UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 117.3

MIDTERM EXAM - SOLUTIONS

Regular Sitting

February 15, 2018 Time: 90 minutes

NAME: SOLUTIONS STUDENT NO.: ___________

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

LECTURE SECTION (please check):

- ☐ 01 Mr. Adam Zulkoskey
- ☐ 02 Mr. Brian Zulkoskey

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), an exam booklet, a formula sheet, a scratch card and an OMR sheet. The test paper consists of 8 pages, including this cover page. **It is the responsibility of the student to check that the test paper is complete.**
3. Only a basic scientific calculator (e.g. Texas Instruments TI-30X series, Hewlett-Packard HP 10s or 30S) may be used. Graphing or programmable calculators, or calculators with communication capability, are **not** allowed.
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 name on the exam booklet and scratch card.
5. Enter your name and NSID on the OMR sheet.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR sheet must all be submitted.
7. No test materials will be returned.

QUESTION NUMBER	MAXIMUM MARKS	MARKS OBTAINED
A1-12	12	
B1-4	8	
B5-8	8	
B9-12	8	
B13-16	8	
MARK	out of 36:	

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PART A

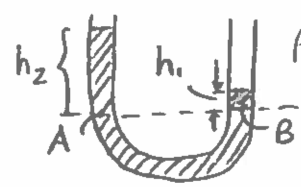
FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. A U-tube is partially filled with water. Mercury (which does not mix with water) is then added to the right side of the tube. The top of the mercury is a distance h_1 above the level of the interface between the mercury and water. On the left side of the tube the top of the water is a distance h_2 above the level of the mercury-water interface on the right side. What is the density of mercury, ρ_{Hg}, in terms of the density of water, ρ_w?

B

(A) $\rho_{Hg} = \dfrac{h_1}{h_2}\rho_w$ (B) $\rho_{Hg} = \dfrac{h_2}{h_1}\rho_w$ (C) $\rho_{Hg} = \dfrac{h_2 - h_1}{h_2}\rho_w$

(D) $\rho_{Hg} = \dfrac{h_1}{h_2 - h_1}\rho_w$ (E) $\rho_{Hg} = \dfrac{h_2 - h_1}{h_2 + h_1}\rho_w$



$P_A = P_B$

$P_{atm} + \rho_w g h_2 = P_{atm} + \rho_{Hg} g h_1$

$\rho_{Hg} = \left(\frac{h_2}{h_1}\right)\rho_w$

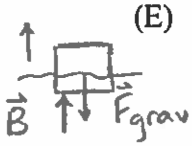
A2. Two solid objects of identical mass are placed in a container that is filled with an unknown liquid. One object floats and the other sinks to the bottom. Which one of the following is a true statement concerning the volumes of the objects?

B

$\therefore \rho_s > \rho_f \Rightarrow \frac{m}{V_s} > \frac{m}{V_f} \Rightarrow V_f > V_s$

(A) Both objects have the same volume.
(B) The floating object's volume is greater than the volume of the object that sinks.
(C) The floating object's volume is less than the volume of the object that sinks.
(D) Nothing can be said about the volumes without knowing the densities of the objects.
(E) Nothing can be said about the volumes without knowing the density of the unknown liquid.

FLOATER:



$B - F_{grav} = 0$
$B = mg$

$\rho_\ell g V_{dis} = \rho_f g V_f$
$V_{dis} < V_f \Rightarrow \rho_\ell > \rho_f$

SUBMERGED:
$B < F_{grav}$
$\rho_\ell g V_s < \rho_s g V_s \Rightarrow \rho_s > \rho_\ell$

A3. An ideal fluid flows through a pipe made of two sections with diameters of 1.0 cm and 4.0 cm, respectively. How is the speed of the fluid flow through the 4.0-cm section, υ_4, related to the speed of the fluid flow through the 1.0-cm section, υ_1?

A

(A) $\upsilon_4 = \frac{1}{16}\upsilon_1$ (B) $\upsilon_4 = \frac{1}{4}\upsilon_1$ (C) $\upsilon_4 = \frac{1}{2}\upsilon_1$ (D) $\upsilon_4 = 4\upsilon_1$ (E) $\upsilon_4 = 16\upsilon_1$

Continuity Equation: $A_1 \upsilon_1 = A_4 \upsilon_4$
$\pi\left(\frac{d_1}{2}\right)^2 \upsilon_1 = \pi\left(\frac{d_4}{2}\right)^2 \upsilon_4$

$\upsilon_4 = \left(\frac{d_1}{d_4}\right)^2 \upsilon_1 = \left(\frac{1.0\text{cm}}{4.0\text{cm}}\right)^2 \upsilon_1 = \frac{1}{16}\upsilon_1$

A~~3~~4. Which one of the following quantities is at ~~a~~ maximum magnitude when an object in simple harmonic motion is at its maximum displacement?

A

(A) acceleration (B) speed (C) momentum
(D) kinetic energy (E) frequency

At max. displacement, $\upsilon = 0$ $\therefore \vec{p} = m\vec{\upsilon}$ and $KE = \frac{1}{2}m\upsilon^2$ are also 0

frequency is constant $\vec{a} = -\frac{k}{m}\vec{x} \Rightarrow |\vec{a}|$ is max. when $|\vec{x}|$ is max.

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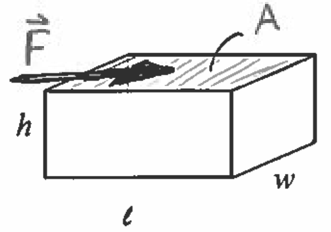
A~~4~~5. A rectangular block has dimensions h, ℓ and w, as shown in the diagram below. If a force of magnitude F is applied parallel to the top surface of the block, which one of the following expressions is correct for the shear stress exerted on the top surface of the block?

B



$$\text{Shear Stress} = \frac{F}{A_{parallel}} = \frac{F}{\ell w}$$

(A) $\frac{F}{h\ell}$ (B) $\frac{F}{w\ell}$ (C) $\frac{F}{hw}$ (D) $\frac{F}{\ell^2}$ (E) $\frac{F}{w^2}$

A6. Due to a build-up of sludge, the effective radius of ~~an~~ horizontal oil pipeline becomes half the original radius. To compensate for this reduced radius, the pipeline operator increases the pressure difference across the length of the pipeline by a factor of four. If Q_1 is the original volume flow rate through the pipeline, what is the new volume flow rate, Q_2, in terms of Q_1? (η does not change)

E

(A) $Q_2 = 4\,Q_1$ (B) $Q_2 = 2\,Q_1$ (C) $Q_2 = Q_1$
(D) $Q_2 = ½\,Q_1$ (E) $Q_2 = ¼\,Q_1$

$$Q_1 = \frac{\pi R_1^4 (P_1 - P_2)_1}{8\eta L} \;;\; Q_2 = \frac{\pi R_2^4 (P_1 - P_2)_2}{8\eta L} = \frac{\pi \left(\frac{R_1}{2}\right)^4 \left(4(P_1-P_2)_1\right)}{8\eta L} = \frac{4}{16}\,\frac{\pi R_1^4 (P_1-P_2)_1}{8\eta L}$$

$$Q_2 = \frac{1}{4} Q_1$$

A7. If one could transport a simple pendulum of constant length from the Earth's surface to the Moon's, where the acceleration due to gravity is one-sixth (1/6) of that on Earth, by what factor would the pendulum frequency be changed?

C

(A) $f_M \approx 6 f_E$ (B) $f_M \approx 2.5 f_E$ (C) $f_M \approx 0.41 f_E$ (D) $f_M \approx 0.17 f_E$ (E) $f_M = 3.5 f_E$

$$T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{g}{L}} \;;\; f_M = \frac{1}{2\pi}\sqrt{\frac{g_M}{L}} = \frac{1}{2\pi}\sqrt{\frac{\frac{1}{6}g_E}{L}} = \sqrt{\frac{1}{6}}\left(\frac{1}{2\pi}\sqrt{\frac{g_E}{L}}\right) = 0.41 f_E$$

A8. Which one of the following pairs of quantities do you need to know in order to calculate the wavelength of a travelling wave?

D

(A) frequency and period (B) speed and amplitude (C) amplitude and frequency
(D) frequency and speed (E) period and amplitude

$$v = f\lambda \Rightarrow \lambda = \frac{v}{f}$$

A9. The speed of a wave in a stretched string is initially 50 m/s. What will be the new wave speed if the tension in the string is increased by 18%?

B

(A) 50 m/s (B) 54 m/s (C) 21 m/s (D) 59 m/s (E) 45 m/s

$$v_1 = \sqrt{\frac{F_1}{\mu}} \;;\; v_2 = \sqrt{\frac{F_2}{\mu}} = \sqrt{\frac{1.18 F_1}{\mu}} = 1.086\sqrt{\frac{F_1}{\mu}} = 1.086\, v_1 = 1.086\,(50\text{ m/s}) = 54\text{ m/s}$$

A10. How is the direction of propagation of an electromagnetic wave oriented relative to the directions of the associated electric and magnetic fields?

C

(A) parallel to the magnetic field, perpendicular to the electric field
(B) perpendicular to the magnetic field, parallel to the electric field
(C) perpendicular to the magnetic field, perpendicular to the electric field
(D) parallel to the magnetic field, parallel to the electric field
(E) parallel to the magnetic field, anti-parallel to the electric field

$\vec{v} \perp \vec{B} \perp \vec{E}$

$\vec{v} \perp \vec{B}, \vec{E}$

A11. It is observed that the air in a pipe resonates at frequencies of 120 Hz (the fundamental) and 600 Hz, and possibly other frequencies between these two values. If the pipe is open at both ends, how many additional resonant frequencies are there between 120 Hz and 600 Hz; and if the pipe is open at one end and closed at the other, how many additional resonant frequencies are there between 120 Hz and 600 Hz?

A

(A) open: 3 ; closed: 1
(B) open: 1 ; closed: 3
(C) open: 2 ; closed: 0
(D) open: 0 ; closed: 2
(E) open: 5 ; closed: 1

f_{open} : all harmonics ; f_{closed} : odd harmonics ⇒

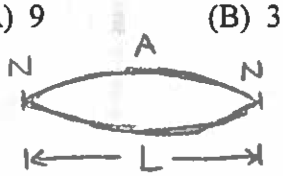
f_{open} : 120 Hz, 240 Hz, 360 Hz, 480 Hz, 600 Hz

f_{closed} : 120 Hz, 360 Hz, 600 Hz

A12. If the tension in a guitar string is increased by a factor of 3, by what factor does the fundamental frequency at which the string vibrates change?

C

(A) 9
(B) 3
(C) $\sqrt{3}$
(D) $\frac{1}{\sqrt{3}}$
(E) $\frac{1}{3}$



$L = \frac{1}{2}\lambda_1$

$\lambda_1 = 2L$

$f_1 = \frac{v}{\lambda_1} = \frac{1}{2L}\sqrt{\frac{F}{\mu}}$; $f_1' = \frac{1}{2L}\sqrt{\frac{3F}{\mu}}$

$f_1' = \sqrt{3}\left(\frac{1}{2L}\sqrt{\frac{F}{\mu}}\right) = \sqrt{3} f_1$

PART B

WORK OUT THE ANSWERS TO THE FOLLOWING PART B QUESTIONS.

WHEN YOU HAVE AN ANSWER THAT IS ONE OF THE OPTIONS AND ARE CONFIDENT THAT YOUR METHOD IS CORRECT, SCRATCH THAT OPTION ON THE SCRATCH CARD. IF YOU REVEAL A STAR ON THE SCRATCH CARD THEN YOUR ANSWER IS CORRECT (FULL MARKS, 2/2).

IF YOU DO NOT REVEAL A STAR WITH YOUR FIRST SCRATCH, TRY TO FIND THE ERROR IN YOUR SOLUTION. IF YOU REVEAL A STAR WITH YOUR SECOND SCRATCH, YOU RECEIVE HALF-MARKS (1/2).

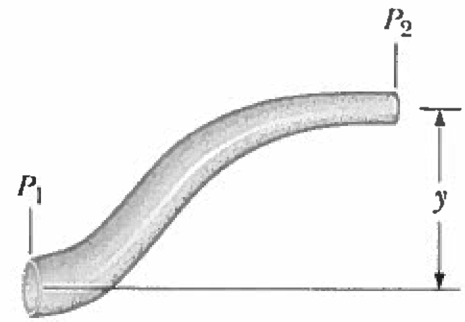
IF YOU STILL DO NOT HAVE THE CORRECT ANSWER, BUT REWORK YOUR SOLUTION AND REVEAL A STAR WITH YOUR THIRD SCRATCH, THEN YOU RECEIVE 0.2/2.

REVEALING THE STAR WITH YOUR FOURTH OR FIFTH SCRATCHES DOES NOT EARN YOU ANY MARKS, BUT IT DOES GIVE YOU THE CORRECT ANSWER.

YOU MAY ANSWER ALL FOUR PART B QUESTION GROUPINGS (1-4, 5-8, 9-12, AND 13-16) AND YOU WILL RECEIVE THE MARKS FOR YOUR BEST 3 GROUPINGS.

USE THE PROVIDED EXAM BOOKLET FOR YOUR ROUGH WORK.

Water moves through the pipe shown below in steady, ideal flow. At the lower point shown in the figure, the flow speed is 2.16 m/s and the pipe radius is 2.50 cm. At the higher point located at $y = 2.50$ m, the pressure is 1.26×10^5 Pa and the pipe radius is 1.30 cm.



B1. Which one of the following pairs of principles/equations apply to the flow situation described above?

C

(A) The Continuity Equation and Poiseuille's Law
(B) Poiseuille's Law and Bernoulli's Principle
(C) The Continuity Equation and Bernoulli's Principle
(D) The Continuity Equation and Stoke's Law
(E) Stoke's Law and Poiseuille's Law

B2. Which one of the following statements is correct concerning the pressure and flow speed in region 2 compared to region 1?

A

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y$; $\underbrace{A_1 v_1 = A_2 v_2}_{v_2 > v_1}$

(A) The pressure is lower in region 2 but the flow speed is higher in region 2.
(B) Both the pressure and flow speed are lower in region 2 than in region 1.
(C) Both the pressure and flow speed are higher in region 2 than in region 1.
(D) The pressure is higher in region 2 but the flow speed is lower in region 1.
(E) The pressure is lower in region 2 than in region 1 but the flow speed is the same.

$\therefore P_1 > P_2$

$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) + \rho g y > 0$

B3. Calculate the volume flow rate in the upper section of the pipe.

$Q = A_1 v_1 = A_2 v_2$

i.e. $Q_{upper} = Q_{lower} = A_1 v_1 = \pi (0.0250\text{m})^2 (2.16\text{m/s}) = \boxed{4.24 \times 10^{-3}\ \text{m}^3/\text{s}}$

$v_2 = \frac{Q}{A_2} = \frac{4.24 \times 10^{-3}\ \text{m}^3/\text{s}}{\pi (0.0130\text{m})^2} = 7.988\ \text{m/s}$

B4. Calculate the pressure in the lower section of the pipe.

$P_1 = P_2 + \frac{1}{2}\rho(v_2^2 - v_1^2) + \rho g y$

$P_1 = 1.26 \times 10^5\ \text{Pa} + \frac{1}{2}\left(1.00 \times 10^3 \frac{\text{kg}}{\text{m}^3}\right)\left((7.988\text{m/s})^2 - (2.16\text{m/s})^2\right) + \left(1.00 \times 10^3 \frac{\text{kg}}{\text{m}^3}\right) \times (9.80\text{m/s}^2)(2.50\text{m})$

$\boxed{P_1 = 1.80 \times 10^5\ \text{Pa}}$

B5. 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

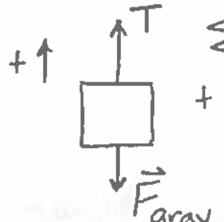
E

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

$$\frac{F}{A} = Y\frac{\Delta L}{L} \Rightarrow \Delta L = \frac{FL}{AY}\ ;\ \Delta L_1 = \frac{F_1 L_1}{AY}\ ;\ \Delta L_2 = \frac{F_2 L_2}{AY} = \frac{2F_1 2L_1}{AY} = 4\frac{F_1 L_1}{AY} = 4\Delta L_1$$

The following 3 questions deal with steel cables of cross-sectional area 4.00 cm² and unstressed length 25.0 m. The elastic limit of steel is 2.50×10^8 Pa. and its Young's modulus is 2.00×10^{11} Pa.

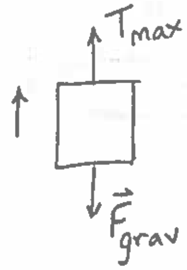
B6. A single steel cable is used in the lifting mechanism of an elevator. Calculate the amount that the cable stretches when a stationary object (a loaded elevator car) of mass 8.50×10^3 kg is hung from the cable.



$$\Sigma\vec{F} = m\vec{a}$$
$$\Sigma\vec{F} = 0$$
$$+T - F_{grav} = 0$$
$$T = mg$$

$$\frac{T}{A} = Y\frac{\Delta L}{L}$$
$$\Delta L = \frac{TL}{AY} = \frac{(mg)L}{AY}$$
$$\Delta L = \frac{(8.50\times10^3\,kg)(9.80\,m/s^2)(25.0\,m)}{(4.00\,cm^2 \times (1\,m/100\,cm)^2)(2.00\times10^{11}\,Pa)} = 2.60\,cm$$

B7. Calculate the maximum upward acceleration that the elevator car can have before the stress on the cable exceeds the elastic limit.



$$\Sigma\vec{F} = m\vec{a}$$
$$+T_{max} - mg = ma_{max}$$
$$\text{Elastic Limit} = S_{max} = \frac{T_{max}}{A}$$

$$S_{max}A - mg = ma_{max}$$
$$a_{max} = \frac{S_{max}\cdot A}{m} - g$$
$$a_{max} = \frac{(2.50\times10^8\,Pa)(4.00\,cm^2)(1\,m/100\,cm)^2}{8.50\times10^3\,kg} - 9.80\,m/s^2$$
$$a_{max} = 1.96\,m/s^2$$

B8. You decide that you want to increase the limit on the maximum upward acceleration to a value of 6.00 m/s² by attaching more than one cable to the elevator car. Calculate the minimum number of cables required so that the upward acceleration is 6.00 m/s² and the stress on each cable does not exceed the elastic limit. Each cable experiences the same stress.

Set the tension in each cable to $S_{max}\cdot A$

Let n be the required number of cables.

From the work in B7, $n_{min}(S_{max}A) - mg = ma$

$$n_{min} = \frac{m(a+g)}{S_{max}\cdot A} = \frac{(8.50\times10^3\,kg)(6.00\,m/s^2 + 9.80\,m/s^2)}{(2.50\times10^8\,Pa)(4.00\,cm^2)(1\,m/100\,cm)^2} = 1.34$$

n must be a whole number $\Rightarrow$ $n = 2$

B9. A speaker designed to emit spherical sound waves is producing a sound intensity of 8 W/m² at a distance of 1 m from the speaker. What would be the intensity of this sound at a distance of 2 m from the speaker?

$$I = \frac{P}{A} \Rightarrow P = IA \Rightarrow I_1(4\pi r_1^2) = I_2(4\pi r_2^2) \Rightarrow I_2 = I_1\left(\frac{r_1}{r_2}\right)^2 = 8\frac{W}{m^2}\left(\frac{1m}{2m}\right)^2 = 2\,W/m^2$$

A sound wave from the siren on Ambulance 1 has an intensity of ~~0.750~~ 0.795 W/m² at a certain location, and, at the same location, a second sound wave from the siren on Ambulance 2 has an intensity level that is 13 dB less than the sound from Ambulance 1.

B10. Calculate the intensity level of the sound wave due to the siren on Ambulance 2.

$$I_1 = 0.750\,W/m^2\ ;\ \beta_1 = 10dB\log_{10}\left(\frac{0.795\,W/m^2}{1.00\times10^{-12}\,W/m^2}\right) = 119.0\,dB$$

$$\beta_2 = \beta_1 - 13\,dB = 106\,dB$$

B11. Calculate the intensity of the sound due to the siren on Ambulance 2.

$$\beta_2 = 10dB\log_{10}\left(\frac{I_2}{I_0}\right) \Rightarrow \frac{\beta_2}{10dB} = \log_{10}\left(\frac{I_2}{I_0}\right) \Rightarrow 10^{\beta_2/10dB} = \frac{I_2}{I_0}$$

$$I_2 = I_0 \times 10^{\beta_2/10dB} = (1.00\times10^{-12}\,W/m^2)(10^{106dB/10dB}) = 3.98\times10^{-2}\,W/m^2$$

$$(3.981\times10^{-2}\,W/m^2)$$

B12. If the location of interest is ~~5.00 × 10²~~ 50.0 m from Ambulance 2, and assuming spherical wave fronts, calculate the average power output of the siren on Ambulance 2.

$$I = \frac{P}{A} \Rightarrow P = IA = I(4\pi r^2) = \left(3.981\times10^{-2}\frac{W}{m^2}\right)\left(4\pi(50.0m)^2\right)$$

$$P = 1.25\times10^3\,W$$

B13. Two tuning forks sounding together result in a beat frequency of 4.00 Hz. If the frequency of one of the forks is 258 Hz, what is the frequency of the other?

$$f_{beat} = |f_2 - f_1|$$

$$\therefore f_2 = f_1 \pm f_{beat} = 262\,\text{Hz or } 254\,\text{Hz}$$

Two train whistles emit identical frequencies of sound of 177 Hz. When one train is at rest at the station and the other is moving nearby, a commuter standing on the station platform hears beats with a frequency of 6.00 beats/s when the whistles are blowing at the same time.

B14. If the temperature is $-\cancel{4}$ 3 5.0°C, calculate the speed of sound.

$$v = (331\,\text{m/s})\sqrt{\frac{T(\text{K})}{273\,\text{K}}} = (331\,\text{m/s})\sqrt{\frac{((-35.0^\circ) + 273)\text{K}}{273\,\text{K}}} = 309\,\text{m/s}$$

B15. Sound waves are longitudinal waves with alternating sections of compression and rarefaction. Calculate the $\underbrace{\text{distance between consecutive sections of compression}}_{=\lambda}$ for the sound wave emitted by the stationary ~~train.~~

$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{309\,\text{m/s}}{177\,\text{Hz}} = 1.75\,\text{m}$$

B16. There are two possible speeds that the moving train can have. Calculate the speed of the train that corresponds to the commuter on the platform hearing a frequency of 183 Hz for the sound from the moving train's whistle.

$$f_o = 183\,\text{Hz}$$

The moving train is a moving source (moving toward the observer)

$$f_o = f_s\left(\frac{v}{v - v_s}\right) \Rightarrow f_o(v - v_s) = f_s v$$

$$f_o v - f_o v_s = f_s v \Rightarrow (f_o - f_s)v = f_o v_s$$

END OF EXAMINATION

$$v_s = \left(\frac{f_o - f_s}{f_o}\right)v$$

$$v_s = \left(\frac{183\,\text{Hz} - 177\,\text{Hz}}{183\,\text{Hz}}\right)(309\,\text{m/s}) = 10.1\,\text{m/s}$$