UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
MIDTERM TEST

February 16, 2012 Time: 90 minutes

NAME: MASTER
(Last) **Please Print** (Given)

STUDENT NO.: ___________

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 Dr. J-P St. Maurice
- ❑ 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 10S or 30S or Texas Instruments TI-30X series calculators, or a calculator approved by your instructor, 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...

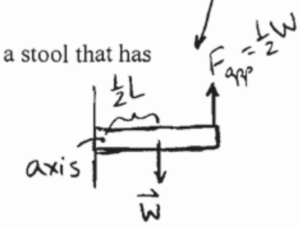
PART A

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

A1. A uniform bar of length *L* and weight *W* is attached to a vertical wall by a frictionless hinge. Which one of the following scenarios can result in the bar being horizontal and stationary?

C

(A) A force of magnitude *W* is applied vertically upward to the bar at a distance of *L* from the hinge.
(B) A force of magnitude *W* is applied horizontally to the bar at a distance of *L* from the hinge.
(C) A force of magnitude ½*W* is applied vertically upward to the bar at a distance of *L* from the hinge.
(D) A force of magnitude ½*W* is applied vertically upward to the bar at a distance of ½*L* from the hinge.
(E) A force of magnitude *W* is applied horizontally to the bar at a distance of ½*L* from the hinge.



Want $\Sigma\tau = 0$

A2. A student holding a pair of dumbbells in his outstretched arms is rotating on a stool that has frictionless bearings. When the student pulls his arms closer to his body…

E

(A) both his angular momentum and his angular velocity increase.
(B) his angular momentum increases and his angular velocity decreases.
(C) both his angular momentum and his angular velocity decrease.
(D) both his rotational inertia and his angular velocity increase.
(E) his angular momentum remains constant and his angular velocity increases.

Cons. of Ang. Momentum
$I_i\omega_i = I_f\omega_f$

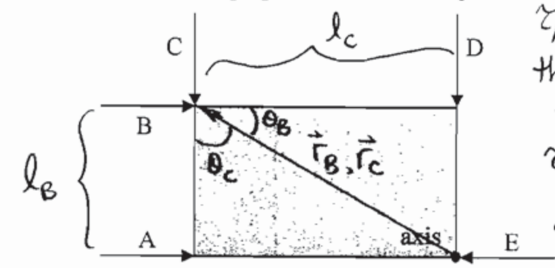
A3. Which one of the following statements is **TRUE**?

E

(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

A4. Five forces, A, B, C, D, and E, all of equal magnitude, act on a rectangular object as shown below. Which force produces the largest magnitude of torque if the axis of rotation is through the lower right corner of the object and perpendicular to the object?

C



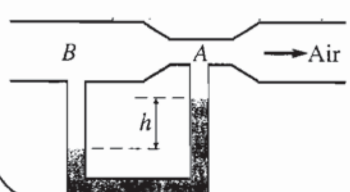
$\tau_A = \tau_D = \tau_E = 0$ b/c the forces act through the axis.
$\tau_c > \tau_B$ b/c $l_c > l_B$
or b/c $\theta_c > \theta_B$

(A) A (B) B (C) C (D) D (E) E

A5. Air is flowing into a Venturi meter (see figure). The narrow section of the pipe at point *A* has a diameter that is ½ of the diameter of the larger section of the pipe at point *B*. The U-shaped tube is filled with water. If the air speed at *B* is υ, how fast is the air moving at point *A*?

E

(A) ¼ υ (B) ½ υ (C) υ (D) 2 υ (E) 4 υ



Continuity Eq'n:
$A_B\upsilon_B = A_A\upsilon_A$
$\frac{\pi d_B^2}{4}\upsilon_B = \frac{\pi d_A^2}{4}\upsilon_A$

$\upsilon_A = \left(\frac{d_B}{d_A}\right)^2 \upsilon_B$

$\upsilon_A = \left(\frac{d_B}{\frac{1}{2}d_B}\right)^2 \upsilon_B = 4\upsilon_B$

continued on page 3...

A6. Which has a greater buoyant force on it, a 25 cm^3 piece of wood floating with part of its volume above water or a 25 cm^3 piece of submerged iron?

B

(A) The floating wood.
(B) The submerged iron.
(C) They each experience the same buoyant force.
(D) It is impossible to say without knowing their weights.
(E) It is impossible to say without knowing the depth of the piece of submerged iron.

$F_B = \rho_f g V_f$

submerged iron displaces more water than floating wood.

A7. A viscous fluid is flowing steadily through a pipe of radius r. Suppose you replace it by two parallel pipes, each of radius ½ r, but the same length as the original pipe. If the pressure difference between the ends of these two pipes is the same as for the original pipe, what is the total rate of flow in the two pipes compared to the original flow rate, Q_1?

A

$Q_1 = \frac{\Delta V}{\Delta t} = \frac{\pi}{8} \frac{\Delta P/L}{\eta} r^4$

(A) $\frac{1}{8}Q_1$ (B) $\frac{1}{4}Q_1$ (C) $\frac{1}{2}Q_1$ (D) Q_1 (E) $2Q_1$

For each new pipe, $Q = \frac{\pi}{8}\frac{\Delta P/L}{\eta}\left(\frac{1}{2}r\right)^4 = \frac{1}{16}Q_1$ so $Q_{new} = 2\left(\frac{1}{16}Q_1\right)$

A8. An object attached to a spring is undergoing simple harmonic motion. Which one of the following statements is **FALSE**?

A

(A) The object's acceleration is maximum at the equilibrium position. F
(B) The restoring force always acts to return the spring to its equilibrium position. T
(C) The object's velocity is instantaneously zero at maximum displacement. T
(D) The object's velocity is maximum at the equilibrium position. T
(E) The restoring force is always directed opposite to the displacement from equilibrium. T

$F = -kx$

A9. Which one of the following statements is **FALSE**?

C

(A) An object in equilibrium can still be deformed by forces. T
(B) An elastic object can return to its original shape, provided the applied force is not too large. T
(C) A tensile (stretching) force applied to the ends of a wire exerts a shear stress on the wire. F
(D) Tensile strain is the fractional change in length. T
(E) Strain is a dimensionless measure of the deformation of an object. T

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

A10. A force F applied to each end of a steel wire (length L, diameter d) stretches it by ΔL. How much does the same force F stretch another steel wire of length $2L$ and diameter $2d$?

B

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

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

$\Delta L' = \frac{F(2L)}{(4A)Y} = \frac{1}{2}\Delta L$

A11. A thin circular hoop is suspended from a knife edge as shown in the figure. Its rotational inertia about the rotation axis (along the knife edge) is $I = 2MR^2$. You want to compare its frequency of oscillation to that of a simple pendulum that has its mass suspended at a distance equal to the radius of the hoop. Let f be the frequency of oscillation of the simple pendulum. The frequency of oscillation of the hoop is

B

(A) $\frac{f}{2}$ (B) $\frac{f}{\sqrt{2}}$ (C) f (D) $\sqrt{2}f$ (E) $2f$

$f = \frac{1}{2\pi}\sqrt{\frac{g}{R}}$

$f_{hoop} = \frac{1}{2\pi}\sqrt{\frac{mgd}{I}} = \frac{1}{2\pi}\sqrt{\frac{MgR}{2MR^2}} = \frac{1}{2\pi}\sqrt{\frac{g}{2R}} = \frac{1}{\sqrt{2}}\left(\frac{1}{2\pi}\sqrt{\frac{g}{R}}\right) = \frac{1}{\sqrt{2}} \cdot f$

A12. A sound source radiates sound uniformly in all directions. The power of the source is constant. The sound intensity is I at a distance of r from the source. The intensity at a distance of $2r$ is

A

(A) ¼ I (B) ½ I (C) I (D) 2 I (E) 4 I

$I = \frac{P}{4\pi r^2}$

A13. Two speakers, separated by a distance d, are producing coherent sound waves that are in phase at a point P that is the same distance from each speaker. The wavelength of the sound being produced is λ. Point Q is a distance r_1 from speaker 1 and a distance r_2 from speaker 2. Which one of the following conditions will ensure that the sound waves from the speakers interfere destructively at Q?

E

(A) $|r_2 - r_1| = 2d$ (B) $|r_2 - r_1| = d$ (C) $|r_2 - r_1| = \frac{1}{2}d$ (D) $|r_2 - r_1| = \lambda$ (E) $|r_2 - r_1| = \frac{1}{2}\lambda$

Constructive interference at P means the two sources are in phase. Destructive interference will occur at Q for $|r_2 - r_1| = \frac{1}{2}\lambda$

continued on page 4...

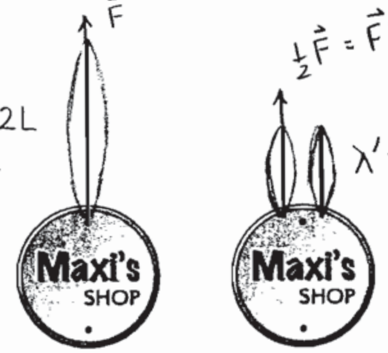
A14. A sign is hanging from a single metal wire, as shown in the left part of the accompanying figure. The shop owner notices that the wire vibrates at a fundamental resonance frequency of f, which irritates his customers. In an attempt to fix the problem, the shop owner cuts the wire in half and hangs the sign from the two halves, as shown in the right part of the figure. Assuming the tension in each of the two wires is now half the original tension, what is the new fundamental frequency of each wire?

D

$\vec{F}$ $\qquad \frac{1}{2}\vec{F} = \vec{F}'$

$\lambda_1 = 2L$

$f = \frac{v}{\lambda} = \frac{1}{2L}\sqrt{\frac{F}{\mu}}$



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

$f' = \frac{v'}{\lambda'} = \frac{1}{L}\sqrt{\frac{F'}{\mu}}$

$f' = \frac{1}{L}\sqrt{\frac{\frac{1}{2}F}{\mu}} = \frac{1}{L}\frac{1}{\sqrt{2}}\sqrt{\frac{F}{\mu}}$

(A) $\frac{f}{2}$ (B) $\frac{f}{\sqrt{2}}$ (C) f (D) $\sqrt{2}f$ (E) $2f$

A15. The accompanying figure shows a snapshot of a transverse wave moving to the left on a string. The wave speed is 10.0 m/s and to the left, as shown. At the instant the snapshot is taken, in what directions are points A and B moving?

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

C

$f' = \frac{2}{\sqrt{2}} f = \sqrt{2} f$

(A) They are both moving to the left.
(B) They are both moving up.
(C) Point A is moving up while point B is moving down.
(D) Point A is moving down while point B is moving up.
(E) They are both moving down.

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.

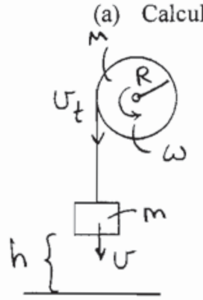
USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

continued on page 5...

Stu. No.: ______________________

B1. A light rope is wrapped several times around a large uniform wheel with a radius of 0.400 m. The wheel rotates in frictionless bearings about a stationary horizontal axis. The free end of the rope is tied to a suitcase with a mass of 15.0 kg. The suitcase is released from rest at a height of 4.00 m above the ground, and has a speed of 3.50 m/s when it reaches the ground.

(a) Calculate the angular velocity of the wheel when the suitcase reaches the ground. (2 marks)



$\boxed{8.75 \text{ rad/s}}$

$$v_{suitcase} = v_{t_{rim}} = R\omega$$

$$\omega = \frac{v}{R} = \frac{3.50 \text{ m/s}}{0.400 \text{ m}} = 8.75 \text{ rad/s}$$

(b) Calculate the rotational inertia of the wheel. If you did not obtain an answer for (a), use a value of 9.00 rad/s (5 marks)

$I = \frac{1}{2}MR^2$, but don't know M.

$\boxed{13.0 \text{ kg}\cdot\text{m}^2}$

Method 1:
Cons. of Energy for Wheel/Suitcase System.

$$E_f = E_i$$

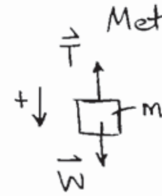
$$\frac{1}{2}I\omega_f^2 + \frac{1}{2}mv_f^2 = mgh$$

$$\frac{1}{2}I\omega_f^2 = mgh - \frac{1}{2}mv_f^2$$

$$I = \frac{2(mgh - \frac{1}{2}mv_f^2)}{\omega_f^2}$$

$$I = 13.0 \text{ kg}\cdot\text{m}^2$$

Method 2: Newton II



$$\Sigma\vec{F} = m\vec{a} \qquad a = \frac{v_f^2 - v_i^2}{2h}$$

$$W - T = ma$$

$$mg - ma = T \qquad a = 1.53 \text{ m/s}^2$$

$$T = 15.0 \text{ kg}(9.80 \text{ m/s}^2 - 1.53 \text{ m/s}^2)$$

$$T = 124 \text{ N}$$

$$\Sigma\tau = I\alpha$$

$$I = \frac{\Sigma\tau}{\alpha} = \frac{TR}{a/R} = \frac{TR^2}{a} = 13.0 \text{ kg}\cdot\text{m}^2$$

(c) Calculate the mass of the wheel. If you did not obtain an answer for (b) use a value of 12.5 kg·m^2. (3 marks)

$\boxed{162 \text{ kg}}$

$I = \frac{1}{2}MR^2$ (uniform solid wheel rotating around central axis)

$$M = \frac{2I}{R^2} = \frac{2(13.0 \text{ kg}\cdot\text{m}^2)}{(0.400 \text{ m})^2} = 162 \text{ kg}$$

continued on page 6...

Stu. No.: ____________________

B2. A block of wood, with density 700 kg/m^3, has a cubic shape with sides 0.330 m long. A rope of negligible mass is used to tie a piece of lead (density 11300 kg/m^3) to the bottom of the wood. The lead pulls the wood into the water (density of 1000 kg/m^3) until the block of wood is just completely covered with water.

(a) Calculate the volume of the wood block in m^3. (1 mark)

$V = l^3$

$V = (0.330\,m)^3 = 3.59\times10^{-2}\,m^3$

$\boxed{3.59\times10^{-2}\,m^3}$

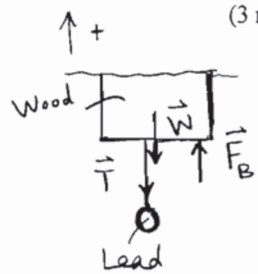
(b) Calculate the mass of the wood block in kg. (1 mark)

$\rho = \frac{m}{V} \Rightarrow m = \rho V$

$m = (700\,kg/m^3)(3.59\times10^{-2}\,m^3) = 25.1\,kg$

$\boxed{25.1\,kg}$

(c) Since lead is so dense, assume for a quick first order answer that the volume of lead is negligible compare to the volume of the block of wood. With this approximation, use Archimedes' principle to obtain an approximate value for the mass of the piece of lead. (3 marks)



In this approximation, the tension in the rope equals the weight of the lead.

$\boxed{10.8\,kg}$

For the wood block, $\Sigma\vec{F} = 0 \Rightarrow F_B - T - W_{wood} = 0$

$\rho_f g V_f - W_{Lead} - W_{wood} = 0$

$\rho_f \cancel{g} V_f - m_{Lead}\cancel{g} - m_{wood}\cancel{g} = 0$

$m_{Lead} = \rho_f V_f - m_{wood} = (1000\,kg/m^3)(3.59\times10^{-2}\,m^3) - 25.1\,kg = 10.8\,kg$

(d) If you were now to take account of the additional volume occupied by the piece of lead, would you expect to obtain a larger value or a smaller value for the mass of the piece of lead? Explain briefly. (2 marks)

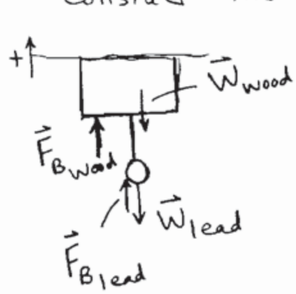
The submerged volume of lead results in an additional upward buoyant force on the wood/lead system, so the required mass of lead will be larger than calculated in (c).

$\boxed{\text{larger}}$

(e) Do the exact calculation for the mass of lead by properly taking its volume into account. (3 marks)

Consider the wood/lead as a single object.

$\boxed{11.8\,kg}$



$\Sigma\vec{F} = 0$

$F_{B\,wood} + F_{B\,lead} - W_{wood} - W_{lead} = 0$

$\rho_f \cancel{g}(V_{wood} + V_{lead}) - m_{wood}\cancel{g} - m_{lead}\cancel{g} = 0$

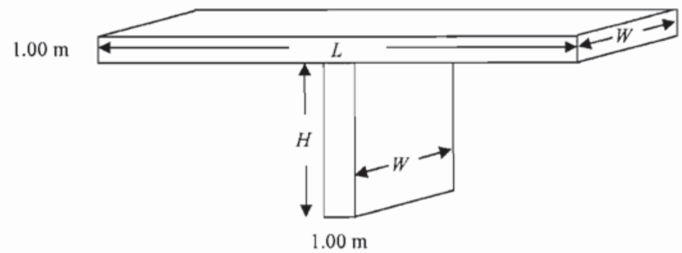
$\rho_f \left(V_{wood} + \frac{m_{lead}}{\rho_{lead}}\right) - m_{wood} - m_{lead} = 0$

$\rho_f V_{wood} - m_{wood} = m_{lead} - \frac{m_{lead}\rho_f}{\rho_{lead}}$

$m_{lead} = \frac{\rho_f V_{wood} - m_{wood}}{1 - \rho_f/\rho_{lead}} = \frac{10.8\,kg}{1 - 1000/11300} = 11.8\,kg$

continued on page 7...

B3. An engineer wants to construct a "table" made of concrete (a piece of super highway over the mountains, really). The "table" is to be 1.00 m thick, W m wide and L m long. It is to be supported by a rectangular column of concrete H m high, with an area W m by 1.00 m large:



(a) Show that the pressure on the bottom of the concrete support column is independent of the width W. For $L = H = 100$ m, calculate the compression stress, in Pa, at the bottom of the column. Use 2400 kg/m^3 for the density of concrete. (3 marks)

The stress at the bottom of the column is the weight of the table plus the weight of the column divided by the cross-sectional area of the column.

$\boxed{4.70 \times 10^6 \text{ Pa}}$

$$P = \frac{F}{A} = \frac{F_{grav\,table} + F_{grav\,column}}{W\,(1.00\text{m})} = \frac{\rho g\,(LW \cdot 1.00\text{m}) + \rho g\,(HW \cdot 1.00\text{m})}{W\,(1.00\text{m})}$$

$$P = \rho g\,(L + H) = (2400 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(100\text{m} + 100\text{m}) = 4.70 \times 10^6 \text{ Pa}$$

(b) The maximum mass load from cars that might pile up on the highway during a traffic jam is estimated to be (9000 L) kg. If the width W is 20.0 m, calculate the additional pressure, in Pa, exerted on the base of the support column in terms of L. (Obtain a number times L which will give you Pa if L is in m). (3 marks)

$$P_{additional} = \frac{F_{grav\,additional}}{W\,(1.00\text{m})} = \frac{m_{additional}\,g}{W\,(1.00\text{m})}$$

$\boxed{(4.41 \times 10^3 L)\text{ Pa}}$

$$P_{additional} = \frac{(9000\,L)\,g}{(20.0\text{m})(1.00\text{m})} = (4.41 \times 10^3\,L)\text{ Pa}$$

(c) In order to make more money, the contractor decides to have each column support a chunk of road 300 m long ($L = 300$ m), while H is still 100 m high. She also uses cheap concrete with a compressive strength of 2.00×10^7 Pa. Under traffic jam conditions, calculate the ratio of the actual compressive stress at the bottom of the column to the compressive strength. If you did not obtain an answer to question (b) use (4100 L) Pa for the compressive stress from the traffic jam. (4 marks)

$\boxed{53.7\%}$

$$\frac{P_{actual}}{P_{strength}} = \frac{\rho g\,(L + H) + 4.41 \times 10^3\,L}{P_{strength}}$$

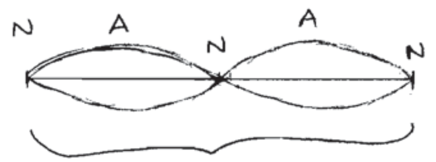
$$= \frac{(2400 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(300\text{m} + 100\text{m}) + (4.41 \times 10^3 \,\tfrac{\text{Pa}}{\text{m}})(300\text{m})}{2.00 \times 10^7 \text{ Pa}}$$

$$= \frac{1.07 \times 10^7 \text{ Pa}}{2.00 \times 10^7 \text{ Pa}} = 53.7\%$$

continued on page 8...

B4. One of the 63.5-cm-long strings of a guitar vibrates at a frequency of 490 Hz in its second resonance mode (the second harmonic).

(a) Draw the wave pattern when the string is vibrating in its second mode of vibration. (2 marks)



$$L = 2\left(\tfrac{1}{2}\lambda\right) = \lambda$$

(b) Calculate the wavelength of the second mode of vibration. (2 marks)

$$\lambda = L = 63.5\ \text{cm}$$

$\boxed{63.5\ \text{cm}}$

(c) Calculate the wave speed on the string. (2 marks)

$$v = f\lambda$$

$$v = (490\ \text{Hz})(0.635\ \text{m}) = 311\ \text{m/s}$$

$\boxed{311\ \text{m/s}}$

(d) If the tension in the string is increased by 1.00 %, calculate the new frequency of vibration of the string in its second mode of vibration. (4 marks)

$$F' = 1.0100 \cdot F$$

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

$$f = \frac{v}{\lambda} = \frac{1}{\lambda}\sqrt{\frac{F}{\mu}}$$

$$f' = \frac{1}{\lambda}\sqrt{\frac{F'}{\mu}} = \frac{1}{\lambda}\sqrt{\frac{1.0100F}{\mu}} = \sqrt{1.0100}\left(\frac{1}{\lambda}\sqrt{\frac{F}{\mu}}\right)$$

$$= \sqrt{1.0100}\ f$$

$$f' = \left(\sqrt{1.0100}\right)(490\ \text{Hz}) = 492\ \text{Hz}$$

$\boxed{492\ \text{Hz}}$

END OF EXAMINATION