UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
MIDTERM TEST

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
- ❑ C15 F. Dean

C16

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	

continued on page 2...

PART A

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

D

A1. Each of the following objects is rotating around an axis passing through the centre of the object:

1. a ring of mass M and radius R rotating with angular velocity ω; $K = \frac{1}{2} I\omega^2 = \frac{1}{2} MR^2\omega^2$
2. a uniform solid disk of mass $2M$ and radius R rotating with angular velocity ω; $K = \frac{1}{2}\left(\frac{1}{2} \cdot 2MR^2\right)\omega^2$
3. a ring of mass $4M$ and radius $\frac{1}{2}R$ rotating with angular velocity ω; $K = \frac{1}{2}\left(4M\left(\frac{1}{2}R\right)^2\right)\omega^2$
4. a ring of mass $\frac{1}{2}M$ and radius $4R$ rotating with angular velocity $\frac{1}{2}\omega$; $K = \frac{1}{2}\left(\frac{1}{2}M(4R)^2\right)\left(\frac{1}{2}\omega\right)^2 = \frac{1}{2}\left(2MR^2\omega^2\right) = MR^2\omega^2$
5. a ring of mass M and radius $2R$ rotating with angular velocity $\frac{1}{2}\omega$. $K = \frac{1}{2}M(2R)^2\left(\frac{1}{2}\omega\right)^2 = \frac{1}{2}MR^2\omega^2$

Which one of these objects does **not** have the same rotational kinetic energy as the other four?

(A) 1 (B) 2 (C) 3 (D) 4 (E) 5

C

A2. Which one of the following statements is **TRUE**? If a constant net torque is acting on an object then

$\Sigma\tau = I\alpha$, $\alpha = \frac{\Delta\omega}{\Delta t}$

(A) the angular displacement of the object is directly proportional to the elapsed time. F
(B) the angular velocity of the object is constant. F
(C) the angular velocity of the object is directly proportional to the elapsed time. T
(D) the angular acceleration of the object is directly proportional to the elapsed time. F
(E) the angular velocity of the object is directly proportional to the square of the elapsed time. F

E

A3. Which one of the following statements is **TRUE**?

(A) If the net force on an object is zero then the net torque on the object must also be zero. F
(B) If the net torque on an object is zero then the net force on the object must also be zero. F
(C) If the net force on an object is zero then the object cannot be rotating. F
(D) If the net torque on an object is zero then the centre of mass of the object must be stationary. F
(E) If the net force on an object is zero and the net torque on the object is zero then the object is in rotational equilibrium (no translational acceleration and no angular acceleration). T

C

A4. When a figure skater, initially spinning with arms outstretched, brings her arms closer to her body, which of the following physical quantities is (are) conserved?

(A) angular velocity (B) rotational kinetic energy (C) angular momentum
(D) rotational inertia (E) all of the above

$L = I\omega$ = ang. mom. is conserved

B

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

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

C

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

(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 the system.

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A5. $P_0 = P_{atm}$

$h \{ P_1$

$h \{ P_2$

$P_1 = P_0 + \rho g h = P_{atm} + \rho g h = 2P_{atm} \Rightarrow \rho g h = P_{atm}$

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

$P_2 = P_{atm} + 2(P_{atm}) = 3P_{atm}$

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**?

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.

At terminal velocity, $\Sigma \vec{F} = 0$ so $\vec{a} = 0$.

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

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 SHM oscillator that is being forced to oscillate by a periodic external driving force. Damping is present. Which one of the following statements describing the situation when the frequency of the driving force is close to the natural frequency of the oscillator? is TRUE?

D

(A) The damping of the oscillations occurs more quickly than if there were no driving force. F
(B) The driving force has no effect on the damping of the oscillations. F
(C) Damping still occurs, but not as quickly as it would if there were no driving force. F
(D) The amplitude of the oscillations increases until the energy lost to damping equals the energy supplied by the driving force. T
(E) It is not possible for there to be damping forces if there is an external driving force. F

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?

~~C~~

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) $\Delta P = -\dfrac{Br}{\Delta r}$

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

A11. Which one of the following statements concerning simple harmonic motion is **FALSE**?

C

(A) The restoring force is proportional to the displacement from the equilibrium position. T
(B) The maximum speed during oscillation occurs at the equilibrium position. T
(C) The maximum acceleration occurs at the equilibrium position. F
(D) The speed at the point of maximum displacement from the equilibrium point is zero. T
(E) The frequency of vibration is independent of the magnitude of the initial displacement which starts the simple harmonic oscillation. T

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**?

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.

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

$P_1 = P_2$

$I_1 \cdot 4\pi r_1^2 = I_2 4\pi r_2^2$

$I_2 = I_1 \frac{r_1^2}{r_2^2} = \frac{I_1 \cdot r_1^2}{(2r_1)^2}$

$I_2 = \frac{I_1}{4}$

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 υ m/s. If the tension is increased by 44%, what is the new speed in terms of υ?

E

(A) 1.44υ (B) $\frac{\upsilon}{1.44}$ (C) $\frac{1.20}{\upsilon}$ (D) $\sqrt{1.20\,\upsilon}$ (E) $1.20\,\upsilon$

$F_2 = 1.44 F_1$ $\quad \upsilon_1 = \sqrt{\frac{F_1}{\mu}}$; $\upsilon_2 = \sqrt{\frac{F_2}{\mu}} = \sqrt{\frac{1.44F_1}{\mu}} = \sqrt{1.44}\sqrt{\frac{F_1}{\mu}} = 1.20\upsilon_1$

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.

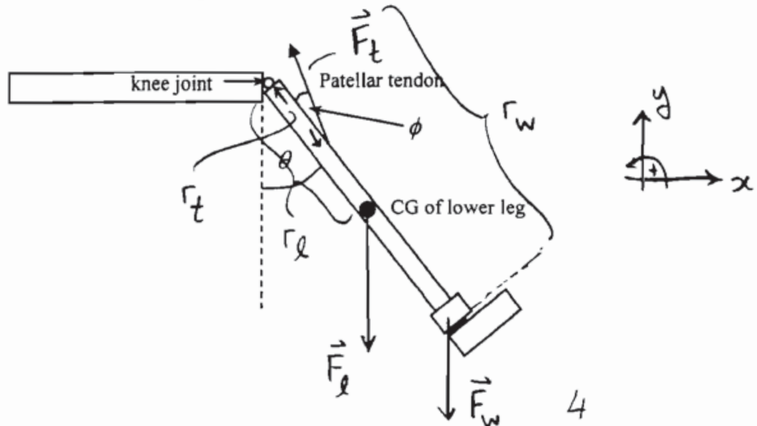
EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

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

continued on page 5...

B1. A person sitting in a chair is doing single leg lifts with a 3.00 kg ankle weight. She lifts her lower leg with her quadriceps muscle so that her lower leg makes an angle of $\theta = 30.0°$ with the vertical. The quadriceps muscle applies a force to the lower leg via the patellar tendon which attaches to the lower leg at a distance of 10.0 cm below the knee joint. The tendon pulls at an angle of $\phi = 19.5°$ with respect to the lower leg. The lower leg has a mass of 5.00 kg and its centre of gravity is 22.0 cm below the knee. The ankle weight is 41.0 cm from the knee.

The quadriceps muscle holds the lower leg in this position.



(a) Calculate the torque exerted on the lower leg by the patellar tendon. (4 marks)

$\boxed{11.4 \text{ N}\cdot\text{m}}$

lower leg is in rotational equilibrium.

$$\Sigma \tau = 0$$

$$\tau_t + \tau_\ell + \tau_w = 0$$

$$\tau_t - r_\ell F_\ell \sin\theta - r_w F_w \sin\theta = 0$$

$$\tau_t = r_\ell F_\ell \sin\theta + r_w F_w \sin\theta$$

$$\tau_t = 11.4 \text{ N}\cdot\text{m}$$

$$\tau_t = (0.220\text{ m})(5.00\text{ kg})(9.80\text{ m/s}^2)\sin 30.0° + (0.410\text{ m})(3.00\text{ kg})(9.80\text{ m/s}^2)\sin 30.0°$$

(b) Calculate the force exerted on the lower leg by the patellar tendon. (3 marks)

$\boxed{342\text{ N}}$

$$\tau_t = r_t F_t \sin\phi$$

$$F_t = \frac{\tau_t}{r_t \sin\phi} = \frac{11.42 \text{ N}\cdot\text{m}}{(0.100\text{ m})\sin 19.5}$$

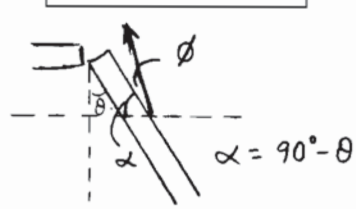
$$F_t = 342\text{ N}$$

(c) Calculate the horizontal component of the joint force. (3 marks)

$\boxed{62.3\text{ N}}$

translational equilibrium $\Rightarrow \Sigma \vec{F} = 0$

$$\Sigma F_x = 0 \Rightarrow F_{joint_x} - F_{t_x} = 0$$



$$F_{joint_x} = F_{t_x} = F_t \cos(90° - \theta + \phi)$$

$$F_{joint_x} = 342\text{ N} \cos(79.5°)$$

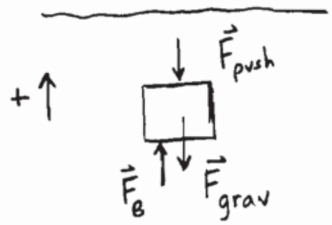
$$F_{joint_x} = 62.3\text{ N}$$

continued on page 6...

B2. A block of wood of density 472 kg/m^3 has a mass of 1.25 kg.

(a) Calculate the downward force that must be applied to the block of wood to hold it completely submerged underwater. (6 marks)

$\boxed{13.7\text{ N}}$



equilibrium $\Rightarrow \sum \vec{F} = 0$

$$\therefore\ F_B - F_{push} - F_{grav} = 0$$

$$\rho_f g V_f - F_{push} - mg = 0$$

completely submerged $\Rightarrow V_f = V_{obj}$; $\rho_{obj} = \dfrac{m}{V_{obj}} \Rightarrow V_{obj} = \dfrac{m}{\rho_{obj}}$

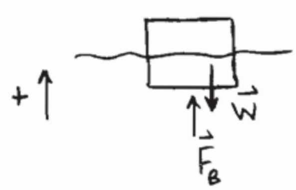
$$\therefore\ F_{push} = \rho_f g V_f - mg = \rho_f g \left(\frac{m}{\rho_{obj}}\right) - mg$$

$$F_{push} = mg\left(\frac{\rho_f}{\rho_{obj}} - 1\right) = (1.25\text{ kg})(9.80\text{ m/s}^2)\left(\frac{1.00\times10^3\text{ kg/m}^3}{472\text{ kg/m}^3} - 1\right)$$

$$F_{push} = 13.7\text{ N}$$

(b) If the block is released it will rise rapidly to the surface and eventually come to rest. Calculate the percentage of the volume of the block that is submerged when the block is floating at rest. (4 marks)

$\boxed{47.2\%}$



$V_{submerged} = V_{\substack{fluid\\displaced}}$

equilibrium $\Rightarrow \sum \vec{F} = 0$

$$F_B - W = 0$$

$$\rho_f g V_f - mg = 0$$

$$\rho_f g V_{sub} - \rho_{obj} V_{obj} g = 0$$

$$\rho_f g V_{sub} = \rho_{obj} V_{obj} g$$

$$\frac{V_{sub}}{V_{obj}} \times 100\% = \frac{\rho_{obj}}{\rho_f} \times 100\% = \frac{472\text{ kg/m}^3}{1.00\times10^3\text{ kg/m}^3} \times 100\%$$

$$\frac{V_{sub}}{V_{obj}} \times 100\% = 47.2\%$$

continued on page 7...

B3. A steel piano wire has a diameter of 0.800 mm and a length of 0.724 m. The wire is held at one end and a mass of 12.6 kg is suspended at rest from the other end. The Young's modulus for steel is 2.00×10^{11} Pa. (6 marks)

(a) Calculate the distance that the wire stretches. Express your answer in mm.

$\boxed{0.889 \text{ mm}}$

$$\frac{F}{A} = Y \frac{\Delta L}{L}$$

$$\Delta L = \frac{FL}{AY} = \frac{mgL}{AY}$$

$$\Delta L = \frac{(12.6\,\text{kg})(9.80\,\text{m/s}^2)(0.724\,\text{m})}{\pi\left(\frac{0.800\times10^{-3}\,\text{m}}{2}\right)^2(2.00\times10^{11}\,\text{Pa})}$$

$$\Delta L = 8.89\times10^{-4}\,\text{m} = 0.889\,\text{mm}$$

(b) The mass is pulled slightly to the side and released. Calculate the period of the back and forth oscillations of the mass. (4 marks)

$\boxed{1.71 \text{ s}}$

The mass on the string becomes a simple pendulum.

$$\omega = \sqrt{\frac{g}{L}} \quad \text{and} \quad T = \frac{2\pi}{\omega}$$

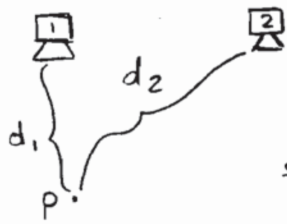
$$\therefore \quad T = 2\pi\sqrt{\frac{L}{g}}$$

$$T = 2\pi\sqrt{\frac{(0.724\,\text{m} + 8.89\times10^{-4}\,\text{m})}{9.80\,\text{m/s}^2}} = 1.71\,\text{s}$$

continued on page 8...

B4. You are listening to the sounds coming from 2 speakers. Both speakers are broadcasting the same frequency. The sound intensity you hear from the speakers is a minimum at a position where the speakers are 2.75 m and 3.41 m away from you. The speed of sound is 343 m/s. The speakers only broadcast sound in the range 128 to 1024 Hz.

(a) Calculate how long the sound takes to reach you from each of the 2 speakers (4 marks).



$v = d/t$

time for speaker 1:	8.02×10^{-3} s
time for speaker 2:	1.01×10^{-2} s

so $t_1 = \frac{d_1}{v_1} = \frac{2.75\text{m}}{343\text{m/s}} = 8.02 \times 10^{-3}\text{s}$

$t_2 = \frac{d_2}{v_2} = \frac{3.45\text{m}}{343\text{m/s}} = 1.01 \times 10^{-2}\text{s}$

(b) Is the sound intensity that you hear due to constructive or destructive interference? Explain your reasoning. (2 marks)

minimum intensity corresponds to destructive interference

*

(c) Determine the possible frequencies coming from the speakers. (4 marks)

know that phase difference = $k(d_2 - d_1)$,

$k = \frac{2\pi}{\lambda}$, $v = f\lambda$, and that

phase difference = $\pi, 3\pi, 5\pi, \ldots$ for destructive interference (i.e. phase diff. = $(2n+1)\pi$)

245 Hz and 735 Hz

$(2n+1)\pi = k(d_2 - d_1)$

$(2n+1)\pi = \frac{2\pi}{\lambda}(d_2 - d_1) \Rightarrow (2n+1)\cancel{\pi} = \frac{2\pi f}{v}(d_2 - d_1)$

so $\left(\frac{2n+1}{2}\right) \cdot \frac{v}{d_2 - d_1} = f$

$f_1 \overset{(n=0)}{=} \frac{v}{2(d_2 - d_1)} = \frac{343 \text{ m/s}}{2(3.45\text{m} - 2.75\text{m})}$

$f_1 = 245$ Hz

$f_2\ (n=1) = 735$ Hz

END OF EXAMINATION

$f_3\ (n=2) = 1.23 \times 10^3$ Hz (out of range)