UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 117.3
Physics for the Life Sciences

FINAL EXAMINATION

April 24, 2013 Time: 3 hours

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

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 N. Zarifi
- ❑ C16 F. Dean

INSTRUCTIONS:

1. This is a closed book examination.
2. The test package includes a test paper (this document), a formula sheet, and an OMR sheet. The test paper consists of 11 pages, including this cover page. **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. None of the test materials will be returned.

ONLY THE FIVE PART B QUESTIONS THAT YOU INDICATE WILL BE MARKED

PLEASE INDICATE WHICH FIVE PART B QUESTIONS ARE TO BE MARKED

QUESTION NUMBER	TO BE MARKED	MAXIMUM MARKS	MARKS OBTAINED
A1-25	☑	25	
B1	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
B5	❑	10	
B6	❑	10	
TOTAL		75	

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 thin rod of mass M and length L is initially able to rotate through an axis that is perpendicular to the rod and passes through one end. When a torque τ is applied to the rod its angular acceleration is α_1. The rod is now set up in such a way that it is able to rotate through an axis that is perpendicular to the rod and passes through the centre of the rod. When the same torque τ is applied to the rod, it now has an angular acceleration of α_2. Which one of the following statements is correct?

(A) $\alpha_2 = \frac{1}{4}\alpha_1$ (B) $\alpha_2 = \frac{1}{2}\alpha_1$ (C) $\alpha_2 = \alpha_1$ (D) $\alpha_2 = 2\alpha_1$ (E) $\alpha_2 = 4\alpha_1$

E

$I_1 = \frac{1}{3}ML^2$ $I_2 = \frac{1}{12}ML^2$ $\Sigma\tau = I\alpha$ $I_2 = \frac{1}{4}I_1$ $\alpha_2 = 4\alpha_1$

A2. When a figure skater is initially rotating with arms outstretched and she then brings her arms closer to her body, it is observed that her angular velocity increases. Ignore any effects due to friction and air resistance. Her angular velocity increases because...

(A) her moment of inertia increases.
(B) her angular momentum increases.
(C) her rotational kinetic energy decreases.
(D) her angular momentum decreases.
(E) her moment of inertia decreases.

E

Ang. momentum is conserved $\Rightarrow I_1\omega_1 = I_2\omega_2$
$\omega\uparrow$ b/c $I\downarrow$

A3. Consider two wires of equal length. One end of each wire is attached to the ceiling and a 10-N weight is suspended from the other end of each wire. The Young's moduli of the materials of which the wires are made are related by $Y_2 = 2Y_1$. Which one of the following relationships between the radii of the wires will result in the wires experiencing equal strains?

(A) $r_2 = \frac{1}{4} r_1$ (B) $r_2 = \frac{1}{2} r_1$ (C) $r_2 = \frac{1}{\sqrt{2}} r_1$ (D) $r_2 = \sqrt{2}\, r_1$ (E) $r_2 = 4r_1$

C

$\frac{F}{A} = Y\frac{\Delta L}{L}$ $\frac{F}{A_1Y_1} = \frac{F}{A_2Y_2}$

$A_1Y_1 = A_2Y_2 \Rightarrow \pi r_2^2 = \pi r_1^2 \frac{Y_1}{Y_2} \Rightarrow r_2^2 = \frac{1}{2}r_1^2 \Rightarrow r_2 = \frac{1}{\sqrt{2}}r_1$

A4. Consider two pipelines carrying the same viscous fluid. The situations are identical except that one pipeline has a radius that is twice that of the other. Let Q be the volume flow rate in the smaller pipeline. The volume flow rate in the larger pipeline is...

(A) Q (B) $2Q$ (C) $4Q$ (D) $8Q$ (E) $16\,Q$

E

Poiseuille's Law : $Q \propto R^4$

A5. The pendulum in a grandfather clock consists of a bob on a rod. Suppose that a grandfather clock is calibrated correctly at sea level and is then brought to the top of a tall mountain. What would need to be done to calibrate the clock at the top of the mountain?

(A) Nothing, it should work fine since it was already calibrated at sea level.
(B) The bob of the pendulum should be slid slightly down the rod.
(C) The bob of the pendulum should be slid slightly up the rod.
(D) It cannot be calibrated at the top of the mountain.
(E) Replace the bob with a heavier bob.

C

Physical Pendulum: $T = 2\pi\sqrt{\frac{I}{mgL}}$
$g\downarrow \therefore I\downarrow \Rightarrow$ mass of bob closer to axis

A6. A 1 kg mass is suspended on the end of a string and it is swinging back and forth. If the string is plucked, the speed of the pulse on the string…

(A) is fastest when the mass is in the middle of its way down from the highest to the lowest point in its swing.
(B) is the same at all points of the swing; the pulse's speed is not a function of the position of the mass as it swings.
(C) is fastest just after the mass leaves the highest point in its swing.
(D) is fastest when the mass is at its highest point in the swing.
(E) is fastest when the mass is at its lowest point in the swing.

E

$v = \sqrt{\frac{F}{\mu}}$, Tension F is greatest at bottom of swing where speed of mass is greatest.

A7. As you travel down the highway in your car, an ambulance approaches you from the rear at a high speed, sounding its siren at a frequency of 500 Hz. Which one of the following statements is correct?

(A) You hear a frequency lower than 500 Hz.
(B) You hear a frequency equal to 500 Hz.
(C) You hear a frequency greater than 500 Hz and the ambulance driver hears a frequency less than 500 Hz.
(D) You hear a frequency greater than 500 Hz and the ambulance driver hears a frequency of 500 Hz.
(E) Both you and the ambulance driver hear a frequency greater than 500 Hz.

D

Doppler Effect: Source moving toward observer.

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A8. When you stand halfway between two speakers, with one on the left and one on the right, a musical note from the speakers results in constructive interference at your location. How far to your left should you move to obtain destructive interference?

A

(A) one-quarter of a wavelength
(B) half a wavelength
(C) one wavelength
(D) one-and-a-half wavelengths
(E) two wavelengths

$\leftarrow r_2 \rightarrow \leftarrow r_1 \rightarrow$, d

Initially, $r_1 = r_2 = d/2$. For destructive interference, $r_1 - r_2 = \frac{1}{2}\lambda$. If you move $\frac{1}{4}\lambda$, then $r_1 = \frac{3}{4}\lambda$, $r_2 = \frac{1}{4}\lambda$ and $r_1 - r_2 = \frac{1}{2}\lambda$ ✓

A9. Which one of the following statements is correct concerning electromagnetic waves traveling through a vacuum?

E

(A) All waves have the same wavelength.
(B) All waves have the same frequency.
(C) The electric and magnetic fields associated with the waves are parallel to each other but perpendicular to the direction of wave propagation.
(D) The direction of wave propagation is parallel to the direction of the electric field.
(E) All waves have the same speed.

A10. Light traveling in a medium of index of refraction n_1 is incident on another medium having an index of refraction n_2. Under which one of the following conditions can total internal reflection occur at the interface of the two media?

B

(A) The indices of refraction have the relation $n_1 < n_2$.
(B) The indices of refraction have the relation $n_1 > n_2$.
(C) Light travels slower in the second medium than in the first.
(D) The angle of incidence equals zero degrees.
(E) The angle of incidence equals the refraction angle.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$n_1 \sin\theta_c = n_2 \sin 90°$
$n_1 \sin\theta_c = n_2$
$\sin\theta_c = \frac{n_2}{n_1} \Rightarrow n_2 < n_1$ $(n_1 > n_2)$

A11. Which one of the following statements best describes the image formed by a diverging lens whenever the magnitude of the object distance is less than that of the lens' focal distance?

E

(A) inverted, enlarged and real
(B) upright, enlarged and virtual
(C) inverted, diminished and real
(D) upright, diminished and real
(E) upright, diminished and virtual (always)

A12. A converging lens forms an image that is a distance of 15 cm past the lens. A second lens is placed 25 cm past the first lens and another image is formed; this second image is 10 cm past the second lens. Which one of the following statements is true?

A

(A) Both of the lenses have positive focal lengths.
(B) The second lens is diverging.
(C) The final image is inverted and virtual.
(D) The final image is upright and virtual.
(E) The overall magnification is negative.

Converging lens has f +ve and the second lens must also be converging to form a real image of its real object.

A13. In a Young's double-slit interference apparatus, by what factor is the distance between adjacent bright and dark fringes changed when the separation between the slits is doubled?

B

(A) ¼ (B) ½ (C) 1 (D) 2 (E) 4

$m\lambda = d\sin\theta$
$\frac{y}{L} \simeq \sin\theta = \frac{m\lambda}{d}$

A14. A Young's double-slit experiment is performed in air and then the apparatus is submerged in water. What happens to the fringe separation, and what can be used to explain the change, if any?

D

(A) The separation stays the same, as it is the same experiment independent of the medium.
(B) The separation decreases because the frequency of the light decreases in the water.
(C) The separation increases because the wavelength of the light increases in the water.
(D) The separation decreases because the wavelength of the light decreases in the water.
(E) The separation decreases because the frequency of the light is constant in the water.

$m\lambda = d\sin\theta$
$\lambda_w = \frac{\lambda}{n}$
$\lambda \downarrow$ so $\sin\theta \downarrow$

A15. Which one of the following statements correctly describes the process by which the human eye adjusts to maintain focus on an object that is approaching the eye?

A

(A) The focal length of the eye lens becomes shorter.
(B) The focal length of the eye lens becomes longer.
(C) The lens-retina distance increases.
(D) The lens-retina distance decreases.
(E) The diameter of the pupil increases.

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$; q fixed
$\frac{1}{f} - \frac{1}{p} = \text{constant}$
$\therefore$ as $p\downarrow$, f must $\downarrow$

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$P = \frac{1}{f(m)} = \frac{1}{0.25} = 4.0D$

A16. A lens has a focal length of 25 cm. What is the refractive power of the lens?

C (A) 0.25 diopters (B) 0.040 diopters (C) 4.0 diopters (D) 8.0 diopters (E) 12 diopters

A17. Which one of the following statements is correct concerning the absolute temperature of an ideal gas?

$KE_{avg} = \frac{3}{2} k_B T$

C

(A) The absolute temperature of an ideal gas is inversely proportional to the mass of the gas molecules.
(B) The absolute temperature of an ideal gas is directly proportional to the average linear momentum of the gas molecules.
(C) The absolute temperature of an ideal gas is directly proportional to the average translational kinetic energy of the gas molecules.
(D) The absolute temperature of an ideal gas is directly proportional to the average speed of the gas molecules.
(E) The absolute temperature of an ideal gas is inversely proportional to the average speed of the gas molecules.

A18. Which one of the following statements correctly describes the situation when an object is in thermal equilibrium with its surroundings?

C

(A) The object no longer absorbs thermal radiation from the surroundings, but it continues to emit thermal radiation at a constant rate.
(B) The object no longer absorbs thermal radiation from the surroundings, but it continues to emit thermal radiation at a rate that is dependent on the temperature of the object.
(C) The object emits thermal radiation at the same rate that it absorbs thermal radiation from its surroundings.
(D) The object no longer emits thermal radiation, but it continues to absorb thermal radiation from its surroundings at a constant rate.
(E) The object no longer emits thermal radiation, but it continues to absorb thermal radiation from its surroundings at a rate that is dependent on the temperature of the surroundings.

A19. Two cylinders A and B at the same temperature contain the same quantity of the same kind of gas. Cylinder A has three times the volume of cylinder B. What can you conclude about the pressures the gases exert?

$PV = Nk_BT \Rightarrow P_AV_A = P_BV_B$

C

(A) We can conclude nothing about the pressures.
(B) The pressure in cylinder A is one-ninth the pressure in cylinder B.
(C) The pressure in cylinder A is one-third the pressure in cylinder B.
(D) The pressure in cylinder A is three times the pressure in cylinder B.
(E) The pressure in cylinder A is nine times the pressure in cylinder B.

$V_A = 3V_B$
$P_A(3V_B) = P_BV_B$
$P_A = \frac{1}{3}P_B$

A20. A steel tank is completely filled with gasoline when the temperature is 20°C. The coefficient of volume expansion of gasoline is greater than the coefficient of volume expansion of steel. What happens when the temperature drops to 15°C?

The gasoline contracts more than the steel when the temp. decreases.

A

(A) The tank will no longer be completely filled.
(B) The tank will still be completely filled, with no spillage of gasoline from the tank.
(C) Some of the gasoline will overflow from the tank.
(D) Nothing can be determined without knowing the volume of the tank.
(E) Nothing can be determined without knowing the values of the volume expansion coefficients.

A21. Which one of the following forces is responsible for preventing a nucleus from breaking apart?

C

(A) The weak force.
(B) The electrostatic force.
(C) The strong nuclear force.
(D) The gravitational force.
(E) The magnetic force.

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D

A22. The Mass Number, A, represents:

(A) The number of protons.
(B) The number of neutrons.
(C) The number of positrons.
(D) The number of nucleons.
(E) The number of electrons.

D

A23. Which one of the following choices can possibly be correct for the products of the following reaction:

$$n + {}^{235}_{92}\mathrm{U} \rightarrow ?$$

(A) ${}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + 2n + e^{+}$
(B) ${}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + 2n + e^{+} + \overline{\nu}$
(C) ${}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + 2n + e^{+} + \nu$
(D) ${}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + 2n$
(E) ${}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + 2p$

Only (D) conserves electric charge.

C

A24. The binding energy of a nucleus is equal to…

(A) the energy needed to remove one of the nucleons.
(B) the average energy with which any nucleon is bound in the nucleus.
(C) the energy needed to separate all the nucleons from each other.
(D) the mass of the nucleus times c^2.
(E) the energy released from a fusion reaction.

A

A25. The K-ratio in a fission reactor is defined as the average number of neutrons from each fission event that will cause another event. In a well-functioning reactor, it is desired to maintain a self-sustained chain reaction. The K-ratio in a well-functioning reactor has a value of

(A) 1. (B) 2.5. (C) 0.9. (D) 0. (E) any integer.

PART B

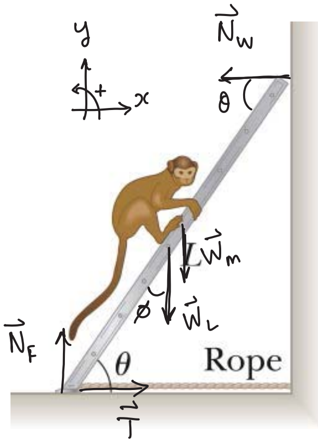
ANSWER <u>FIVE</u> PART B QUESTIONS AND INDICATE YOUR CHOICES ON THE COVER PAGE.

IN EACH OF THE 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 6…

Student No.: ______________________

B1. A 10.0-kg monkey climbs a uniform ladder that weighs 125 N and has a length of L = 3.00 m. The ladder rests against a wall at an angle of θ = 60.0° with the ground. The upper and lower ends of the ladder rest on frictionless surfaces, with the lower end of the ladder fastened to the wall by a horizontal rope that can exert a maximum tension of 80.0 N.



$\phi = 90° - \theta$

$\phi = 30.0°$

(a) On the above diagram, draw and clearly label the forces acting on the ladder. (3 marks)

(b) Calculate the normal force exerted on the bottom of the ladder. (3 marks)

The ladder is in equilibrium: $\Sigma \vec{F} = 0$ and $\Sigma \tau = 0$

$\Sigma F_y = 0 \Rightarrow + N_F - W_m - W_L = 0$

$N_F = W_m + W_L = m_m g + W_L = \boxed{223\ N}$

(a) Calculate the maximum distance, measured along the ladder, that the monkey can climb up the ladder before the rope breaks. (4 marks)

2.33 m

Take the contact point with the ground as the axis of rotation.

Note that from $\Sigma F_x = 0$, $N_W = T$

At the breaking point, $N_W = T_{max} = 80.0 N$

$\Sigma \tau = 0 \Rightarrow \tau_{W_L} + \tau_{W_m} + \tau_{N_W} = 0$

$-W_L \left(\frac{L}{2}\right) \sin\phi - W_m r_m \sin\phi + N_W L \sin\theta = 0$

$N_W L \sin\theta - W_L \left(\frac{L}{2}\right) \sin\phi = W_m r_m \sin\phi$

$$r_m = \frac{N_W L \sin\theta}{W_m \sin\phi} - \frac{W_L (L/2)}{W_m} = \frac{(80.0 N)(3.00 m) \sin 60.0°}{98.0 kg \sin 30.0°} - \frac{125 N (1.50 m)}{98.0 kg}$$

$\boxed{r_m = 2.33\ m}$

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 Student No.: ______________________

B2. A steel wire with mass 25.0 g and length 1.35 m is strung on a bass guitar so that the length of the string that is free to vibrate is 1.10 m.

(a) Calculate the linear mass density of the string. (2 marks)

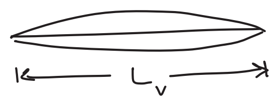
1.85×10^{-2} kg/m

$$\mu = \frac{m}{L} = \frac{25.0\,g \times 1\,kg/1000\,g}{1.35\,m} = 1.85\times10^{-2}\ kg/m$$

(b) Calculate the velocity of the wave on the string that will produce a fundamental frequency of 41.2 Hz. (3 marks)

90.6 m/s

At fundamental,



$L_v = \frac{1}{2}\lambda \Rightarrow \lambda = 2L_v$

$\lambda = 2(1.10\,m) = 2.20\,m$

$$v = f\lambda = (41.2\,Hz)(2.20\,m) = 90.6\ m/s$$

(c) Calculate the tension in the string required to produce a fundamental frequency of 41.2 Hz. (3 marks)

152 N

$$v = \sqrt{\frac{F}{\mu}} \Rightarrow F = v^2\mu = (90.6\,m/s)^2(1.85\times10^{-2}\,kg/m)$$

$$F = 152\,N$$

(d) Calculate the wavelength of the sound wave produced in air when the string is vibrating at a frequency of 41.2 Hz. Assume that the speed of sound in air is 343 m/s. (2 marks)

8.33 m

$$\lambda = \frac{v_s}{f} = \frac{343\,m/s}{41.2\,Hz} = 8.33\,m$$

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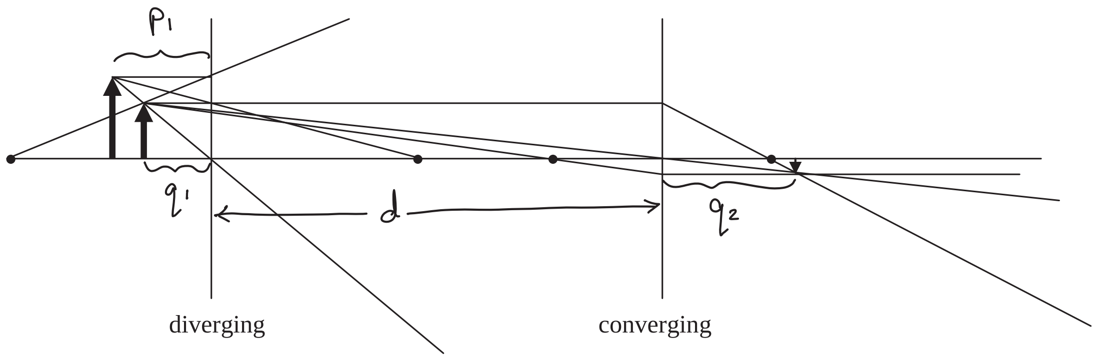
Student No.: ______________________

B3. A diverging lens with a focal distance of 20.0 cm and a converging lens with a focal distance of 10.0 cm are placed 50.0 cm apart. An object is placed a distance of 8.00 cm to the left of the diverging lens.

(a) In the space below, draw the ray diagram to locate the position of the final image. To obtain full marks you must show all three principal rays for each lens. (3 marks)



(b) Calculate the position of the final image relative to the converging lens. (4 marks)

$\frac{1}{f_1} = \frac{1}{p_1} + \frac{1}{q_1}$

+12.2 cm

$f_1 = -20.0\text{ cm}$ (−ve b/c diverging)

$p_1 = +8.00\text{ cm}$; $q_1 = \left(\frac{1}{-20.0\text{cm}} - \frac{1}{+8.00\text{cm}}\right)^{-1} = -5.71\text{ cm}$

$p_2 = |q_1| + d = |-5.71\text{ cm}| + 50.0\text{ cm} = +55.71\text{ cm}$

$q_2 = \left(\frac{1}{f_2} - \frac{1}{p_2}\right)^{-1} = \left(\frac{1}{+10.0\text{cm}} - \frac{1}{+55.71\text{cm}}\right)^{-1} = +12.2\text{ cm}$

(c) Calculate the total magnification. If you did not obtain an answer for (b), use a value of 15.0 cm. (3 marks)

$M_{tot} = M_1 \cdot M_2 = \left(-\frac{q_1}{p_1}\right)\left(-\frac{q_2}{p_2}\right)$

−0.156

$M_{tot} = \frac{q_1 q_2}{p_1 p_2} = \frac{(-5.71\text{cm})(+12.2\text{cm})}{(+8.00\text{cm})(+55.71\text{cm})} = -0.156$

− : inverted ✓

0.156 << 1 so image much smaller than object. ✓

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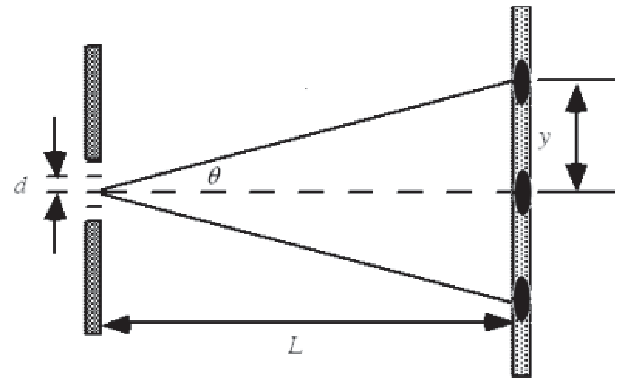
B4. The wavelength of the laser beam used in a compact disc player is 482 nm. Suppose that a diffraction grating produces a first-order tracking beam that is a distance y = 0.625 mm from the central bright fringe at a distance of L = 4.00 mm from the grating as shown in the diagram below.



(a) Calculate the angle θ. (3 marks)

$$\tan\theta = \frac{y}{L}$$

$$\theta = \text{invtan}\left(\frac{y}{L}\right) = \text{invtan}\left(\frac{0.625\text{ mm}}{4.00\text{ mm}}\right) = 8.88°$$

8.88°

(b) Calculate the slit separation, d, of the grating. If you did not obtain an answer for (a), use a value of 7.50° (4 marks)

$$m\lambda = d\sin\theta$$

$$d = \frac{m\lambda}{\sin\theta} = \frac{1(482\text{ nm})}{\sin(8.88°)} = 3.12\times10^{3}\text{ nm} \times \frac{1\text{ mm}}{10^{6}\text{ nm}} = 3.12\times10^{-3}\text{ mm}$$

3.12×10^{-3} mm

(c) Calculate the number of lines per mm for the diffraction grating. If you did not obtain an answer for (b), use a value of 3.00×10^{-3} mm. (3 marks)

320 lines/mm

$$N = \frac{1}{d} = \frac{1}{3.12\times10^{-3}\text{ mm}} = 320\text{ lines/mm}$$

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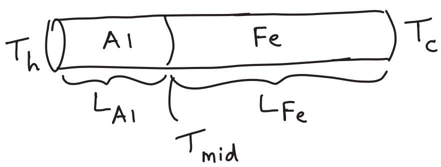
Student No.: ______________________

B5. An aluminum rod of length 22.5 cm and an iron rod of length 37.4 cm are joined end-to-end in good thermal contact. The two rods have equal radii of 6.00 cm. The free end of the aluminum rod is maintained at a temperature of 80.0°C and the free end of the iron rod is maintained at a temperature of 30.0°C.

(a) Calculate the temperature at the interface between the two rods. (4 marks)

$k_{Al} = 238\ \mathrm{W/m\,°C}$; $k_{Fe} = 79.5\ \mathrm{W/m \cdot °C}$

71.6°C



$$P_{Al} = P_{Fe}$$

$$\frac{k_{Al} A_{Al} (T_h - T_{mid})}{L_{Al}} = \frac{k_{Fe} A_{Fe} (T_{mid} - T_c)}{L_{Fe}}$$

$$1058\,(T_h - T_{mid}) = 212.6\,(T_{mid} - T_c)$$

$$84640 - 1058\,T_{mid} = 212.6\,T_{mid} - 6378$$

$$T_{mid} = 71.6°C$$

(b) Calculate the rate at which energy is transferred through the aluminum rod. If you did not obtain an answer for (a), use a value of 70.0°C. (4 marks)

$\mathbf{1.00 \times 10^2\ W}$

$$P_{Al} = \frac{k_{Al} A_{Al} (T_h - T_{mid})}{L_{Al}} = \frac{\left(\frac{238\,\mathrm{W}}{\mathrm{m \cdot °C}}\right) \pi\,(0.0600\,\mathrm{m})^2 (80.0°C - 71.6°C)}{0.225\,\mathrm{m}}$$

$$P_{Al} = 100\,\mathrm{W} = 1.00 \times 10^2\,\mathrm{W}$$

(c) Calculate the energy transferred through the rods in 30.0 minutes. If you did not obtain an answer for (b), use a value of 125 W. (2 marks)

$\mathbf{1.80 \times 10^5\ J}$

$$E = P \cdot t = 100\,\mathrm{W} \cdot 30\,\mathrm{min} \times \frac{60\,\mathrm{s}}{\mathrm{min}} = 1.80 \times 10^5\,\mathrm{J}$$

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Student No.: ______________________

B6. Polonium, ${}^{210}_{84}Po$ (atomic mass = 209.982848 u), undergoes alpha decay to become Lead, ${}^{206}_{82}Pb$ (atomic mass = 205.974440 u). The atomic mass of the alpha particle is 4.002603 u.

(a) Calculate the approximate volume of the Polonium nucleus. (3 marks)

$1.52 \times 10^{-42}\ m^3$

$$r = r_0 A^{1/3}$$

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi r_0^3 A = \frac{4}{3}\pi (1.2\times10^{-15}\,m)^3 (210)$$

$$V = 1.52\times10^{-42}\,m^3$$

(b) Calculate the energy released in the alpha decay of Polonium-210. (3 marks)

$5.41\ MeV$

$$\Delta E = (\Delta m)c^2 = (209.982848u - 205.974440u - 4.002603u)\cdot 931.5\,\frac{MeV}{u}$$

$$\Delta E = 5.41\ MeV$$

(c) The half-life of Uranium-238 is 4.47×10^9 years. Calculate the age of a rock specimen that contains 60.0% of its original number of Uranium-238 atoms. (4 marks)

$3.30\times10^9\ yr$

$$T_{1/2} = \frac{\ln 2}{\lambda} \Rightarrow \lambda = \frac{\ln 2}{T_{1/2}}$$

$$\lambda = \frac{\ln 2}{4.47\times10^9\,yr} = 1.55\times10^{-10}/yr$$

$$N = N_0 e^{-\lambda t}\ ;\ \text{given } N = 60.0\%\,N_0 \Rightarrow \frac{N}{N_0} = 0.600$$

$$\frac{N}{N_0} = e^{-\lambda t} \Rightarrow \ln\left(\frac{N}{N_0}\right) = -\lambda t \Rightarrow t = \frac{\ln(N/N_0)}{-\lambda}$$

$$t = \frac{\ln(0.600)}{-1.55\times10^{-10}/yr} = 3.30\times10^{9}\,yr$$

END OF EXAMINATION