UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
MIDTERM TEST

February 11, 2016 Time: 90 minutes

NAME: ____SOLUTIONS____ STUDENT NO.: ____________
(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- ❑ 01 Dr. Y. Yao
- ❑ 02 B. Zulkoskey
- ❑ C16 Dr. A. Farahani

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, 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 student number in the top right-hand corner of each page of the test paper.
5. Enter your name and NSID on the OMR sheet.
6. The test paper, the formula sheet and the OMR sheet must all be submitted.
7. The marked 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. A tensile force F stretches a wire of original length L by an amount ΔL. Consider another wire of the same composition and cross-sectional area, but of length $2L$. If a force of $2F$ is applied to this wire of length $2L$, then the amount that it stretches is:

(A) $\frac{1}{2}\Delta L$ (B) ΔL (C) $2\,\Delta L$ (D) $4\,\Delta L$ (E) $8\,\Delta L$

$\frac{F_1}{A} = Y\frac{\Delta L_1}{L_1}$

$\Delta L_2 = \frac{F_2 L_2}{AY} = \frac{2F_1\,2L_1}{AY} = 4\left(\frac{F_1 L_1}{AY}\right) = 4\Delta L_1$

D

A2. Which one of the following is **not** a unit of pressure?

(A) Pascal (Pa) (B) atmosphere (atm) (C) cm of mercury (cm Hg)
(D) kg·m/s^2 = Newton ≠ unit of pressure (E) pounds per square inch (psi)

C

A3. How deep under the surface of a lake would the pressure be double the pressure at the surface? (1 atm = 1.01×10^5 Pa, density of water = 1.00×10^3 kg/m^3)

$P_2 = P_1 + \rho g(y_1 - y_2)$; $P_1 = P_{atm}$, $P_2 = 2P_{atm}$

(A) 1.00 m (B) 9.80 m (C) 10.3 m (D) 32.2 m (E) 43.6 m

$2P_{atm} = P_{atm} + \rho g(y_1 - y_2) \Rightarrow P_{atm} = \rho g(y_1 - y_2) \Rightarrow y_1 - y_2 = P_{atm}/\rho g = 10.3\,m$

E

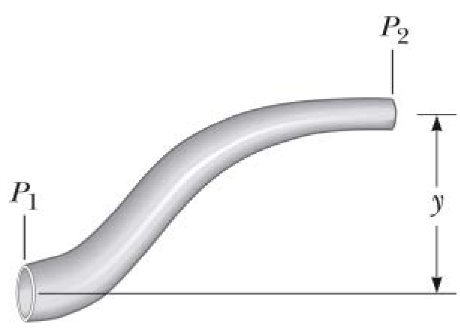
A4. Assuming that water is an incompressible fluid, what happens as a rock, released when fully-submerged just below the surface of the water in a swimming pool, sinks toward the bottom?

As the rock sinks, $B = \rho_{fluid}\, g\, V_{fluid}$ and $V_{fluid} = V_{object}$ = constant once the object is fully-submerged

(A) the buoyant force on the rock increases and the average pressure on the rock increases.
(B) the buoyant force on the rock increases and the average pressure on the rock decreases.
(C) the buoyant force on the rock decreases and the average pressure on the rock decreases.
(D) the buoyant force on the rock decreases and the average pressure on the rock increases.
(E) the buoyant force on the rock remains constant and the average pressure on the rock increases.

A5. Water moves through the pipe shown below in steady, ideal flow.

C



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

$A_1 v_1 = A_2 v_2$ (Continuity Equation) $\Rightarrow v_2 > v_1$

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

$v_2 > v_1$ and $y_2 > y_1 \Rightarrow P_2 < P_1$

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

A

A6. A 3.0-cm-diameter pipe is replaced by one of the same length but of 6.0-cm-diameter. If the pressure difference between the ends of the pipe remains the same as for the original pipe, by what factor is the volume flow rate of a viscous liquid through the new pipe greater than the volume flow rate through the original pipe? Poiseuille's Law: $\frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L}$

(A) 16 (B) 8 (C) 4 (D) 2 (E) 1 (no change)

$\Delta V/\Delta t \propto R^4$; $d_2 = 2d_1 \Rightarrow R_2 = 2R_1 \Rightarrow (\Delta V/\Delta t)_2 = (2)^4 (\Delta V/\Delta t)_1 = 16\left(\frac{\Delta V}{\Delta t}\right)_1$

D

A7. Three identical ideal springs each have the same spring constant k. If these three springs are connected end-to-end, forming a spring three times the length of one of the original springs, what is the effective spring constant of the combination?

(A) $9\,k$ (B) $3\,k$ (C) k (D) $k/3$ (E) $k/9$

Let x be the amount that one spring stretches when a force F is applied. When this same force F is applied to the 3 springs connected end-to-end, each spring stretches the amount x, so $x_{tot} = 3x$

$|F| = |k_{eff}\, x_{tot}| = |kx| \Rightarrow k_{eff} = \frac{kx}{x_{tot}} = \frac{kx}{3x} = \frac{1}{3}k$

continued on page 3...

A8. Which one of the following statements is **FALSE** regarding a horizontal mass-spring system that moves with simple harmonic motion in the absence of friction?

B

(A) The total energy of the system remains constant. T
(B) The potential energy stored in the system is greatest when the mass passes through the equilibrium position. F $PE = \frac{1}{2}kx^2 = 0$ when $x = 0$ (at equilibrium)
(C) The energy of the system is continually transformed between kinetic and potential energy. T
(D) The total energy of the system is proportional to the square of the amplitude of the motion. T
(E) The speed of the oscillating mass has its maximum value when the mass passes through the equilibrium position. T $E = KE + PE = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 \Rightarrow v = \max$ when $x = 0$

A9. Simple pendulum 1, of length L_1, has a bob of mass m_1. Simple pendulum 2, of length L_2, has a bob of mass m_2. $L_2 = 3L_1$ and $m_2 = 3m_1$. Which one of the following statements concerning the periods, T_1 and T_2, of the pendula is correct? $T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow T_2/T_1 = \sqrt{L_2/L_1} = \sqrt{\frac{3L_1}{L_1}} = \sqrt{3}$

D

(A) $T_2 = \frac{1}{\sqrt{3}}T_1$ (B) $T_2 = \frac{1}{3}T_1$ (C) $T_2 = T_1$ (D) $T_2 = \sqrt{3}\,T_1$ (E) $T_2 = 3\,T_1$

A10. What is the increase in the decibel level at a particular location when the power output from a sound source emitting a single frequency is doubled? Options B, C, D, E all correspond to factors of 10 or more for P_2 compared to P_1.

A

(A) 3.0 dB (B) 10.0 dB (C) 20.0 dB (D) 40.0 dB (E) 200 dB

A11. A wave is travelling with a speed of υ along a string in which the tension is T. If the tension is suddenly doubled, what is the new wave speed? $v = \sqrt{F/\mu} \Rightarrow v_2 = \sqrt{F_2/\mu} = \sqrt{\frac{2F_1}{\mu}} = \sqrt{2}\cdot\sqrt{\frac{F_1}{\mu}} = \sqrt{2}\cdot v$

D

(A) $\frac{1}{4}\upsilon$ (B) $\frac{1}{2}\upsilon$ (C) $\frac{\upsilon}{\sqrt{2}}$ (D) $\sqrt{2}\,\upsilon$ (E) 4υ

A12. The distance between consecutive crests of a water wave is 2.0 m. As the wave passes a duck floating on the water, you notice that the interval between times when the duck is at maximum upward displacement is 2.0 s. The speed of the water wave is $v = \lambda/T = 1.0\,m/s$

C

(A) 0.25 m/s (B) 0.50 m/s (C) 1.0 m/s (D) 2.0 m/s (E) 4.0 m/s

A13. If you double the tension in a guitar string, the fundamental frequency of vibration of the string… $L = \frac{1}{2}\lambda \Rightarrow \lambda = 2L$ $f = \frac{v}{\lambda} = \frac{1}{2L}\sqrt{F/\mu}$; $f_2 = \frac{1}{2L}\sqrt{\frac{2F_1}{\mu}}$

A

(A) increases by a factor of $\sqrt{2}$. (B) becomes half as large. (C) doubles.
(D) increases by a factor of 4. (E) does not change.

$f_2 = \sqrt{2}\cdot\left(\frac{1}{2L}\sqrt{\frac{F_1}{\mu}}\right) = \sqrt{2}\cdot f_1$

A14. Given that the strings of a guitar are the same length, is it possible for the strings to have the same tension but have different fundamental frequencies of vibration? $f = \frac{1}{2L}\sqrt{F/\mu}$; $f\downarrow$ as $\mu\uparrow$

B

(A) Yes, and the lower the desired fundamental frequency, the smaller the required linear mass density of the string.
(B) Yes, and the lower the desired fundamental frequency, the larger the required linear mass density of the string.
(C) No, this is not possible because all strings at the same tension must have the same fundamental frequency.
(D) Yes, and the higher the desired fundamental frequency, the larger the required linear mass density of the string.
(E) No, this is not possible because all strings of the same length must have the same fundamental frequency.

A15. A truck is being driven at a speed of 130 km/h due East. Two police cars, both moving with a speed of 150 km/h, and both with sirens emitting sound of the same frequency, f, are approaching the truck. Car 1 is approaching the truck from behind and car 2 is approaching the truck from ahead. Which one of the following statements is correct?

E

(A) The driver of the truck hears the same frequency f from each of the police sirens.
(B) The driver of the truck hears the same frequency $f_o > f$ from each of the police sirens.
(C) The driver of the truck hears the same frequency $f_o < f$ from each of the police sirens.
(D) The driver of the truck hears a higher frequency from the siren of the police car behind than he does from the siren of the police car ahead.
(E) The driver of the truck hears a higher frequency from the siren of the police car ahead than he does from the siren of the police car behind.

$f_{o1} = \left(\frac{v - |v_o|}{v - |v_s|}\right)f_s$; $f_{o2} = \left(\frac{v + |v_o|}{v - |v_s|}\right)f_s$; $\therefore f_{o2} > f_{o1}$

continued on page 4...

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.

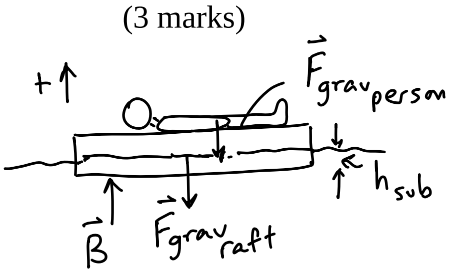
USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

continued on page 5...

B1. A 62.0-kg survivor of a cruise ship disaster rests atop a block of Styrofoam insulation, using it as a raft. The Styrofoam has dimensions 2.00 m × 2.00 m × 0.0900 m. The bottom 0.0240 m of the Styrofoam block is submerged. Sea water has a density of 1.03×10^3 kg/m^3.

(a) Calculate the magnitude of the buoyant force exerted by the water on the Styrofoam block. (3 marks)

$\boxed{969\text{ N}}$



$$B = \rho_{fluid}\, g\, V_{fluid}$$

V_{fluid} = volume of Styrofoam block that is submerged = $l \cdot w \cdot h_{sub}$

$$B = (1.03 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(2.00\text{m} \times 2.00\text{m} \times 0.0240\text{m})$$

$$B = 969\text{N}$$

(b) Calculate the weight of the Styrofoam block. If you did not obtain an answer for (a), use a value of 955 N. (4 marks)

$\boxed{361\text{ N}}$

From the force diagram in (a):

$$\Sigma \vec{F} = 0 \Rightarrow B - F_{grav_{raft}} - F_{grav_{person}} = 0$$

$$B - F_{grav_{person}} = F_{grav_{raft}}$$

$$F_{grav_{raft}} = 969\text{N} - m_{person}\, g = 969\text{N} - (62.0\text{kg})(9.80\text{m/s}^2)$$

$$F_{grav_{raft}} = 361\text{N}$$

(c) Calculate the density of Styrofoam. If you did not obtain an answer for (b), use a value of 355 N. (3 marks)

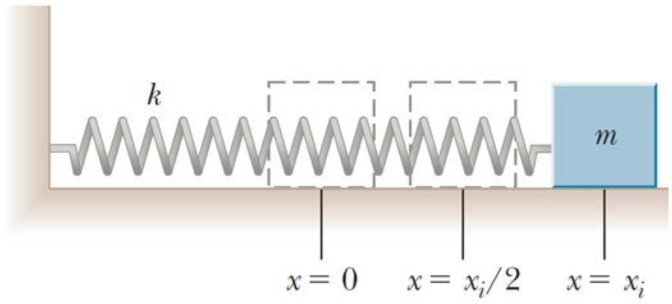
$\boxed{102\ \text{kg/m}^3}$

$$\rho = \frac{M}{V} = \frac{F_{grav}/g}{V}$$

$$\rho = \frac{361\text{N}/9.80\text{m/s}^2}{(2.00\text{m} \times 2.00\text{m} \times 0.0900\text{m})} = 102\ \text{kg/m}^3$$

continued on page 6...

B2. A horizontal spring attached to a wall has a spring constant of k = 851 N/m. A block of mass m = 1.00 kg is attached to the spring and rests on a frictionless, horizontal surface. The block is pulled to a position x_i = 6.00 cm from equilibrium and released.



(a) Calculate the potential energy stored in the spring when the block is 6.00 cm from equilibrium. (3 marks)

$\boxed{1.53\ \text{J}}$

$PE_s = \frac{1}{2}kx^2$

$PE_s = \frac{1}{2}(851\ \text{N/m})(0.0600\text{m})^2$

$PE_s = 1.53\ \text{J}$

(b) Calculate the speed of the block as it passes through the equilibrium position. If you did not obtain an answer for (a), use a value of 1.50 J. (3 marks)

$\boxed{1.75\ \text{m/s}}$

Mechanical energy is conserved

$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \text{constant}$

At max displacement $(x = A)$, $E = \frac{1}{2}m\cdot(0)^2 + \frac{1}{2}kA^2$

$\therefore \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$

At $x = 0$ (equilibrium position), $\frac{1}{2}mv_0^2 = \frac{1}{2}kA^2$ (= 1.53J since $A = 0.0600\text{m}$)

$v_0 = A\sqrt{\frac{k}{m}} = 0.0600\text{m}\sqrt{\frac{851\ \text{N/m}}{1.00\ \text{kg}}} = 1.75\ \text{m/s}$ or $v_0 = \sqrt{\frac{2(1.53\text{J})}{1.00\ \text{kg}}} = 1.75\ \text{m/s}$

(c) Calculate the speed of the block when it is at a position $x_i/2$ = 3.00 cm. (4 marks)

$\boxed{1.52\ \text{m/s}}$

$\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$

$mv^2 = k(A^2 - x^2)$

$v = \sqrt{\frac{k}{m}}\cdot\sqrt{A^2 - x^2} = \sqrt{\frac{851\ \text{N/m}}{1.00\ \text{kg}}}\cdot\sqrt{(0.0600\text{m})^2 - (0.0300\text{m})^2}$

$v = 1.52\ \text{m/s}$

continued on page 7...

B3. A speaker that emits sound waves uniformly in all directions is placed between two observers who are 36.0 m apart, along the line connecting them. Observer 1 records an intensity level of 82.4 dB and observer 2 records an intensity level of 75.7 dB.

(a) Calculate the intensity of the sound detected by each observer. (4 marks)

Observer 1:	$1.74\times10^{-4}\,\mathrm{W/m^2}$
Observer 2:	$3.72\times10^{-5}\,\mathrm{W/m^2}$

$$\beta = 10\log\left(I/I_o\right)$$

$$\therefore\ \beta/10 = \log\left(I/I_o\right)$$

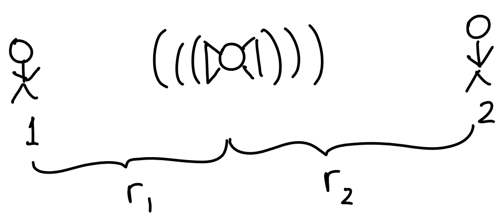
$$10^{\beta/10} = \frac{I}{I_o} \Rightarrow I = I_o\cdot 10^{\beta/10}$$

$$I_1 = \left(1.00\times10^{-12}\,\mathrm{W/m^2}\right)10^{82.4/10} = 1.74\times10^{-4}\,\mathrm{W/m^2}$$

$$I_2 = \left(1.00\times10^{-12}\,\mathrm{W/m^2}\right)10^{75.7/10} = 3.72\times10^{-5}\,\mathrm{W/m^2}$$

(b) Calculate the distance of Observer 1 from the speaker. If you did not obtain answers for (a), use $I_1 = 1.75\times10^{-4}\ \mathrm{W/m^2}$ and $I_2 = 3.50\times10^{-5}\ \mathrm{W/m^2}$. (6 marks)

$$\boxed{11.4\,\mathrm{m}}$$



$$I_1 = \frac{P}{4\pi r_1^2}\ ;\ I_2 = \frac{P}{4\pi r_2^2}$$

and $r_1 + r_2 = 36.0\,\mathrm{m}$

$$P = I_1 4\pi r_1^2 = I_2 4\pi r_2^2 \Rightarrow r_2 = \sqrt{\frac{I_1}{I_2}}\cdot r_1$$

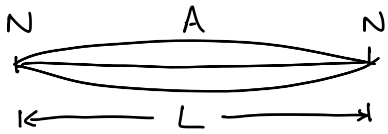
$$r_1 + \sqrt{\frac{I_1}{I_2}}\cdot r_1 = 36.0\,\mathrm{m}$$

$$r_1 = \frac{36.0\,\mathrm{m}}{1+\sqrt{\dfrac{17.4\times10^{-5}\,\mathrm{W/m^2}}{3.72\times10^{-5}\,\mathrm{W/m^2}}}} = 11.4\,\mathrm{m}$$

continued on page 8...

B4. A steel wire in a piano has a length of 0.700 m and a mass of 4.30 g.

(a) Calculate the tension force that must be applied to the string so that the fundamental resonant frequency is 261.6 Hz. (4 marks)



At fundamental mode of vibration,

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

$\boxed{824\,N}$

$$f_1 = \frac{v}{\lambda_1} = \frac{1}{\lambda_1}\sqrt{\frac{F}{\mu}} = \frac{1}{2L}\sqrt{\frac{F}{m/L}} = \frac{1}{2L}\sqrt{\frac{FL}{m}} \Rightarrow f_1 \cdot 2L = \sqrt{\frac{FL}{m}}$$

$$4f_1^2 L^2 = \frac{FL}{m} \Rightarrow F = 4f_1^2 L m$$

$$F = 4(261.6\,Hz)^2(0.700\,m)(4.30\times10^{-3}\,kg) = 824\,N$$

(b) Given that the density of steel is 7.85×10^3 kg/m^3, calculate the cross-sectional area of the wire. (3 marks)

$\boxed{7.83\times10^{-7}\,m^2}$

$$\rho = \frac{M}{V} \quad \text{and} \quad V = AL \Rightarrow \rho = \frac{M}{AL}$$

$$A = \frac{M}{\rho L} = \frac{4.30\times10^{-3}\,kg}{\left(7.85\times10^3\,\frac{kg}{m^3}\right)(0.700\,m)} = 7.83\times10^{-7}\,m^2$$

(c) Given that Young's modulus for steel is 2.00×10^{11} Pa, calculate the amount that the string stretches when the force calculated in (a) is applied to it. If you did not obtain an answer for (a), use a value of 825 N and if you did not obtain an answer for (b), use a value of 7.80×10^{-7} m^2. (3 marks)

$\boxed{3.68\,mm}$

$$\frac{F}{A} = Y\frac{\Delta L}{L} \Rightarrow \Delta L = \frac{FL}{AY}$$

$$\Delta L = \frac{(824\,N)(0.700\,m)}{(7.83\times10^{-7}\,m^2)(2.00\times10^{11}\,Pa)} = 3.68\times10^{-3}\,m = 3.68\,mm$$

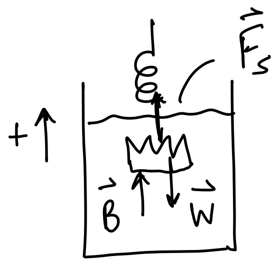
END OF EXAMINATION

B1. When a crown of mass 14.5 kg is suspended from an accurate spring scale and fully-submerged in water, the spring scale reads only 129.0 N.

(a) Calculate the buoyant force on the crown when it is fully-submerged in water. (3 marks)

$m_c = 14.5\ \text{kg}$

$\boxed{13.1\ \text{N}}$



At equilibrium, $\Sigma \vec{F} = 0$

$\therefore +B + F_s - W = 0 \Rightarrow B = W - F_s$

$B = m_c g - F_s$

$B = (14.5\ \text{kg})(9.80\ \text{m/s}^2) - 129\ \text{N}$

$B = 13.1\ \text{N}$

(b) Calculate the volume of the crown. If you did not obtain an answer for (a), use a value of 12.5 N. (4 marks)

$\boxed{1.34 \times 10^{-3}\ \text{m}^3}$

$B = \rho_{fluid}\, g\, V_{fluid}$

Since the crown is fully-submerged, $V_{fluid} = V_{crown}$

$$\therefore V_{crown} = \frac{B}{\rho_{fluid}\, g} = \frac{13.1\ \text{N}}{\left(1.00 \times 10^3\ \frac{\text{kg}}{\text{m}^3}\right)(9.80\ \text{m/s}^2)}$$

$V_{crown} = 1.34 \times 10^{-3}\ \text{m}^3$

(c) Calculate the density of the crown. If you did not obtain an answer for (b), use a value of $1.30 \times 10^{-3}\ \text{m}^3$. (3 marks).

$\boxed{1.08 \times 10^4\ \text{kg/m}^3}$

$$\rho = \frac{M}{V} = \frac{14.5\ \text{kg}}{1.34 \times 10^{-3}\ \text{m}^3}$$

$\rho = 1.08 \times 10^4\ \text{kg/m}^3$

continued on page 6...

B2. The position of a 0.300-kg object attached to a spring and undergoing simple harmonic motion (SHM) is described by

$$x = (0.250 \text{ m}) \cos(0.400\pi\, t)$$

where t is in seconds.

(a) Determine the amplitude of the motion. (1 mark)

In general, $x = A\cos(\omega t)$

$\therefore$ By inspection, $A = 0.250\,\text{m}$

$\boxed{0.250\,\text{m}}$

(b) Calculate the spring constant. (3 marks)

Recall that $\omega = \sqrt{\frac{k}{m}}$

and from $x = (0.250\,\text{m})\cos(0.400\pi t)$, $\omega = 0.400\pi$ rad/s

$\therefore \omega^2 = \frac{k}{m} \Rightarrow k = m\omega^2 = (0.300\,\text{kg})(0.400\pi\,\text{rad/s})^2$

$k = 0.474\,\text{kg/s}^2 = 0.474\,\text{N/m}$

$\boxed{0.474\,\text{N/m}}$

(c) Calculate the position of the object at time $t = 0.300$ s. (3 marks)

$x = (0.250\,\text{m})\cos\Big[\underbrace{(0.400\pi\,\text{rad/s})(0.300\,\text{s})}_{\text{angle in radians}}\Big]$

$x = 0.232\,\text{m}$

$\boxed{0.232\,\text{m}}$

(d) Calculate the speed of the object at time $t = 0.300$ s. (3 marks)

$v = -A\omega\sin(\omega t)$

$|v| = |A\omega\sin(\omega t)|$

$|v| = (0.250\,\text{m})(0.400\pi\,\text{rad/s})\sin\Big[(0.400\pi\,\text{rad/s})(0.300\,\text{s})\Big]$

$|v| = 0.116\,\text{m/s}$

$\boxed{0.116\,\text{m/s}}$

continued on page 7...

B3. A bomb explodes in mid-air and generates a sound wave which radiates uniformly in all directions. At a distance of r = 10.0 m from the blast, the sound wave intensity level is measured to be β = 135 dB, relative to the threshold of hearing.

(a) Calculate the intensity of the sound wave at a distance of 1.00×10^2 m from the explosion. (4 marks)

$$\boxed{0.316\ \mathrm{W/m^2}}$$

$$\beta = 10 \log\left(\frac{I}{I_o}\right) \Rightarrow \frac{\beta}{10} = \log\left(\frac{I}{I_o}\right)$$

$$10^{\beta/10} = \frac{I}{I_o} \Rightarrow I = I_o \cdot 10^{\beta/10}$$

∴ Intensity corresponding to a level of 135 dB is

$$I = (1.00\times10^{-12}\ \mathrm{W/m^2})\,10^{135/10} = 31.6\ \mathrm{W/m^2}$$

Since the sound wave radiates uniformly in all directions, the wavefronts are spherical shells. With no energy loss,

$$P = IA = \text{constant} \Rightarrow I_1A_1 = I_2A_2 \Rightarrow I_1 \cdot 4\pi r_1^2 = I_2 \cdot 4\pi r_2^2$$

$$\therefore I_1 \cdot r_1^2 = I_2 \cdot r_2^2 \Rightarrow I_{100} = \frac{I_{10} \cdot r_{10}^2}{r_{100}^2}$$

$$I_{100} = \frac{(31.6\ \mathrm{W/m^2})(10.0\ \mathrm{m})^2}{(1.00\times10^2\ \mathrm{m})^2} = 0.316\ \mathrm{W/m^2}$$

(b) Calculate the intensity level at a distance of 2.00×10^2 meters from two of these explosions if the bombs explode simultaneously at the same location. (If you did not obtain answer for (a), use a value of 0.300 W/m^2.) (6 marks)

$$\boxed{112\ \mathrm{dB}}$$

As shown above, $I_1 r_1^2 = I_2 r_2^2$

Let I_1 be the intensity of one explosion at $r_1 = 100$ m

Let I_2 be the intensity of one explosion at $r_2 = 200$ m

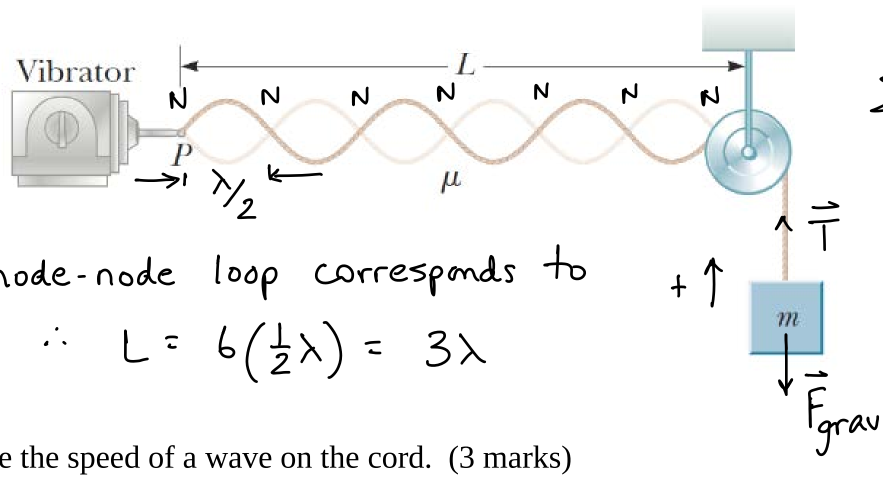
$$I_2 = I_1\left(\frac{r_1}{r_2}\right)^2 = 0.316\ \frac{\mathrm{W}}{\mathrm{m^2}}\left(\frac{100\ \mathrm{m}}{200\ \mathrm{m}}\right)^2 = 7.90\times10^{-2}\ \mathrm{W/m^2}$$

I_{tot} = Intensity due to two explosions at $r = 200\ \mathrm{m} = 2I_2$

$$I_{tot} = 0.158\ \mathrm{W/m^2}\ ; \quad \beta_{tot} = 10 \log\left(\frac{0.158\ \mathrm{W/m^2}}{1.00\times10^{-12}\ \mathrm{W/m^2}}\right) = 112\ \mathrm{dB}$$

continued on page 8...

B4. An object of mass *m* hangs from a cord around a light pulley. The length of the cord between point *P* and the pulley is $L = 2.00$ m. The mass of the cord between point *P* and the pulley is $m_c = 9.80$ grams. When the vibrator is set to a frequency of 151 Hz, a standing wave with six loops is formed.



$\sum \vec{F} = 0$

$+T - mg = 0$

$T = mg$

Each node-node loop corresponds to $\frac{1}{2}\cdot\lambda$ $\therefore$ $L = 6\left(\frac{1}{2}\lambda\right) = 3\lambda$

(a) Calculate the speed of a wave on the cord. (3 marks)

$\boxed{101 \text{ m/s}}$

$v = f\lambda$

From above, $L = 3\lambda \Rightarrow \lambda = \frac{L}{3}$

$\therefore v = \frac{fL}{3} = \frac{(151\text{ Hz})(2.00\text{ m})}{3} = 101\text{ m/s}$

(b) Calculate *m*, the mass of the object. If you did not obtain an answer for (a), use a value of 105 m/s. (4 marks)

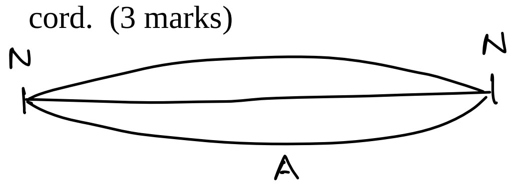
$\boxed{5.07 \text{ kg}}$

$v = \sqrt{\frac{T}{\mu}}$ where $\mu = \frac{m_c}{L}$ and $T = mg$

$\therefore v = \sqrt{\frac{mgL}{m_c}} \Rightarrow \frac{v^2 m_c}{gL} = m = \frac{(101\text{ m/s})^2(9.80\times10^{-3}\text{ kg})}{(9.80\text{ m/s}^2)(2.00\text{ m})}$

$m = 5.07\text{ kg}$

(c) If *m* is changed to 10.0 kg, calculate the fundamental frequency of standing waves on the cord. (3 marks)



$\boxed{35.4 \text{ Hz}}$

At the fundamental, $L = \frac{1}{2}\lambda_1 \Rightarrow \lambda_1 = 2L$

$f_1 = \frac{v}{\lambda_1} = \frac{1}{2L}\sqrt{\frac{T}{m_c/L}} = \frac{1}{2L}\sqrt{\frac{mgL}{m_c}} = \sqrt{\frac{mg}{4Lm_c}}$

$f_1 = \sqrt{\frac{(10.0\text{ kg})(9.80\text{ m/s}^2)}{4(2.00\text{ m})(9.80\times10^{-3}\text{ kg})}} = 35.4\text{ Hz}$

END OF EXAMINATION