UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
MIDTERM TEST – Alternative Sitting

12

February 11, 2010

Time: 90 minutes

NAME: _____MASTER_____   STUDENT NO.: _____

(Last)   **Please Print**   (Given)

LECTURE SECTION (please check):

❑ 01 B. Zulkoskey
❑ 02 Dr. A. Robinson

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 10S or 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	

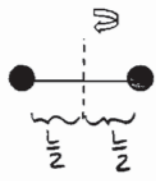## PART A

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

A1. An ice skater is spinning at an angular speed of ω_1 rad/s with her arms outstretched. She pulls her arms in, reducing her rotational inertia to 80% of its original value. What is her new angular speed? You may assume that no external torques act.

D

(A) $0.64\,\omega_1$ (B) $0.8\,\omega_1$ (C) ω_1 (D) $1.25\,\omega_1$ (E) $1.6\,\omega_1$

$\omega_2 = \dfrac{I_1 \omega_1}{I_2}$

$I_2 = 0.80 I_1$ Ang. mom. is conserved so $I_1\omega_1 = I_2\omega_2$ $\omega_2 = \dfrac{I_1\omega_1}{I_2}$
(no ext. torque) $\omega_2 = \dfrac{I_1\omega_1}{0.80 I_1}$

A2. Which one of the following statements concerning torque and equilibrium is **FALSE**?

C

(A) The sign convention for torque is that a clockwise torque is negative. T
(B) An object in rotational equilibrium must have a net torque of zero exerted on it. T $\omega_2 =$
(C) The magnitude of torque is defined as the distance from the centre of rotation to the point of application multiplied by the magnitude of the force. F $\tau = rF\sin\theta$
(D) Torque is a vector quantity. T
(E) An object in translational equilibrium must have a net force of zero exerted on it. T
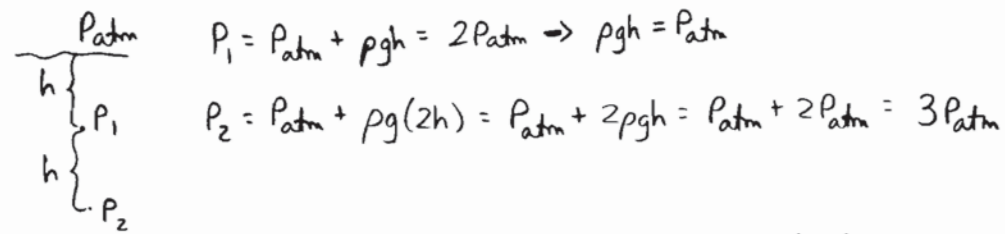
A3. A model for molecular nitrogen consists of two solid spheres, each of mass M and radius R, connected by a rod of length L and negligible mass. If this molecule is rotating about the axis shown in the diagram, what is the moment of inertia of the molecule? You may assume that $R \ll L$.

A

(A) $\dfrac{ML^2}{2}$ (B) ML^2 (C) $2ML^2$ (D) $4ML^2$ (E) $8ML^2$

$I_{tot} = M\left(\dfrac{L}{2}\right)^2 + M\left(\dfrac{L}{2}\right)^2 = 2\dfrac{ML^2}{4} = \dfrac{ML^2}{2}$.

A4. A centrifuge used in a biology lab has rotational inertia I and is spinning at $-\omega$ radians/second. To bring it to a complete halt, a constant torque $+\tau$ is applied. Which is the correct expression for the angle in radians through which the centrifuge turns as it comes to a halt?

E

(A) $-\dfrac{I\omega^2}{\tau}$ (B) $-\dfrac{\tau I\omega^2}{2}$ (C) $-I\omega^2$ (D) $-\dfrac{2I\omega^2}{\tau}$ (E) $-\dfrac{I\omega^2}{2\tau}$

$\theta = -\dfrac{I\omega^2}{2\tau}$

Use Work-Kinetic Energy Theorem: $\tau\theta = \Delta K_{rot} = 0 - \frac{1}{2}I(-\omega)^2$

A5. Let h be the depth below the surface of the ocean at which the absolute pressure is twice atmospheric pressure (i.e. $2P_{atm}$). The pressure at a depth of $2h$ below the surface of the ocean is

B

(A) $2.5P_{atm}$ (B) $3P_{atm}$ (C) $4P_{atm}$ (D) $5P_{atm}$ (E) $9P_{atm}$

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

Pascal's Principle: pressure change is the same throughout the system.

A5.

$P_1 = P_{atm} + \rho g h = 2P_{atm} \Rightarrow \rho g h = P_{atm}$

$P_2 = P_{atm} + \rho g(2h) = P_{atm} + 2\rho g h = P_{atm} + 2P_{atm} = 3P_{atm}$

A7. A spherical object of radius r falls through a fluid of viscosity η with a speed v. When the object reaches its terminal velocity which one of the following statements is **TRUE**?

$\underline{C}$

(A) The net force on the object has magnitude mg. F   At terminal velocity, velocity
(B) The object has an acceleration of g. F   is constant, so $\vec{a} = 0$, so $\Sigma \vec{F} = 0$.
(C) The viscous drag force causes the net force on the object to be zero. T
(D) The viscous drag force is in the same direction as the force of gravity on the object. F
(E) The viscous drag force is the only force acting on the object. F

A8. Which one of the following statements is correct concerning simple harmonic motion (SHM)?

$\underline{D}$

(A) SHM can occur near any point of equilibrium (point of stable or unstable equilibrium). F
(B) SHM occurs for any force that tends to restore equilibrium. F
(C) SHM occurs for any force whose magnitude is proportional to the square of displacement from a point of stable equilibrium. F
(D) SHM occurs for any force whose magnitude is proportional to the magnitude of the displacement from a point of stable equilibrium. T
(E) SHM occurs for any force whose magnitude varies inversely with the magnitude of the displacement from a point of stable equilibrium. F

A9. Consider a material that is being stressed within its proportional limit. An object made of this material has a length L and a cross-sectional area A and is subject to a tensile force F. As a result, the length of the object changes by ΔL. Which one of the following situations will result in the same change of length ΔL? $\frac{F}{A} = Y \frac{\Delta L}{L} \Rightarrow \Delta L = \frac{FL}{AY}$

$\underline{E}$

(A) exerting twice the force on an object of the same length with half the cross-sectional area ✗
(B) exerting twice the force on an object that is twice as long and has the same cross-sectional area ✗
(C) exerting the same force on an object that is twice as long and has half the cross-sectional area ✗
(D) exerting the same force on an object that is half the length and has twice the cross-sectional area ✗
(E) exerting twice the force on an object that is one quarter the length and has half the cross-sectional area ✓

$\Delta L = \dfrac{2F\left(\frac{1}{4}L\right)}{\frac{1}{2}AY} = \dfrac{FL}{AY}$

A10. A spherical cell, radius r, in the bloodstream, moves from a place where the blood pressure is low, to a place where the blood pressure is high. When it does so, the radius of the cell decreases by Δr. If the bulk modulus of the cell is B, which one of the following expressions for the change in pressure is correct?

None of the options is correct.

(A) $\Delta P = -B\dfrac{\Delta r}{r}$ (B) $\Delta P = -B\left(\dfrac{\Delta r}{r}\right)^2$ (C) $\Delta P = -B\left(\dfrac{\Delta r}{r}\right)^3$

(D) $\Delta P = -B\Delta r$ (E) $\Delta P = -\dfrac{Br}{\Delta r}$

$\Delta P = -B \frac{\Delta V}{V} = -B \Delta\left(\frac{\frac{4}{3}\pi r^3}{\frac{4}{3}\pi r^3}\right) = -B \frac{\Delta(r^3)}{r^3} = -B\left(\frac{\Delta r}{r}\right)^3$

A11. A simple pendulum, of length L, has a period T. If the length is doubled, what is the new period in terms of T?

$\underline{C}$

(A) $\dfrac{T}{\sqrt{2}}$ (B) $\dfrac{T}{2}$ (C) $\sqrt{2}\times T$ (D) $2T$ (E) $4T$

$\omega_1 = \sqrt{\dfrac{g}{L_1}} \Rightarrow T_1 = 2\pi\sqrt{\dfrac{L_1}{g}} \; ; \; T_2 = 2\pi\sqrt{\dfrac{2L_1}{g}} = 2\pi\sqrt{\dfrac{L_1}{g}}\cdot\sqrt{2}$

$= \sqrt{2}\cdot T_1$

A12. A periodic wave passes by an observer who notices that the time between two consecutive wave crests is 1 second. Which one of the following statements about the wave is **TRUE**?

$\underline{B}$

(A) The angular frequency is 1 rad/s.   (B) The period is 1 second.
(C) The wavelength is 1 metre.   (D) The amplitude is 1 metre.
(E) The wave speed is 1 m/s.

Time b/w consecutive crests = period = 1 s.

A13. The sound intensity is I at a distance of R metres from an isotropic point source of sound. If the distance from the source is doubled, what is the new intensity, in terms of I?

B

(A) $\dfrac{I}{8}$ (B) $\dfrac{I}{4}$ (C) $\dfrac{I}{2}$ (D) $2I$ (E) $4I$

$$P_1 = P_2 \Rightarrow I_1 \cdot 4\pi r_1^2 = I_2 \cdot 4\pi r_2^2 \Rightarrow I_2 = \frac{I_1 \cdot 4\pi r_1^2}{4\pi r_2^2} = \frac{I_1 \cdot r_1^2}{(2r_1)^2} = \frac{I_1}{4} .$$

A14. Which one of the following statements regarding waves on a spring is **FALSE**?

D

(A) In a longitudinal wave on a spring, the spring oscillates parallel to the direction of wave propagation. T

(B) In a transverse wave on a spring, the spring oscillates perpendicular to the direction of wave propagation. T

(C) The wave transfers energy between points in space. T

(D) The speed of the wave along the spring is always equal to the speed of the individual coils. F

(E) The speed of the wave depends on the mechanical properties of the spring. T

A15. A transverse wave travels along a string at a speed v m/s. If the tension is increased by 44%, what is the new speed in terms of v?

E

(A) $1.44v$ (B) $\dfrac{v}{1.44}$ (C) $\dfrac{1.20}{v}$ (D) $\sqrt{1.20}\,v$ (E) $1.20\,v$

$$v_1 = \sqrt{\frac{F_1}{\mu}} \; ; \quad v_2 = \sqrt{\frac{F_2}{\mu}} = \sqrt{\frac{1.44\,F_1}{\mu}} = \sqrt{1.44} \cdot \sqrt{\frac{F_1}{\mu}} = 1.20 \cdot v_1$$

PART B

ANSWER <u>THREE</u> 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.

<u>SHOW AND EXPLAIN YOUR WORK</u> – 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.

B1. The Saharan rolling spider (*Araneus rota*) is capable of rolling on its outstretched legs, achieving linear speeds of 6.40 km/h when rolling downhill to escape from predators.
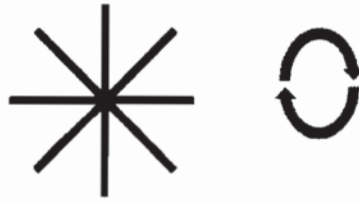
(a) Model the spider as a set of 8 identical thin rods, each of length 1.00 cm and mass 0.200×10^{-3} kg, with all the rods arranged radially around the axis of rotation. Calculate the rotational inertia, *I*, of the spider. (4 marks)

I for a thin rod rotating around an axis through its end is $\frac{1}{3}ML^2$.

$$\boxed{5.33 \times 10^{-8} \ kg \cdot m^2}$$

$$\therefore \ I_{tot} = 8\left(\frac{1}{3}ML^2\right) = \frac{8}{3}\left(0.200 \times 10^{-3} kg\right)\left(0.0100 m\right)^2$$

$$I_{tot} = 5.33 \times 10^{-8} \ kg \cdot m^2$$

(b) Calculate the (linear) kinetic energy when the spider is rolling at 6.40 km/h. (3 marks)

— translational

$$K_{tr} = \frac{1}{2}mv^2$$

$$\boxed{2.53 \times 10^{-3} \ J}$$

$$K_{tr} = \frac{1}{2}\left(8\left(0.200 \times 10^{-3} kg\right)\right)\left(6.40 \frac{km}{h} \times \frac{1 h}{3600 s} \times \frac{1000 m}{km}\right)^2$$

$$\boxed{K_{tr} = 2.53 \times 10^{-3} \ J}$$

(c) Calculate the rotational kinetic energy of the spider when it is rolling with a linear speed of 6.40 km/h. If you did not obtain an answer to part (a), use $I = 4.00 \times 10^{-8}$ kg.m^2. (3 marks)

$$K_{rot} = \frac{1}{2}I\omega^2 \ ; \ \omega = \frac{v}{r} = \frac{v}{L}.$$

$$\boxed{8.42 \times 10^{-4} \ J}$$

$$K_{rot} = \frac{\frac{1}{2}\left(5.33 \times 10^{-8} kg \cdot m^2\right)\left(6.40 \frac{km}{h} \times \frac{1h}{3600s} \times \frac{1000 m}{km}\right)^2}{\left(0.0100 m\right)^2}$$

$$\boxed{K_{rot} = 8.42 \times 10^{-4} \ J}$$

B2. A Venturi meter measures the flow speed of water through a pipe. The speed to be measured is v_1, the speed in the pipe where the cross-sectional area is $A_1 = 4.10 \times 10^{-4}$ m^2. Pressure meters measure the pressure in this pipe (P_1), and the pressure (P_2) at a narrow section of pipe with cross-sectional area $A_2 = 3.24 \times 10^{-4}$ m^2. Assume water behaves as an ideal, non-viscous fluid.
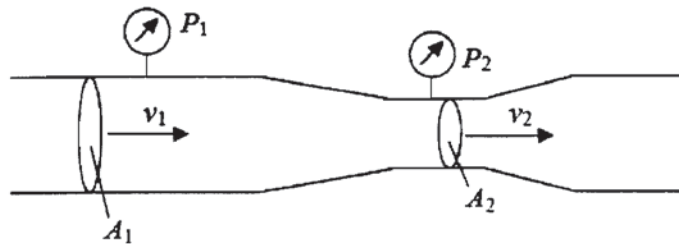
(a) Derive an expression for v_2, the speed where the cross-sectional area is A_2, in terms of v_1, A_1, and A_2. (3 marks)

Apply the continuity eq'n for incompressible fluids: $\frac{\Delta V}{\Delta t} = $ constant

$$\boxed{v_2 = \frac{A_1 v_1}{A_2}}$$

$\therefore A_1 v_1 = A_2 v_2$

$$\boxed{v_2 = \frac{A_1 v_1}{A_2}}$$

the pipe is horizontal and

(b) If the pressure difference, $P_1 - P_2$, is measured to be 81.0 Pa, calculate the speed, v_1, of the water in the pipe. (7 marks)

Told to assume non-viscous flow.

$\therefore$ Apply Bernoulli's equation.

$$\boxed{0.519 \text{ m/s}}$$

horizontal:

$$P_1 + \rho g y_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \tfrac{1}{2}\rho v_2^2 \quad ; \quad y_1 = y_2$$

$$P_1 - P_2 = \tfrac{1}{2}\rho v_2^2 - \tfrac{1}{2}\rho v_1^2$$

$$P_1 - P_2 = \tfrac{1}{2}\rho \left[\left(\frac{A_1 v_1}{A_2}\right)^2 - v_1^2 \right]$$

$$P_1 - P_2 = \tfrac{1}{2}\rho \left[\left(\frac{A_1}{A_2}\right)^2 - 1 \right] v_1^2$$

$$v_1 = \sqrt{\frac{P_1 - P_2}{\tfrac{1}{2}\rho \left(\frac{A_1^2}{A_2^2} - 1\right)}} = \sqrt{\frac{81.0 \text{ Pa}}{\tfrac{1}{2}\left(1000 \frac{\text{kg}}{\text{m}^3}\right)\left(\frac{(4.10 \times 10^{-4} \text{ m}^2)^2}{(3.24 \times 10^{-4} \text{ m}^2)^2} - 1\right)}}$$

$$\boxed{v_1 = 0.519 \text{ m/s}}$$

B3. The upper thigh bone in the human body (the femur) can be modeled as a cylinder of length 48.0 cm and diameter 2.35 cm for an adult male. The cylinder contains a core of bone marrow, of diameter 2.13 cm, which does not contribute to the mechanical strength of the bone. The outer part of the bone has a Young's Modulus of 9.40×10^9 Pa for compressive forces. Half of the weight of the human upper body, a force of 255 N, pushes down on top of the femur.
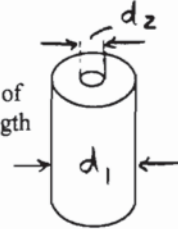
(a) Calculate the effective cross sectional area of the femur on which the force acts. (4 marks)

$$A = \pi r_1^2 - \pi r_2^2$$

$$A = \pi \left(\left(\frac{0.0235m}{2} \right)^2 - \left(\frac{0.0213m}{2} \right)^2 \right)$$

$$\boxed{A = 7.74 \times 10^{-5} m^2}$$

$$\boxed{7.74 \times 10^{-5} m^2}$$

(b) Calculate the stress on the femur. (3 marks)

$$Stress = \frac{F}{A} = \frac{255N}{7.74 \times 10^{-5} m^2}$$

$$\boxed{Stress = 3.29 \times 10^6 Pa}$$

$$\boxed{3.29 \times 10^6 Pa}$$

(c) Calculate the distance   by which the femur is compressed due to the stress. (If you did not calculate an answer for (b), use 2.95×10^6 Pa.) (3 marks)
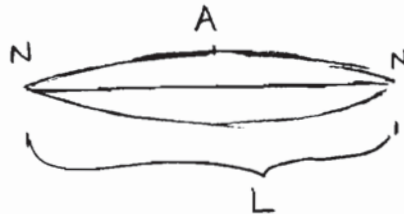
$$\frac{F}{A} = Y \frac{\Delta L}{L}$$

$$\Delta L = \frac{FL}{AY} = \left(\frac{F}{A} \right) \frac{L}{Y} = \left(3.29 \times 10^6 Pa \right) \left(\frac{0.480m}{9.40 \times 10^9 Pa} \right)$$

$$\boxed{\Delta L = 1.68 \times 10^{-4} m}$$

$$\boxed{1.68 \times 10^{-4} m}$$

B4. The C string of a cello has a linear mass density of 1.56×10^{-2} kg/m. The string has a length of 0.800 m between its fixed ends and, when properly tuned, produces a fundamental frequency of 65.4 Hz.

(a) Calculate the speed of a transverse wave on the string. (5 marks)

A

N ⟨~~~~~~~~~~~~~~~⟩ N

L

$$\boxed{105 \text{ m/s}}$$

For fundamental mode of vibration, $L = \frac{1}{2}\lambda$

$$v = f\lambda = f(2L)$$

$$v = (65.4 \text{ Hz})(2(0.800\text{m}))$$

$$\boxed{v = 105 \text{ m/s}}$$

(b) Calculate the tension in the string. (5 marks)

$$\boxed{171 \text{ N}}$$

$$v = \sqrt{\frac{F}{\mu}}$$

$$v^2 = \frac{F}{\mu}$$

$$F = \mu v^2 = \left(1.56 \times 10^{-2} \frac{\text{kg}}{\text{m}}\right)\left(105 \text{ m/s}\right)^2$$

$$\boxed{F = 171 \text{ N}}$$

END OF EXAMINATION