UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
MIDTERM TEST

February 17, 2011 Time: 90 minutes

NAME: MASTER STUDENT NO.: ________
(Last) **Please Print** (Given)

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

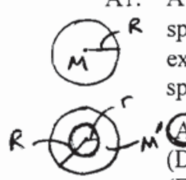
QUESTION NUMBER	TO BE MARKED	MAXIMUM MARKS	MARKS OBTAINED
A1-15	-	15	
B1	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
TOTAL		45	

continued on page 2...

PART A

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

A



A1. A uniform solid cylinder rolls without slipping down an incline. At the bottom of the incline the speed, υ, of the cylinder is measured. A hole is drilled through the cylinder along its axis and the experiment is repeated; at the bottom of the incline the cylinder now has speed υ'. How does the speed of the cylinder compare with its original value?

(A) υ' < υ (B) υ' = υ (C) υ' > υ
(D) The answer depends on the radius of the hole.
(E) The answer depends on the height of the incline.

$E_{top} = E_{bottom}$

$Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$

$\omega = \frac{v}{R}$

ORIGINAL $Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}\left(\frac{1}{2}MR^2\right)\frac{v^2}{R^2} \Rightarrow gh = \frac{3}{4}v^2$; NEW $M'gh = \frac{1}{2}M'v'^2 + \frac{1}{2}\left(\frac{1}{2}M'(r^2+R^2)\right)\frac{v'^2}{R^2}$

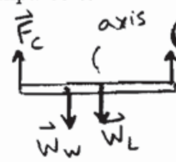
$gh = \left(\frac{3}{4} + \frac{r^2}{4R^2}\right)v'^2$

$\therefore v' < v$

C

A2. Chris and Jamie are carrying Wayne on a horizontal stretcher. The uniform stretcher has length L and weight W_L. Wayne weighs W_W. Wayne's centre of gravity is a distance of $(1/3)L$ from Chris. Chris and Jamie are at the ends of the stretcher. The force, F_C, that Chris is exerting to support the stretcher, with Wayne on it, compared to the force, F_J, that Jamie is exerting, is

(A) $F_C < F_J$ (B) $F_C = F_J$ (C) $F_C > F_J$
(D) dependent on the value of L.
(E) dependent on the value of W_L.



Take centre as axis: $\Sigma\tau = 0 \Rightarrow F_C > F_J$

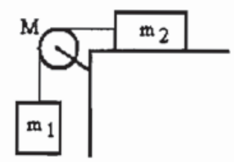
E

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.
(B) If the net torque on an object is zero then the net force on the object must also be zero.
(C) If the net force on an object is zero then the object cannot be rotating.
(D) If the net torque on an object is zero then the centre of mass of the object must be stationary.
(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)

E

A4. A mass m_1 is connected by a light string that passes over a pulley of mass M to a mass m_2 sliding on a frictionless horizontal surface as shown in the figure. There is no slippage between the string and the pulley. The pulley has a radius of R and a moment of inertia of I_P. Which one of the following is the correct expression for a_1, the acceleration of m_1?



(A) $a_1 = g$ (B) $a_1 = \left(\frac{m_1}{m_1+m_2}\right)g$ (C) $a_1 = \left(\frac{m_1+m_2}{m_1}\right)g$

(D) $a_1 = \left(\frac{m_1+m_2+I_P/R^2}{m_1}\right)g$ (E) $a_1 = \left(\frac{m_1}{m_1+m_2+I_P/R^2}\right)g$

Know that $a_1 < g$ due to inertial effect of m_2 and I_P.

C

A5. The absolute pressure at a depth d below the ocean surface is 2 atm. The pressure at a depth of $2d$ below the surface of the ocean is

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

A

A6. When an object is suspended from a spring scale, the scale reads 12 N when the object is in air and 8 N when the object is fully submerged in a liquid. The magnitude of the buoyant force exerted by the liquid on the object is

(A) 4 N. (B) 20 N. (C) 10 N. (D) 16 N. (E) 2 N.

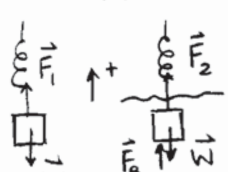
A5. 1 atm, d, • 2 atm, 2d, • 3 atm

$P_d = P_{atm} + \rho g d = 2$ atm

so $\rho g d = 1$ atm

$\rho g(2d) = 2$ atm

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



$F_1 - W = 0$

continued on page 3...

$F_2 + F_B - W = 0$

so

$F_1 = F_2 + F_B$

$F_B = F_1 - F_2$

A7. An ideal incompressible fluid is flowing through a horizontal pipe with a constriction. One end of the pipe has a radius of R and the other end of the pipe has a radius of $\frac{1}{2}R$. Which one of the following statements is **TRUE**?

D

$A_1 v_1 = A_2 v_2$

$P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$

(A) Both the flow speed and pressure are higher at the larger end.
(B) The flow speed is the same throughout the pipe but the pressure is lower at the larger end.
(C) The flow speed at the larger end is half the flow speed at the narrower end.
(D) The flow speed at the narrower end is four times the flow speed at the larger end.
(E) The pressure is the same throughout the pipe.

A8. Water undergoes viscous flow through two pipes with the same pressure difference between their ends. The radius of pipe 2 is twice the radius of pipe 1. The length of pipe 2 is three times the length of pipe 1. If the volume flow rate through pipe 1 is Q_1, then the flow rate, Q_2, through pipe 2 is

B

(A) $\frac{4}{3}Q_1$. (B) $\frac{16}{3}Q_1$. (C) $8Q_1$. (D) $\frac{2}{9}Q_1$. (E) $48Q_1$.

$$Q = \frac{\Delta V}{\Delta t} = \frac{\pi}{8}\frac{\Delta P/L}{\eta} r^4 \Rightarrow Q_2 = \frac{\pi}{8}\frac{\Delta P/3L_1}{\eta}(2r_1)^4 = \frac{\pi}{8}\frac{\Delta P/L_1}{\eta} r_1^4 \cdot \frac{16}{3} = \frac{16}{3}Q_1$$

A9. A mass is suspended vertically from a spring so that it is at rest at the equilibrium position. The mass is pulled straight down to an extension x and released so that it oscillates about the equilibrium position. The speed of the mass is greatest when the mass is

C

(A) at its maximum upward travel.
(B) at its maximum downward travel.
(C) at the equilibrium position.
(D) somewhere between the equilibrium position and the maximum upward travel.
(E) somewhere between the equilibrium position and the maximum downward travel.

A10. A mass M is attached to the end of a thin steel wire of length L and cross-sectional area A. Let Y represent the Young's modulus for steel. The mass is pulled straight down so that the wire stretches a small amount ΔL and then the mass is released. Which one of the following expressions is correct for the angular frequency of the simple harmonic motion of the mass?

A

(A) $\omega = \sqrt{\frac{YA}{LM}}$ (B) $\omega = \sqrt{\frac{YA}{\Delta LM}}$ (C) $\omega = \sqrt{\frac{LM}{YA}}$

(D) $\omega = \sqrt{\frac{YL}{AM}}$ (E) $\omega = \sqrt{\frac{YM}{AL}}$

"k"

$\omega = \sqrt{\frac{k}{M}}$ and $\frac{F}{A} = Y\frac{\Delta L}{L} \Rightarrow F = \left(\frac{YA}{L}\right)\Delta L$

$\omega = \sqrt{\frac{YA/L}{M}} = \sqrt{\frac{YA}{ML}}$

A11. Consider a material that is being stressed within its proportional limit. A wire 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 wire changes by ΔL. The wire is now cut in half, and the same tensile force F is applied to one of the halves. What is the change of length of this wire of length $\frac{1}{2}L$ when the force F is applied to it?

B

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

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

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

$\Delta L \propto L$.

A12. Two simple pendula, A and B, have the same length, but the mass of A is twice the mass of B. Their amplitudes of oscillation are equal. Their periods are T_A and T_B, respectively, and their energies are E_A and E_B. Which one of the following statements is correct?

A

(A) $T_A = T_B$ and $E_A > E_B$ (B) $T_A > T_B$ and $E_A > E_B$
(C) $T_A > T_B$ and $E_A < E_B$ (D) $T_A = T_B$ and $E_A < E_B$
(E) $T_A < T_B$ and $E_A > E_B$

$\omega = \sqrt{\frac{g}{L}}$; $T = 2\pi\sqrt{\frac{L}{g}}$ same length, so $T_A = T_B$.

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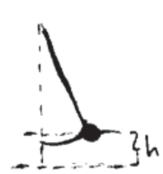


equal amplitude $\Rightarrow h_A = h_B$

$E_A = M_A g h$
$E_B = M_B g h$

$M_A > M_B \Rightarrow E_A > E_B$

A13. 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 $3R$ is

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

$I_1 r_1^2 = I_2 r_2^2 \Rightarrow I_2 = \frac{1}{9} I_1$

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. Two speakers are placed a distance d apart and are vibrating in phase. The frequency and wavelength of the sound being produced are f and λ respectively. A person standing a distance L from one of the speakers hears no sound. Which one of the following expressions can possibly be correct for the person's distance from the other speaker?

B

(A) $L + d$ (B) $L + \frac{1}{2}\lambda$ (C) $L - 2\lambda$ (D) $L + \lambda$ (E) $d + \lambda$

no sound ⇒ destructive interference

$\Rightarrow L' - L = (n + \tfrac{1}{2})\lambda \Rightarrow L' = L + (n + \tfrac{1}{2})\lambda$

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.

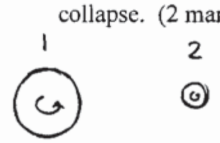
EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

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

continued on page 5...

B1. A rotating star collapses under the influence of its own gravitational forces to form a pulsar. The radius of the star after collapse is 1.00×10^{-4} times the radius before collapse. There is no change in mass. In both cases, the mass of the star is uniformly distributed in a spherical shape.

(a) Calculate the ratio of the angular momentum of the star after collapse to the value before collapse. (2 marks)



$$R_2 = 1.00 \times 10^{-4} R_1$$

$$M_2 = M_1$$

$$I = \frac{2}{5} M R^2$$

$\boxed{1.00}$

$\Sigma \tau_{ext} = 0$ so ang. momentum is conserved.

$$\therefore L_2 = L_1 \Rightarrow \frac{L_2}{L_1} = 1.00$$

(b) Calculate the ratio of the angular velocity of the star after collapse to the value before collapse. (2 marks)

$$L_1 = L_2$$

$$I_1 \omega_1 = I_2 \omega_2$$

$\boxed{1.00 \times 10^8}$

$$\frac{\omega_2}{\omega_1} = \frac{I_1}{I_2} = \frac{\frac{2}{5} M R_1^2}{\frac{2}{5} M R_2^2} = \left(\frac{R_1}{R_2}\right)^2 = \left(\frac{R_1}{1.00 \times 10^{-4} R_1}\right)^2 = 1.00 \times 10^8$$

(c) Calculate the ratio of the kinetic energy of the star after collapse to the value before collapse. (2 marks)

$\boxed{1.00 \times 10^8}$

$$\frac{K_2}{K_1} = \frac{\frac{1}{2} I_2 \omega_2^2}{\frac{1}{2} I_1 \omega_1^2} = \left(\frac{I_2}{I_1}\right)\left(\frac{\omega_2}{\omega_1}\right)^2$$

$$\frac{K_2}{K_1} = \left(\frac{R_2}{R_1}\right)^2 \left(1.00 \times 10^8\right)^2 = \left(\frac{1.00 \times 10^{-4} R_1}{R_1}\right)^2 \left(1.00 \times 10^8\right)^2$$

$$\frac{K_2}{K_1} = 1.00 \times 10^8$$

(d) If the period of the star's rotation before collapse is 1.00×10^7 s, calculate its period after collapse. (4 marks)

$\boxed{0.100\text{s}}$

$$T = \frac{2\pi}{\omega} \Rightarrow \frac{T_2}{T_1} = \frac{2\pi/\omega_2}{2\pi/\omega_1} = \frac{\omega_1}{\omega_2}$$

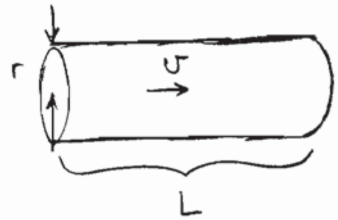
$$T_2 = T_1 \left(\frac{\omega_1}{\omega_2}\right) = \left(1.00 \times 10^7 \text{s}\right)\left(\frac{1}{1.00 \times 10^8}\right) = 0.100\text{s}$$

continued on page 6...

B2. The cardiac output of a small dog is 4.12×10^{-3} m^3/s, the radius of its aorta is 0.512 cm, and the length of its aorta is 40.0 cm. The viscosity of blood is 4.05×10^{-3} Pa·s and the density of blood is 1.06×10^3 kg/m^3.

(a) Calculate the flow speed of blood in the aorta. (4 marks)

$\boxed{50.0\ \text{m/s}}$



$$\frac{\Delta V}{\Delta t} = Av = \pi r^2 v$$

$$v = \frac{\Delta V/\Delta t}{\pi r^2}$$

$$v = \frac{4.12 \times 10^{-3}\ \text{m}^3/\text{s}}{\pi (0.00512\ \text{m})^2} = 50.0\ \text{m/s}$$

(b) Calculate the pressure difference across the aorta. (6 marks)

$\boxed{2.47 \times 10^4\ \text{Pa}}$

Viscous flow ⇒ Poisseuille's Law

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

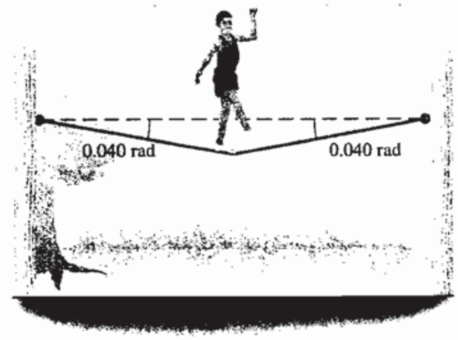
$$\Delta P = \frac{\frac{\Delta V}{\Delta t} \cdot 8\eta L}{\pi r^4}$$

$$\Delta P = \frac{(4.12 \times 10^{-3}\ \text{m}^3/\text{s})\, 8\, (4.05 \times 10^{-3}\ \text{Pa}\cdot\text{s})(0.400\ \text{m})}{\pi (0.00512\ \text{m})^4}$$

$$\Delta P = 2.47 \times 10^4\ \text{Pa}$$

continued on page 7...

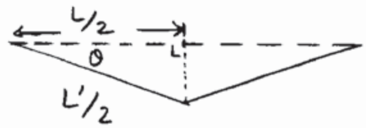
B3. A tightrope walker who weighs 641 N is standing in the middle of a steel cable. The cable makes an angle of 0.0400 rad below the horizontal. The Young's modulus of steel is 2.00×10^{11} Pa.



(a) Calculate the strain in the cable. (Assume that the cable is horizontal before the walker steps onto it and ignore the weight of the cable itself.)
(3 marks)

$$\text{Strain} = \frac{\Delta L}{L} = \frac{L' - L}{L} = \frac{L/\cos\theta - L}{L}$$

$\boxed{8.01 \times 10^{-4}}$



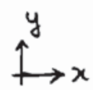
$$\text{so Strain} = \frac{1}{\cos\theta} - 1$$

$$\cos\theta = \frac{L/2}{L'/2} = \frac{L}{L'} \Rightarrow L' = \frac{L}{\cos\theta}$$

$$\text{Strain} = \frac{1}{\cos(0.0400\,\text{rad})} - 1$$

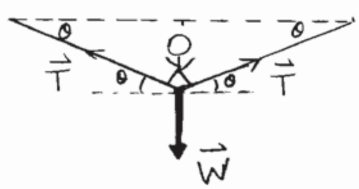
$$\text{Strain} = 8.01 \times 10^{-4}$$

(b) Calculate the tension in the cable when the tightrope walker is standing at the mid-point.
(3 marks)



$$\Sigma \vec{F}_y = 0$$

$\boxed{8.01 \times 10^3\,\text{N}}$



$$T\sin\theta + T\sin\theta - W = 0$$

$$T = \frac{W}{2\sin\theta}$$

$$T = \frac{641\,\text{N}}{2\sin(0.0400\,\text{rad})} = 8.01 \times 10^3\,\text{N}$$

(c) Calculate the cross-sectional area of the cable. (2 marks)

$\boxed{5.00 \times 10^{-5}\,\text{m}^2}$

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

$$F = T\ (\text{tension}) \text{ and } \frac{\Delta L}{L} = \text{strain}$$

$$A = \frac{T}{Y} \cdot \frac{1}{\text{Strain}} = \frac{8.01 \times 10^3\,\text{N}}{(2.00 \times 10^{11}\,\text{N/m}^2)(8.01 \times 10^{-4})} = 5.00 \times 10^{-5}\,\text{m}^2$$

(d) Has the cable been stretched beyond its elastic limit of 2.50×10^{8} Pa? Circle your choice and provide calculations that support your choice. (2 marks)

$$\text{Stress} = \frac{F}{A} = \frac{8.01 \times 10^3\,\text{N}}{5.00 \times 10^{-5}\,\text{m}^2} = 1.60 \times 10^8\,\text{Pa} < 2.50 \times 10^8\,\text{Pa}$$

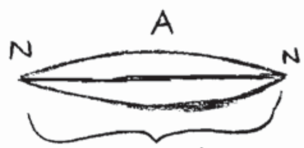
YES	NO

continued on page 8...

B4. The A string on a guitar has length 64.0 cm and fundamental frequency 110 Hz. The tension in the string is 133 N. It is vibrating in its fundamental standing wave mode with a maximum displacement from equilibrium of 2.30 mm.

(a) Calculate the wavelength of the fundamental mode of vibration. (2 marks)

1.28 m



$$L = \tfrac{1}{2}\lambda \Rightarrow \lambda = 2L = 2(64.0\text{cm}) = 128\text{ cm}$$

$$\lambda = 1.28\text{ m}$$

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

141 m/s

$$v = f\lambda = (110\text{ Hz})(1.28\text{ m})$$

$$v = 141\text{ m/s}$$

(c) Calculate the linear mass density of the string. (3 marks)

6.70×10^{-3} kg/m

$$v = \sqrt{\frac{F}{m/L}} \Rightarrow v^2 = \frac{F}{m/L}$$

$$\text{so} \quad \frac{m}{L} = \frac{F}{v^2} = \frac{133\text{N}}{(141\text{ m/s})^2} = 6.70 \times 10^{-3}\text{ kg/m}$$

(d) Calculate the maximum speed of a point on the oscillating string. (3 marks)

1.59 m/s

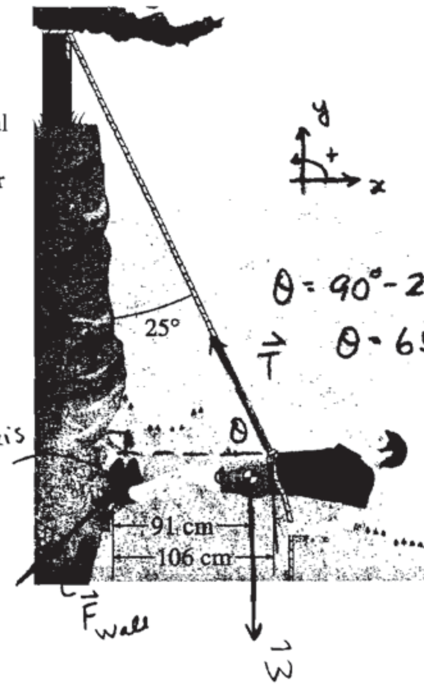
$$v_{max} = \omega A_{max} = 2\pi f A_{max}$$

$$v_{max} = 2\pi(110\text{ Hz})(2.30\text{ mm}) = 1.59 \times 10^3\text{ mm/s} = 1.59\text{ m/s}$$

END OF EXAMINATION

Stu. No.: ____________________

B1. A mountain climber is rappelling down a vertical wall. The climber has stopped his descent, and so is currently at rest. The climber's centre of gravity is 91.0 cm from his feet. The rope is at an angle of 25.0° with the vertical and attaches to a buckle strapped to the climber's waist 15.0 cm to the right of his centre of gravity. The climber weighs 770 N.



$\theta = 90° - 25.0°$

$\theta = 65.0°$

(a) Calculate the magnitude of the tension in the rope. (4 marks)

$\boxed{729\text{ N}}$

Climber is in equilibrium:

$\sum \vec{F} = 0$ and $\sum \tau = 0$

Choose the axis of rotation as the contact point b/w the climber's feet and the wall.

$$\sum \tau = 0$$

$$T r_T \sin\theta - W r_W \sin 90° = 0$$

$$T = \frac{W r_W}{r_T \sin\theta} = \frac{(770\text{N})(91.0\text{cm})}{(106\text{cm})\sin 65.0°} = 729\text{ N}$$

(b) Calculate the magnitude of the contact force exerted by wall on the climber's feet. (6 marks)

$\boxed{327\text{ N}}$

$$\sum F_x = 0 \Rightarrow F_{wall_x} - T\cos\theta = 0$$

$$F_{wall_x} = T\cos\theta = 729\text{N}\cos 65.0° = 308\text{N}$$

$$\sum F_y = 0 \Rightarrow F_{wall_y} + T\sin\theta - W = 0$$

$$F_{wall_y} = W - T\sin\theta = 770\text{N} - 729\text{N}\sin 65.0°$$

$$F_{wall_y} = 109\text{ N}$$

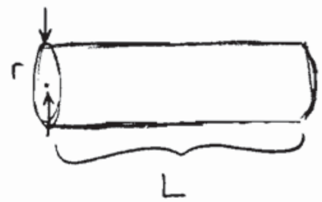
$$F_{wall} = \sqrt{F_{wall_x}^2 + F_{wall_y}^2} = 327\text{N}$$

continued on page 6...

B2. A cylindrical air duct has a length of 6.25 m and a radius of 7.25×10^{-2} m. A fan forces air of viscosity 1.80×10^{-5} Pa·s through the duct such that the air in a room of volume 265 m^3 is replenished every fifteen minutes.

(a) Calculate the volume flow rate of air through the duct. (4 marks)

$\boxed{0.294\ m^3/s}$



$$\frac{\Delta V}{\Delta t} = \frac{265\ m^3}{15\ min} \times \frac{1\ min}{60.0\ s} = 0.294\ m^3/s$$

(b) Calculate the difference in pressure between the ends of the air duct. (6 marks)

Viscous flow ⇒ Poisseuille's Law $\boxed{3.05\ Pa}$

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

$$\Delta P = \frac{\left(\frac{\Delta V}{\Delta t}\right)(8\eta L)}{\pi r^4}$$

$$\Delta P = \frac{(0.294\ m^3/s)(8)(1.80 \times 10^{-5}\ Pa \cdot s)(6.25\ m)}{\pi\ (7.25 \times 10^{-2}\ m)^4}$$

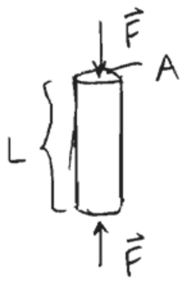
$$\Delta P = 3.05\ Pa$$

continued on page 7...

B3. A man has a mass of 75.0 kg. The average cross-sectional area of his femur is 8.12 cm^2 and the length of his femur when he is lying down is 44.5 cm. Young's modulus for compression of the femur is 9.40×10^9 Pa and the ultimate compressive strength of the femur is 1.70×10^8 N/m^2.

(a) Assuming that the compressive force on each femur is half the man's weight, calculate the compressive stress on each femur when the man is standing upright. (2 marks)

$$\boxed{4.53 \times 10^5\ Pa}$$



$$F = \frac{W}{2}$$

$$\text{Stress} = \frac{F}{A} = \frac{W}{2A} = \frac{mg}{2A}$$

$$\text{Stress} = \frac{(75.0\,kg)(9.80\,m/s^2)}{2(8.12\,cm^2)\left(\frac{1\,m}{100\,cm}\right)^2} = 4.53 \times 10^5\ Pa$$

(b) Calculate the amount that each femur is shortened when the man is standing upright compared to when he is lying down. (3 marks)

$$\boxed{2.14 \times 10^{-5}\,m}$$

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

$$\Delta L = \frac{\left(\frac{F}{A}\right) \cdot L}{Y} = \frac{(4.53 \times 10^5\ Pa)(0.445\,m)}{9.40 \times 10^9\ Pa} = 2.14 \times 10^{-5}\,m$$

(c) Consider a giant whose mass is $N^3 \times 75.0$ kg and whose femurs have cross-sectional areas of $N^2 \times (8.12\text{ cm}^2)$ and lengths of $N \times (44.5\text{ cm})$. Assume that the Young's modulus for compression of the giant's femur is 9.40×10^9 Pa and the ultimate compressive strength of the giant's femur is 1.70×10^8 N/m^2. Calculate the maximum value of the factor N such that the giant's femurs are on the verge of crumbling under the giant's weight. (5 marks)

$$\boxed{376}$$

At $N = N_{max}$, $\left(\frac{F}{A}\right)_{max} = 1.70 \times 10^8\ N/m^2$

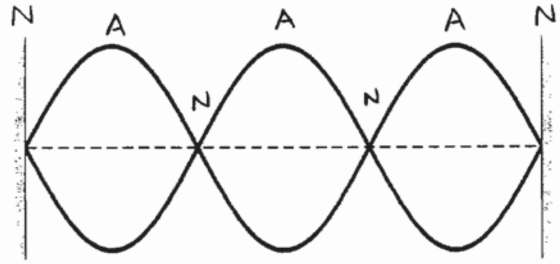
$$\frac{F}{A} = \frac{mg}{2A} \Rightarrow \left(\frac{F}{A}\right)_{max} = \frac{m_{max}\,g}{2A_{max}}$$

$$\left(\frac{F}{A}\right)_{max} = \frac{N_{max}^3(75.0\,kg)(9.80\,m/s^2)}{2N_{max}^2 \cdot 8.12\,cm^2\left(\frac{1\,m}{100\,cm}\right)^2} = 1.70 \times 10^8\ N/m^2$$

$$N_{max} = \frac{(1.70 \times 10^8\ N/m^2)(2)(8.12 \times 10^{-4}\,m^2)}{(75.0\,kg)(9.80\,m/s^2)} = 376$$

continued on page 8...

B4. A string has a linear mass density of 8.50×10^{-3} kg/m and is under a tension of 282 N. The string is 1.80 m long, is fixed at both ends, and is vibrating in the standing wave pattern shown in the diagram below.



$N-N = \frac{1}{2}\lambda$

(a) Calculate the wave speed. (4 marks)

$L = 3\left(\frac{1}{2}\lambda\right)$

$\boxed{182\ m/s}$

$$v = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{282N}{8.50\times10^{-3}\,kg/m}} = 182\ m/s$$

(b) Use the diagram to determine the wavelength of the wave. Show your calculation/explain your work. (3 marks)

$\boxed{1.20\,m}$

$L = 3\left(\frac{1}{2}\lambda\right)$ as shown above

$$\lambda = \frac{2L}{3} = \frac{2(1.80\,m)}{3} = 1.20\,m$$

(c) Calculate the frequency of the standing wave. (3 marks)

$\boxed{152\ Hz}$

$v = f\lambda$

$$f = \frac{v}{\lambda} = \frac{182\,m/s}{1.20\,m} = 152\ Hz$$

END OF EXAMINATION