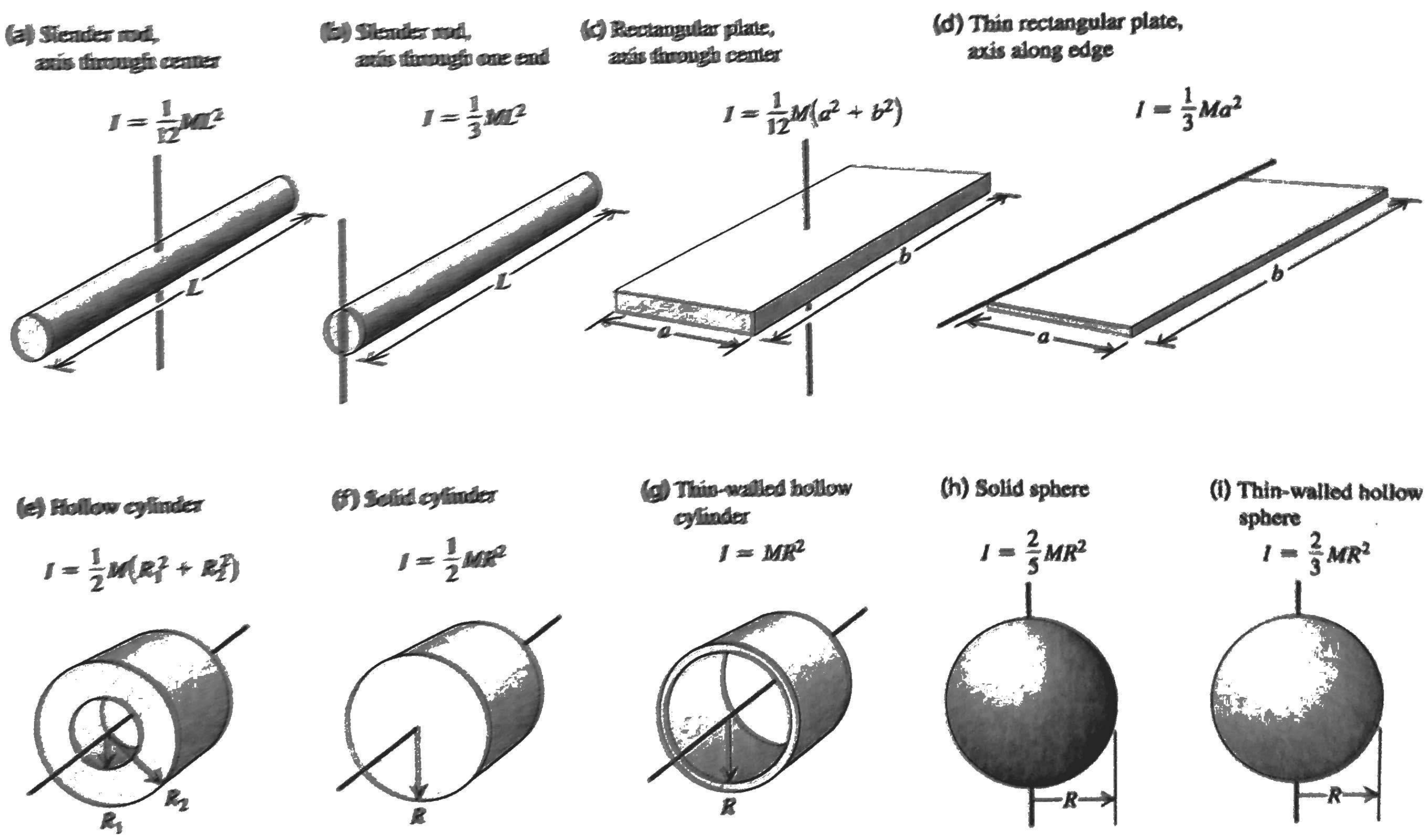
$$\sin(\pi \pm \theta) = \mp\sin(\theta)$$

$$\sin(\alpha \pm \beta) = \sin(\alpha)\cos(\beta) \pm \cos(\alpha)\sin(\beta)$$

$$\sin(\alpha) + \sin(\beta) = 2\sin\left(\frac{\alpha+\beta}{2}\right) + \cos\left(\frac{\alpha-\beta}{2}\right)$$

$$\sin(\alpha) - \sin(\beta) = 2\cos\left(\frac{\alpha+\beta}{2}\right) + \sin\left(\frac{\alpha-\beta}{2}\right)$$

Moments of Inertia



Question 1 $I = \frac{1}{2} m r^2$ $m = 8.23$ $r = 12.2\text{ cm} = 0.122\text{ m}$

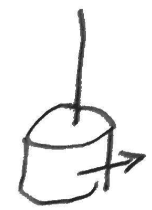
A uniform, solid metal disk cylinder of mass 8.23 kg and diameter 24.4 cm hangs in a horizontal plane, supported at its center by a vertical metal wire. You find that it requires a horizontal force of 4.00 N tangent to the rim of the disk to turn it by 3.50°, thus twisting the wire. You now remove this force and release the disk from rest.

(a) How long does it take the disk to turn from initial angle 3.50° to negate -3.50°?

If the initial angle is now doubled, how long does it take the disk to turn:

(b) from 0° to -3.50°?

(c) from -3.50° to -7.00°?



$$\frac{4\text{ N}}{3.5°}$$

$K = 1.1429$ N/degree
-3

a. Torsional Pendulum

$$\omega = \sqrt{\frac{K}{I}} = \sqrt{\frac{1.1429}{\frac{1}{2} 8.23 \cdot 0.122^2}} = 4.320$$

$$\omega = \frac{2\pi}{T} \qquad T = \frac{2\pi}{\omega} = 1.455 \text{ sec.}$$

Takes $\frac{1}{2}T$ to go from 3.5° to -3.5°, so it takes 0.727 seconds (Takes some if ×2)

b. Init. angle = 7° now At t_1, 0° t_2, -3.5° t_3, -7°

ω stays the same

$$y(t) = 7° \cos(\omega t) = 7\cos(4.320t)$$

$$y(t_1) = 0° = 7°\cos(4.32 t_1) \qquad t_1 = 0.3636 \text{ seconds}$$

$$y(t_2) = -3.5° = 7°\cos(4.32 t_2) \qquad t_2 = 0.4848 \text{ seconds}$$

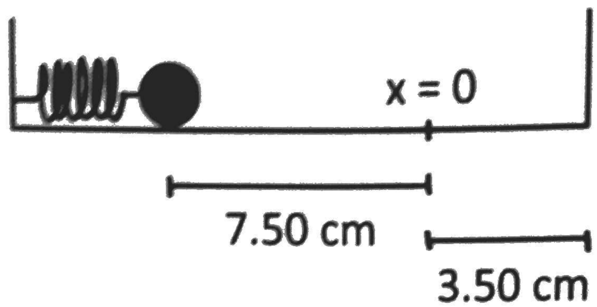
$$y(t_3) = -7° = 7°\cos(4.32 t_3) \qquad t_3 = 0.7272 \text{ seconds}$$

b. From 0° to -3.5° takes $t_2 - t_1$ = 0.1212 seconds

c. From -3.5° to -7° takes $t_3 - t_2$ = 0.2424 seconds

Question 2

A ball with mass 0.500 kg is attached to a horizontal spring with spring constant 200 N/m. The other end of the spring is attached to one wall in a box as shown in the figure. The mass is displaced by a distance 7.50 cm from equilibrium ($x = 0$) and is set free from rest. Assuming the collision of the ball against the wall to be perfectly elastic, find the oscillation period of this system.



$k = 200\ N/m$

20

$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{200}{0.5}} = 20$

Total energy $U = \frac{1}{2}kA^2 = \frac{1}{2}200 \cdot (0.075)^2 = 0.5625\ J$

At 3.5 cm, $U = \frac{1}{2}200(0.035)^2 = 0.1225\ J$,

leaving $0.5625 - 0.1225 = 0.44\ J$ of KE

$0.44 = \frac{1}{2}mv^2 \quad m = 0.5 \quad v = 1.3266\ m/s$

Bounces of wall, changing to be 1.3266 m/s back

Lost time: from 3.5 to 7.5 and back

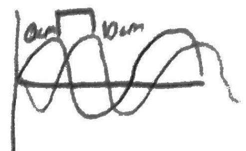
$x(t) = 0.075\cos(20t)$

$0.035 = 0.075\cos(20t_1) \quad t_1 = 0.0543$

$0.075 = 0.075\cos(20t_2) \quad t_2 \approx 0$

Takes $(0.0543 - 0) \times 2$ less seconds for full period

$T = 0.314 - (0.0543 \times 2) = \boxed{0.2056 \text{ seconds}}$



$y(x,t) = A\sin(kx \pm \omega t + \phi)$

Question 3

A sinusoidal wave is propagating along a stretched string that lies along the x-axis. The displacement of the string as a function of time for particles at x = 0 and at x = 10 cm is given by:

$$y(0,t) = (2\ cm)\ \sin(5\pi\, t)$$

$$y(10\ cm, t) = (2\ cm)\ \sin(5\pi t\ +\ 2\pi/3)$$

(a) You are told that the two points x = 0 and x = 10 cm are within one wavelength of each other. If the wave is moving in the +x-direction, determine the wavelength and wave speed.

(b) If instead the wave is moving in the –x-direction, determine the wavelength and the wave speed.

a. Wavelength $\lambda = \frac{v}{f}$ $\quad \omega = 5\pi \quad f = \frac{\omega}{2\pi} = \frac{5}{2}$

First peak of $y(0,t)$: $.02 = .02 \sin 5\pi t$

$t = 0.1$ seconds

First peak of $y(0.1,t)$: $0.02 = 0.02 \sin(5\pi t + 2\pi/3)$

$t = 0.233$ seconds

Takes $0.233 - 0.1 = 0.133$ seconds to travel 0.1 m.

$v = 0.752\ m/s$

$\lambda = \frac{0.752\ m/s}{2.5} = 0.3\ m$

✓ 2

b. First peak of $y(0.1,t)$ happens at 0.233 seconds, as above.

First peak of $y(0,t)$ after the above is at

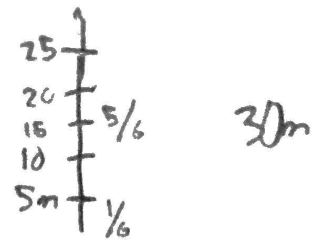
$0.02 = 0.02 \sin(5\pi t - 2\pi)$ $\quad t = 0.5$ seconds

Takes $0.5 - 0.233 = 0.267$ seconds to travel 0.1 m.

$v = \frac{0.1}{0.267} = 0.375\ m/s$

$\lambda = \frac{0.375\ m/s}{2.5\ Hz} = 0.150\ m$

✓ 2



Question 4

Part I: At a new building construction site, a 30.0 m steel beam is held in place with cement at one-sixth of the length from the end of the pole. The rest of the beam is free from constraint.

A construction worker hits the beam with a sledgehammer. The beam resonates at the lowest possible frequency.

(a) What is that frequency? The speed of sound in steel is 5980 m/s.

Part II: A guitar player near the construction site notices that the beam causes one of his strings to vibrate with large amplitude. The string tension is 8940 N, its mass is 0.100 kg, and its length is 1.00 m.

(b) What is the mode produced in the string? Round to the nearest whole number.
Note: if you've chosen an indexing scheme that is different from the textbook(s), state your answer in terms of the fundamental or overtone.

a Behaves as open-open tube, with 3 nodes at its fundamental frequency.

$$f = \frac{nV}{2L} = \frac{3 \cdot 5980}{2 \cdot 30} = 299 \text{ Hz}$$

b. Frequency still $= 299$ Hz

$$v = \sqrt{\frac{F}{\mu}} \qquad F = 8940 \text{ N} \qquad \mu = \frac{0.1}{1} = 0.1 \text{ kg/m}$$

$$v = \sqrt{\frac{8940}{0.1}} = 299.0 \text{ m/s}$$

$$299 = \frac{n \cdot 299}{2 \cdot 1} \qquad n = 2$$

The string produces its 2nd harmonic, or 1st overtone.

Question 5

A stationary police car emits a sound of frequency 1400 Hz that bounces off a car on the highway and returns with a frequency of 1325 Hz. The police car is right next to the highway, so the moving car is travelling directly toward or away from it. The speed of sound in air is 340m/s.

(a) How fast is the car going? Was it moving toward or away from the police car?
(b) What frequency would the police car have received if it had been traveling away from the other car at 30 m/s?

a.

Observed by car: $f_c = 1400\left(\frac{340 \mp V_c}{340}\right)$

Observed by police: $1325 = f_c\left(\frac{340}{340 + V_c}\right)$

$1325 = 1400\left(\frac{340 - V_c}{340}\right)\left(\frac{340}{340 + V_c}\right)$

$0.946 = \frac{340^2 - 340 V_c}{340^2 + 340 V_c}$

$109407 + 321.79 V_c = 115600 - 340 V_c$ $\quad 661.79 V_c = 6193$

$|V_{car}| = 9.358\ m/s$ away from the police car

b. $f_c = 1400\left(\frac{340 - 9.358}{340 + 30}\right)$

$f_o = f_c\left(\frac{340 - 30}{340 + 9.358}\right)$

$f_c = 1251\ Hz$ $\quad f_o = 1110.\ Hz$ received by police car