UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
MIDTERM TEST

February 11, 2009 Time: 90 minutes

NAME: SOLUTIONS MASTER STUDENT NO.: ___________
(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 Dr. A. Robinson
- ❑ C15 F. Dean

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), a formula sheet, and an OMR sheet. The test paper consists of 8 pages. **It is the responsibility of the student to check that the test paper is complete.**
3. Only Hewlett-Packard hp 30S or Texas Instruments TI-30X series calculators may be used.
4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your student number in the top right-hand corner of each page of the test paper.
5. Enter your name and STUDENT NUMBER on the OMR sheet.
6. The test paper, the formula sheet and the OMR sheet must all be submitted.
7. The test paper will be returned. The formula sheet and the OMR sheet will NOT be returned.

ONLY THE THREE PART B QUESTIONS THAT YOU INDICATE WILL BE MARKED

PLEASE INDICATE WHICH THREE PART B QUESTIONS ARE TO BE MARKED

QUESTION NUMBER	TO BE MARKED	MAXIMUM MARKS	MARKS OBTAINED
A1-15	-	15	
B1	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
TOTAL		45	

continued on page 2...

PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. Consider two objects: a solid wood disk and a metal hoop. The disk and the hoop have the same mass and radius. If the two objects have the same velocity as they roll along a horizontal surface, which one of the following statements is correct?

A

(A) Their translational kinetic energies are the same but the rotational kinetic energy of the disk is less than that of the hoop.
(B) Their translational kinetic energies are the same but the rotational kinetic energy of the disk is greater than that of the hoop.
(C) Both their translational kinetic energies and their rotational kinetic energies are the same.
(D) Their rotational kinetic energies are the same but the translational kinetic energy of the disk is less than that of the hoop.
(E) Their rotational kinetic energies are the same but the translational kinetic energy of the disk is less than that of the hoop.

$K_{rot} = \frac{1}{2}I\omega^2$ $K_{rot_{hoop}} = \frac{1}{2}(MR^2)\omega^2$

$K_{tr} = \frac{1}{2}mv^2$ = same for both $K_{rot_{disk}} = \frac{1}{2}(\frac{1}{2}MR^2)\omega^2$ disk < hoop

A2. Solid disk 1 has a mass of M and a radius of R. Solid disk 2 has a mass of $2M$ and a radius of R. The same torque is applied to each of the disks. The angular acceleration of disk 2, compared to that of disk 1, is

B

(A) $\alpha_2 = \frac{1}{4}\alpha_1$ (B) $\alpha_2 = \frac{1}{2}\alpha_1$ (C) $\alpha_2 = \alpha_1$ (D) $\alpha_2 = 2\alpha_1$ (E) $\alpha_2 = 4\alpha_1$

$\Sigma\tau = I\alpha$ $I_1\alpha_1 = I_2\alpha_2 \Rightarrow \alpha_2 = \frac{I_1}{I_2}\alpha_1 = \left[\frac{(\frac{1}{2}MR^2)}{(\frac{1}{2}(2MR^2))}\right]\cdot\alpha_1 = \frac{1}{2}\alpha_1$

A3. When a spinning figure skater pulls her arms in closer to her body her rotation rate increases. Which one of the following statements is correct? (You may ignore any frictional effects.)

A

(A) As the skater pulls her arms in, her rotational inertia decreases and her angular momentum remains constant.
(B) As the skater pulls her arms in, both her rotational inertia and her angular momentum decrease.
(C) As the skater pulls her arms in, her rotational inertia decreases and her angular momentum increases.
(D) As the skater pulls her arms in, her rotational inertia increases and her angular momentum remains constant.
(E) As the skater pulls her arms in, her rotational inertia increases and her angular momentum decreases.

Cons. of Ang. Momentum ; $I_1\omega_1 = I_2\omega_2$; $I\downarrow$ so $\omega\uparrow$

A4. A compact disc (CD) with a rotational inertia of 5.28×10^{-5} kg·m^2 spins at a speed of 41.9 radians/s. How much work must be done to bring it to rest?

D

(A) -1.01×10^{-2} J (B) -1.99×10^{-2} J (C) -2.23×10^{-2} J
(D) -4.63×10^{-2} J (E) -8.34×10^{-2} J

Work = ΔK

$W = K_f - K_i = 0 - \frac{1}{2}I\omega^2 = -\frac{1}{2}(5.28\times10^{-5}\,kg\cdot m^2)(41.9\,rad/s)^2 = -4.63\times10^{-2}$ J

A5. Consider a large rectangular block of wood that has a weight of 1.8×10^4 N and dimensions of 1 m × 2 m × 3 m. Which one of the following statements is correct concerning the pressure(s) that the block of wood can exert on a flat horizontal floor.

A

(A) The pressure exerted by the block can be 9000 Pa, 6000 Pa, or 3000 Pa, depending on its orientation.
(B) The pressure exerted by the block can only be 9000 Pa.
(C) The pressure exerted by the block can only be 6000 Pa.
(D) The pressure exerted by the block can only be 3000 Pa..
(E) The pressure exerted by the block can be 9000 Pa or 6000 Pa, but not 3000 Pa.

$P = \frac{F}{A}$; $P_1 = \frac{18000\,N}{1m \times 2m} = 9000\,Pa$

$P_2 = \frac{18000\,N}{1m \times 3m} = 6000\,Pa$

$P_3 = \frac{18000\,N}{2m \times 3m} = 3000\,Pa$

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A6. Which one of the following statements best describes the situation in a hydraulic lift.

C

(A) A small pressure change in a small cylinder produces a large pressure change in a large cylinder.
(B) A small pressure change in a large cylinder produces a large pressure change in a small cylinder.
(C) A small force applied to a small piston produces a large force on a large piston.
(D) A small force applied to a large piston produces a large force on a small piston.
(E) A small displacement of a small piston produces a large displacement of a large piston.

Pascal's Principle: pressure change is the same throughout, $\frac{F_1}{A_1} = \frac{F_2}{A_2}$, $F_2 = \frac{A_2}{A_1} \cdot F_1$

A7. A liquid with a viscosity of η is flowing through a pipe of radius R and length L. A pressure difference of ΔP is required to maintain a volume flow rate Q. If the radius of the pipe is reduced to ½ R then the pressure difference required to maintain the same volume flow rate is:

A

(A) 16 ΔP (B) 8 ΔP (C) 4 ΔP (D) 2 ΔP (E) ½ ΔP

$Q = \frac{\Delta V}{\Delta t} = \frac{\pi}{8} \frac{\Delta P/L}{\eta} \cdot r^4$; $Q_1 = Q_2 \Rightarrow \frac{\pi}{8} \frac{\Delta P_1/L}{\eta} \cdot r_1^4 = \frac{\pi}{8} \frac{\Delta P_2/L}{\eta} \cdot r_2^4$

$\Delta P_1 \cdot r_1^4 = \Delta P_2 \cdot r_2^4$

$\Delta P \cdot R^4 = \Delta P_2 \cdot (\frac{1}{2}R)^4$

$\Delta P_2 = 16 \Delta P$

A8. A spherical object of radius r falls with a terminal speed v through a fluid with viscosity η. Which one of the following statements is **true**? (equilibrium)

C

(A) The net force on the object has magnitude mg.
(B) The object has an acceleration of g.
(C) The viscous drag force causes the net force on the object to be zero.
(D) The viscous drag force is in the same direction as the force of gravity on the object.
(E) The viscous drag force is the only force acting on the object.

$\vec{F}_D$, $\vec{W}$

A9. A tensile force F stretches a wire of original length L by an amount ΔL. Consider another wire of the same composition and thickness as the first wire, but of length $2L$. If a force of $2F$ is applied to this wire of length $2L$, then the amount that it stretches is

E

(A) ¼ ΔL (B) ½ ΔL (C) ΔL (D) 2 ΔL (E) 4 ΔL

Y and A are the same for both wires. $\frac{F}{A} = Y\frac{\Delta L}{L}$ $\Delta L_1 = \frac{FL}{AY}$

$\Delta L_2 = \frac{F_2 L_2}{AY}$

$\Delta L_2 = \frac{(2F)(2L)}{AY}$

$\Delta L_2 = 4\left(\frac{FL}{AY}\right)$

$\Delta L_2 = 4\Delta L_1$

A10. Which one of the following statements concerning an object in simple harmonic motion is **false**?

D

(A) The maximum speed of the object is at the point of zero displacement from the equilibrium position.
(B) The maximum magnitude of acceleration of the object occurs at positions of maximum magnitude of displacement from equilibrium.
(C) The speed of the object is zero at positions of maximum magnitude of displacement.
(D) The angular frequency of oscillation depends on the amplitude of vibration.
(E) The acceleration is zero at the point of zero displacement from the equilibrium position.

A11. Two masses, m_1 and m_2, are hung on identical springs with spring constant k and set in simple harmonic motion. The ratio of the periods of oscillation, T_1/T_2, is given by:

A

(A) $\frac{T_1}{T_2} = \sqrt{\frac{m_1}{m_2}}$ (B) $\frac{T_1}{T_2} = 2\pi$ (C) $\frac{T_1}{T_2} = \frac{m_2}{m_1}$ (D) $\frac{T_1}{T_2} = 2\pi k$ (E) $\frac{T_1}{T_2} = \frac{m_1 + m_2}{m_1 - m_2}$

A12. A periodic wave passes by an observer who notices that the time between two consecutive wave crests is 2 seconds. Which one of the following statements about the wave is **true**?

B

(A) The frequency is 2 Hz.
(B) The period is 2 seconds.
(C) The wavelength is 2 metres.
(D) The amplitude is 2 metres.
(E) The wave speed is 2 m/s.

= repeat time = period

$\omega = \sqrt{\frac{k}{m}}$, $\omega = \frac{2\pi}{T}$, so $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$

$\frac{T_1}{T_2} = \frac{2\pi\sqrt{m_1/k}}{2\pi\sqrt{m_2/k}} = \sqrt{\frac{m_1}{m_2}}$

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A13. Two speakers are separated by a distance of d. They are vibrating in phase and they both produce sound with identical frequency f and wavelength λ. A listener is a distance L from one of the speakers. Which one of the following distances from the other speaker will ensure the listener is at a position of constructive interference?

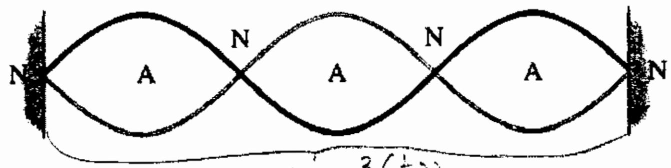
C

(A) $L + d$ (B) $L - \frac{1}{2}\lambda$ (C) $L + \lambda$ (D) $L + \frac{1}{2}\lambda$ (E) $d + \lambda$

For constructive interference $L_2 - L_1 = n\lambda \Rightarrow L_2 = L_1 + n\lambda$

A14. The diagram shows the third harmonic of a standing wave on a string of length L that is fixed at both ends. Which one of the equations correctly describes the wavelength λ_3 of this harmonic?

C



$L = 3(\frac{1}{2}\lambda)$

$L = \frac{3}{2}\lambda$

$\lambda = \frac{2}{3}L$

$\lambda = \frac{2L}{3}$

(A) $\lambda_3 = \frac{L}{2}$ (B) $\lambda_3 = \frac{L}{3}$ (C) $\lambda_3 = \frac{2L}{3}$ (D) $\lambda_3 = \frac{3L}{2}$ (E) $\lambda_3 = \frac{L}{6}$

A15. The intensity of the sound of an aircraft taking off is measured as 3.50×10^2 W/m^2 at a distance of 10.0 metres. Calculate the intensity at a distance of 125 metres. You may assume that the aircraft acts as an isotropic source of sound and you may ignore any absorption of sound energy by the air.

A

(A) 2.24 W/m^2 (B) 3.04 W/m^2 (C) 4.11 W/m^2 (D) 4.87 W/m^2 (E) 5.05 W/m^2

$P_1 = P_2$ $\quad I_1(4\pi r_1^2) = I_2(4\pi r_2^2)$

$I_1 A_1 = I_2 A_2$ $\quad I_2 = \frac{I_1 r_1^2}{r_2^2} = \frac{(350\,W/m^2)(10.0\,m)^2}{(125\,m)^2} = 2.24\,W/m^2$

PART B

ANSWER THREE OF THE PART B QUESTIONS ON THE FOLLOWING PAGES AND INDICATE YOUR CHOICES ON THE COVER PAGE.

FOR EACH OF YOUR CHOSEN PART B QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

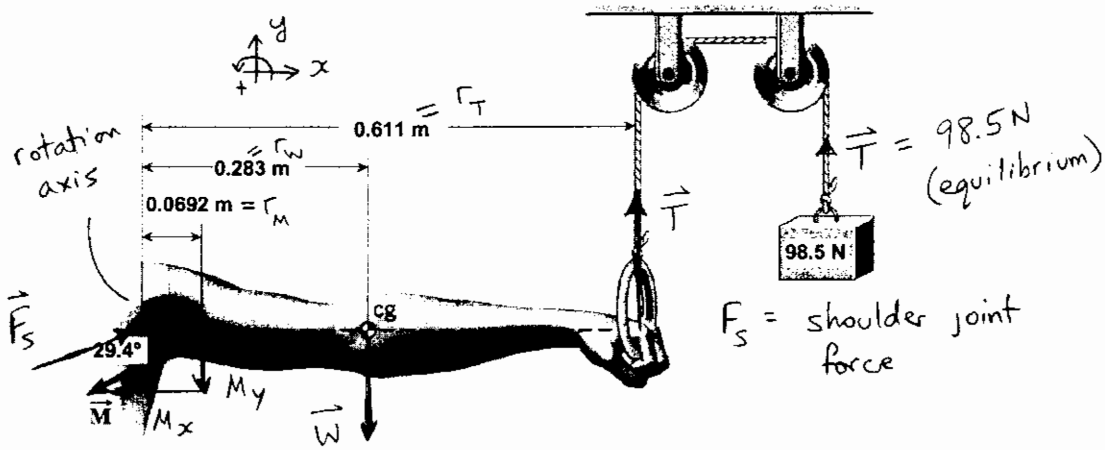
SHOW AND EXPLAIN YOUR WORK – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY.

EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

continued on page 5...

B1. The drawing shows an outstretched arm (0.611 m in length) that is parallel to the floor. The arm is pulling downward against the ring attached to the pulley system, in order to hold the 98.5-N weight stationary. The latissimus dorsi muscle applies the force **M** at a point that is 0.0692 m from the shoulder joint and oriented at an angle of 29.4° as shown. The arm has a mass of 4.86 kg and a centre of gravity that is located 0.283 m from the shoulder joint.



(a) Calculate the magnitude of **M**.

1.37×10^3 N

Choose the shoulder joint as the rotation axis. The arm is at rest ⇒ equilibrium.

$\therefore \sum \vec{F} = 0$ and $\sum \tau = 0 \Rightarrow \tau_M + \tau_W + \tau_T = 0$

$$-M_y \cdot r_M - W \cdot r_W + T \cdot r_T = 0$$

$$T r_T - W r_W = (M \sin\theta) r_M$$

$$M = \frac{T r_T - W r_W}{(\sin\theta) r_M} = \frac{(98.5\,N)(0.611\,m) - (4.86\,kg)(9.80\,m/s^2)(0.283\,m)}{[\sin(29.4°)] \cdot 0.0692\,m}$$

$$M = 1.37 \times 10^3\,N$$

(b) Calculate the vertical component of the force on the shoulder joint.

622 N

$$\sum F_y = 0$$

$$F_{sy} - M_y - W + T = 0$$

$$F_{sy} = M_y + W - T = M \sin\theta + mg - T$$

$$F_{sy} = (1.37 \times 10^3 N) \sin(29.4°) + (4.86\,kg)(9.80\,m/s^2) - 98.5 N$$

$$F_{sy} = 622\,N$$

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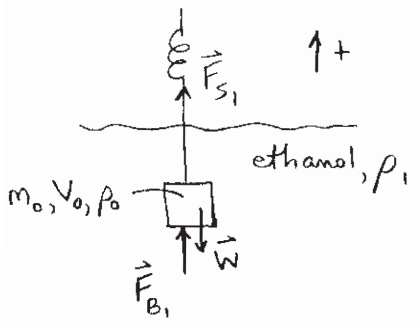
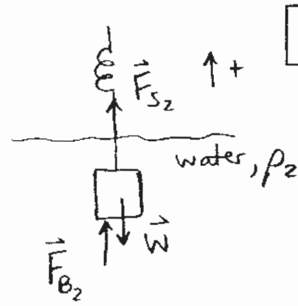
B2. When a solid object is suspended at rest from a spring scale and completely submerged in ethyl alcohol the reading on the spring scale is 15.2 N. When the same object is completely submerged in water the reading on the spring scale is 13.7 N. The density of ethyl alcohol is 806 kg/m^3 and the density of water is 1.00×10^3 kg/m^3.

Calculate the density of the object.





2.77×10^3 kg/m^3

The object is in equilibrium in both situations

$$\Sigma \vec{F} = 0 \Rightarrow F_{S_1} + F_{B_1} - W = 0 \quad \text{and} \quad F_{S_2} + F_{B_2} - W = 0$$

$$F_{S_1} + \rho_1 g V_o = m_o g \qquad F_{S_2} + \rho_2 g V_o = m_o g$$

$$F_{S_1} + \rho_1 g V_o = \rho_o V_o g \qquad F_{S_2} + \rho_2 g V_o = \rho_o V_o g$$

$$F_{S_1} = \rho_o V_o g - \rho_1 g V_o \qquad F_{S_2} = \rho_o V_o g - \rho_2 g V_o$$

$$F_{S_1} = V_o(\rho_o g - \rho_1 g) \qquad F_{S_2} = V_o(\rho_o g - \rho_2 g)$$

$$V_o = \frac{F_{S_1}}{\rho_o g - \rho_1 g} \qquad F_{S_2} = \left(\frac{F_{S_1}}{\rho_o g - \rho_1 g}\right)(\rho_o g - \rho_2 g)$$

$$F_{S_2}\rho_o g - F_{S_2}\rho_1 g = F_{S_1}\rho_o g - F_{S_1}\rho_2 g$$

$$F_{S_2}\rho_o - F_{S_1}\rho_o = F_{S_2}\rho_1 - F_{S_1}\rho_2$$

$$\rho_o = \frac{F_{S_2}\rho_1 - F_{S_1}\rho_2}{F_{S_2} - F_{S_1}} = \frac{(13.7\,\text{N})(806\,\text{kg/m}^3) - 15.2\,\text{N}(1000\,\text{kg/m}^3)}{13.7\,\text{N} - 15.2\,\text{N}}$$

$$\rho_o = 2.77 \times 10^3\,\text{kg/m}^3$$

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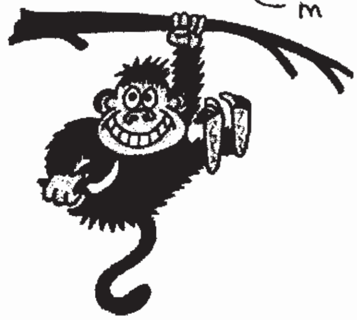
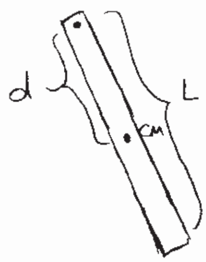
B3. A monkey, hanging onto a horizontal tree branch with one arm, swings in simple harmonic motion. The centre of mass of the monkey is 0.425 cm from the branch. Its mass is 9.50 kg.



(a) Calculate the rotational inertia of the monkey, assuming it can be modelled as a thin rod of length 0.850 m.



Thin rod, $I = \frac{1}{3}ML^2$ rotating around end,

$$I = \frac{1}{3}(9.50\,\text{kg})(0.850\,\text{m})^2$$

$$I = 2.29\ \text{kg}\cdot\text{m}^2$$

2.29 kg·m²

(b) Calculate the frequency with which the monkey swings.

The monkey is swinging in SHM, ∴ can treat the monkey as a physical pendulum

$$\omega = \sqrt{\frac{mgd}{I}}$$ where d = distance of centre of mass/gravity from rotation axis.

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{mgd}{I}} = \frac{1}{2\pi}\sqrt{\frac{(9.50\,\text{kg})(9.80\,\text{m/s}^2)(0.425\,\text{m})}{2.29\ \text{kg}\cdot\text{m}^2}}$$

$$f = 0.662\ \text{Hz}$$

0.662 Hz

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Stu. No.: ____________________

B4. Light of wavelength 556 nm in air enters the water in a swimming pool. The speed of light in the water is 0.750 times the speed in air. The light hits the water at an angle of incidence of 35.0° with respect to the surface normal. Some of the light is reflected at the air-water interface, and some is refracted as it passes into the water.

(a) Calculate the wavelength of the light in the water.

417 nm

$v = f\lambda$ and f is constant

$$\therefore f = \frac{v_{air}}{\lambda_{air}} = \frac{v_{water}}{\lambda_{water}}$$

$$\lambda_{water} = \frac{v_{water}\lambda_{air}}{v_{air}} = \frac{(0.750)v_{air}(556\,nm)}{v_{air}}$$

$$\lambda_{water} = 417\,nm$$

(b) Calculate the angle of refraction of the light at the air-water boundary.

25.5°

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$$ (see diagram below)

$$\sin\theta_2 = \frac{v_2}{v_1}\cdot\sin\theta_1$$

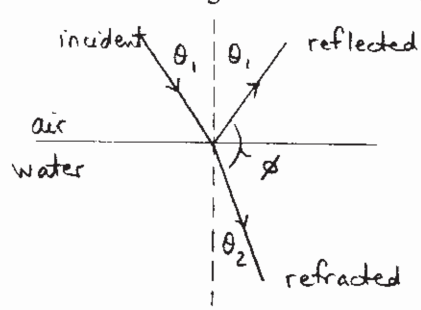
$$\theta_2 = \arcsin\left(\frac{v_2}{v_1}\cdot\sin\theta_1\right) = \arcsin\left(\frac{0.750\,v_{air}}{v_{air}}\cdot\sin(35.0°)\right)$$

$$\theta_2 = 25.5°$$

(c) Draw a diagram and clearly label the incident, reflected and refracted rays and the angle of incidence, the angle of reflection and the angle of refraction.

Calculate the angle between the reflected light and the refracted light.

120°



ϕ = angle b/w reflected and refracted light

$$\phi = 180° - \theta_1 - \theta_2$$

$$\phi = 180° - 35.0° - 25.5° = 119.5° = 120°$$

END OF EXAMINATION