UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
Physics for the Life Sciences

FINAL EXAMINATION

April 12, 2016 Time: 3 hours

NAME: ____________ SOLUTIONS __________________ STUDENT NO.: ____________

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

LECTURE SECTION (please check):

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

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 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. 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	

PART A

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

A1. C Consider two rods made of the same type of steel. The length of rod 2 is twice the length of rod 1. i.e. $L_{02} = 2L_{01}$. The cross-sectional area of rod 2 is three times the cross-sectional area of rod 1. i.e. $A_2 = 3A_1$. The same tensile stress is exerted on each rod. The relationship between the Young's modulus of rod 2 and the Young's modulus of rod 1 is… same material, same Y.

(A) $Y_2 = 3\,Y_1$ (B) $Y_2 = 1.5\,Y_1$ (C) $Y_2 = Y_1$ (D) $Y_2 = 0.5\,Y_1$ (E) $Y_2 = 0.33\,Y_1$

A2. C In a person with advanced arteriosclerosis, an artery develops a constricted region as a result of accumulated plaque on its inner walls. Which one of the following statements is true regarding the blood flow speed and pressure in the constricted region as compared to an adjacent non-constricted region? $A_1 v_1 = A_2 v_2$; $A\downarrow$, $\therefore v\uparrow$ $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

(A) The blood moves at the same speed and has the same pressure in both regions.
(B) The blood moves at a higher speed and has a higher pressure in the constricted region. $y_1 = y_2$
(C) The blood moves at a higher speed and has a lower pressure in the constricted region. $v\uparrow$,
(D) The blood moves at a lower speed and has a higher pressure in the constricted region.
(E) The blood moves at a lower speed and has a lower pressure in the constricted region. $\therefore P\downarrow$

A3. B The buoyant force on a floating object has the same magnitude as…

(A) twice the weight of the object. definition of buoyant force.
(B) the weight of the fluid displaced by the object.
(C) the difference between the weights of the object and the displaced fluid.
(D) the sum of the weights of the object and the displaced fluid.
(E) the average pressure of the fluid multiplied by the surface area of the object.

A4. D A circular loop is completely immersed in a stream of water, and oriented so that it is perpendicular to the current. If the area of the loop is doubled, the volume of water through the loop per unit time…

$\frac{\Delta V}{\Delta t}$ = volume flow rate = Av

$\therefore \frac{\Delta V}{\Delta t} \propto A$

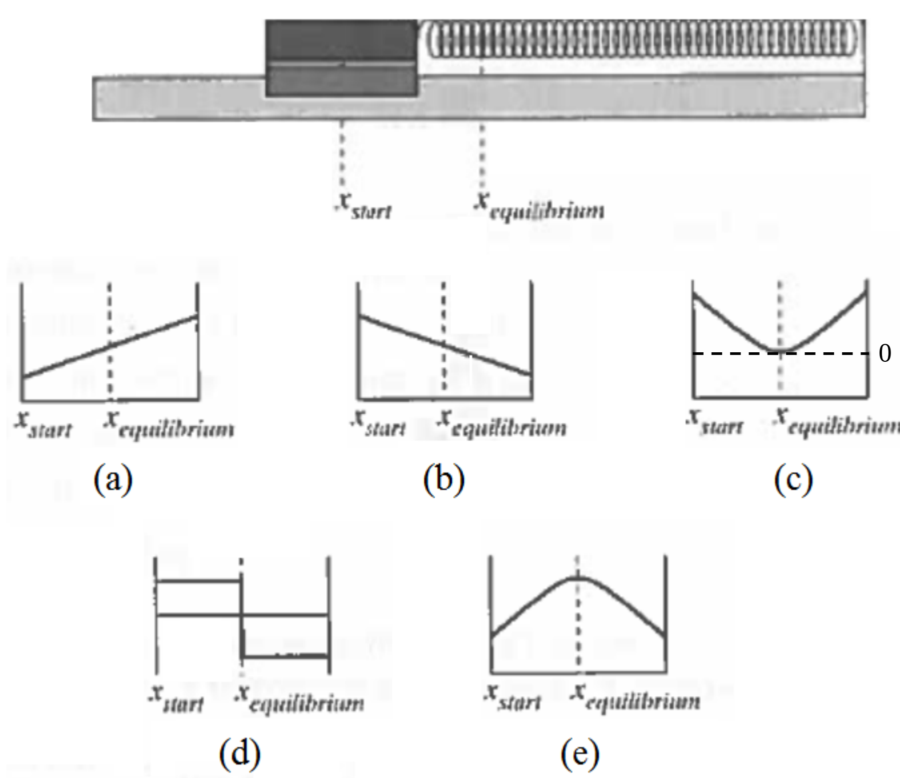
(A) decreases by a factor of 4.
(B) decreases by a factor of 2.
(C) remains the same.
(D) increases by a factor of 2.
(E) increases by a factor of 4.

A5. B A tube open at one end and closed at the other has a fundamental resonant frequency of f. What is the second lowest resonant frequency? $f_1 = \frac{v}{4L}$; $f_2 = \frac{v}{4/3 L} = \frac{3v}{4L}$

(A) $4\,f$ (B) $3\,f$ (C) $2.5\,f$ (D) $2\,f$ (E) $1.5\,f$

A6. C The figure below shows an air track cart attached to a spring. The cart was pulled to the position x_{start} and released. The cart oscillates about $x_{equilibrium}$. Which graph correctly represents the potential energy of the spring as a function of the position of the cart?

$PE_{elastic} = \frac{1}{2}kx^2$



A7. A train accelerates and toots its whistle (frequency f_0) when it leaves the station. As the train moves faster and faster away from a stationary observer at the station, what happens to the frequency of the whistle as heard by this observer?

$f_o = \left(\frac{1}{v - v_s}\right) f_s$ and v_s -ve and increasing

E

(A) The frequency heard is still f_0.
(B) The frequency heard is greater than f_0 and remains constant.
(C) The frequency heard is less than f_0 and remains constant.
(D) The frequency heard is greater than f_0 and increases as the train accelerates.
(E) The frequency heard is less than f_0 and decreases as the train accelerates.

A8. A 420-Hz tuning fork is sounded together with an out-of-tune guitar string, and a beat frequency of 4 Hz is heard. As the string is slowly loosened, the beat frequency is heard to increase. The original frequency of the guitar string was…

B

$f \downarrow$ as string is loosened. Since $f_{beat} \uparrow$, f_{guitar} must have already been $< f_{fork}$

(A) 412 Hz. (B) 416 Hz. (C) 424 Hz. (D) 428 Hz. (E) 432 Hz.

A9. A diverging lens has a focal distance f. An object is placed on the lens's principal axis at a distance of $\frac{3}{2} f$ from the lens. The image formed will be…

D

(A) real, inverted, and larger than the object.
(B) real, inverted, and smaller than the object.
(C) real, upright, and larger than the object.
(D) virtual, upright, and smaller than the object. — always true for a single diverging lens
(E) virtual, upright, and larger than the object.

A10. Consider a ray of light, initially travelling in water, that strikes a water-air interface. Which one of the following statements is correct?

E

(A) All of the light passes into the air.
(B) All of the light reflects back into the water.
(C) Some of the light reflects back into the water and some refracts into the air. The angle of refraction is greater than the angle of incidence.
(D) Some of the light reflects back into the water and some refracts into the air. The angle of refraction is less than the angle of incidence.
(E) The answer depends on whether or not the angle of incidence is greater than the critical angle for a water-air interface.

A11. Which one of these regions of the electromagnetic spectrum has the shortest wavelength?

B

(A) visible light (B) x-rays (C) radio waves (D) ultraviolet light (E) microwaves

A12. Let $\vec{E}$ represent the electric field, $\vec{B}$ represent the magnetic field, and $\vec{v}$ represent the velocity of an electromagnetic wave. Which one of the following statements is correct?

E

(A) $\vec{E}$ and $\vec{B}$ are parallel to each other and perpendicular to $\vec{v}$
(B) $\vec{E}$ and $\vec{v}$ are parallel to each other and perpendicular to $\vec{B}$
(C) $\vec{B}$ and $\vec{v}$ are parallel to each other and perpendicular to $\vec{E}$
(D) $\vec{E}$, $\vec{B}$, and $\vec{v}$ are parallel to each other
(E) $\vec{E}$, $\vec{B}$, and $\vec{v}$ are mutually perpendicular

$m\lambda = d\sin\theta \Rightarrow m_b\lambda_b = m_r\lambda_r$

$3\lambda_b = 2\lambda_r$

A13. A slide containing two slits is illuminated with light from a source that emits only two spectral lines – a blue line of 400 nm wavelength and a red line of 600 nm wavelength. The resulting interference pattern is observed on a screen. As you look outward from the central fringe, at what minimum order of the blue light will you observe a blue fringe superposed on a red fringe?

C

(A) 1 (B) 2 (C) 3 (D) 4 (E) 6

A14. What will be the result if Young's double slit interference experiment is performed with the entire apparatus (source, slits, screen) immersed in water?

C

$m\lambda = d\sin\theta \Rightarrow \sin\theta = \frac{m\lambda}{d}$

(A) There will be fewer interference fringes.
(B) The fringes will be further apart.
(C) The fringes will be closer together.
(D) There will be no interference fringes.
(E) The fringe pattern will be no different than if the experiment is done in air.

$v = f\lambda \Rightarrow \lambda\downarrow$ when $v\downarrow$ since f is constant

$\therefore \theta_{water} < \theta_{air}$

A15. Consider two slides. One has two slits, the other has five slits. Both slides have the same slit widths and slit spacings. Identical lasers are shone through the slides and the interference patterns are observed on a screen that is the same distance from each slide. Which one of the following statements concerning the interference patterns on the screen is correct?

E

(A) The patterns are identical. d same ⇒ fringe spacing is the same
(B) The bright fringes of the two-slit pattern are narrower and further apart than those of the five-slit pattern.
(C) The bright fringes of the five-slit pattern are narrower and further apart than those of the two-slit pattern.
(D) The bright fringes of the five-slit pattern are narrower and closer together than those of the two-slit pattern.
(E) The bright fringes of the five-slit pattern are narrower but the same spacing as those of the two-slit pattern.

A16. Which one of the following lenses will correct the vision of a nearsighted person?

A

(A) A diverging lens with a focal distance equal to the person's uncorrected far point.
(B) A diverging lens with a focal distance of 25 cm. $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ and $p = \infty$, so $f = q$
(C) A converging lens with a focal distance of 25 cm.
(D) A converging lens with a focal distance equal to the person's uncorrected far point.
(E) A converging lens with a focal distance equal to the person's uncorrected near point.

A17. During a change in the weather, the air temperature changes from −35.0°C to +5.00°C in a 24-hour period. This corresponds to a temperature change of $\Delta T = T_f - T_i = 40C° = 40K$

C

(A) 30.0 K (B) 303 K (C) 40.0 K (D) 313 K (E) 278 K

A18. Consider two stars, A and B. Both stars have the same emissivity, but star A has twice the radius and twice the absolute temperature as compared to star B. Let P_A and P_B represent the power output of each star due to the emission of electromagnetic radiation. Which one of the following statements is correct? $P = \sigma A e T^4 \Rightarrow P_A = \sigma(4A_B)e(2T_B)^4 = 64\sigma A_B e T_B^4 = 64P_B$

E

(A) $P_A = 4P_B$ (B) $P_A = 8P_B$ (C) $P_A = 16P_B$ (D) $P_A = 32P_B$ (E) $P_A = 64P_B$

A19. Light of a certain frequency and intensity, shining on a metal surface, causes electrons to be ejected. Which one of the following statements correctly describes the result if light of lower intensity, but the same frequency, now shines on the same metal surface?

D

(A) There is a non-zero intensity threshold below which electrons are no longer ejected.
(B) Both the maximum energy and the rate of emission of electrons decrease.
(C) The maximum energy of the ejected electrons decreases but the rate of emission remains the same.
(D) The maximum energy of the ejected electrons remains the same but the rate of emission decreases. same freq'y ⇒ same KE_{max} ; lower intensity ⇒ fewer electrons per unit time
(E) Electrons are still ejected at the same rate and with the same maximum energy.

A20. A ring of metal A is fitted tightly on a rod of metal B at room temperature. The ring can be separated from the rod when the ring-rod system is sufficiently cooled. Possible choices of metals are aluminum (Al), copper (Cu), and iron (Fe). Given the relation of the coefficients of linear expansion, $\alpha_{Fe} < \alpha_{Cu} < \alpha_{Al}$, which one of the following combinations can possibly result in the ring separating from the rod? rod must contract more than the ring.

E

∴ want $\alpha_{rod} > \alpha_{ring}$ i.e. $\alpha_{ring} < \alpha_{rod}$

(A) copper ring on iron rod (B) aluminum ring on iron rod
(C) aluminum ring on aluminum rod (D) aluminum ring on copper rod
(E) copper ring on aluminum rod

A21. An ideal gas in an enclosed container at 3.0 atm and 10°C is heated to 150°C. If the volume is held constant during the heating, what is the final pressure? $PV = nRT \Rightarrow P_1/T_1 = P_2/T_2$

B

(A) 45 atm (B) 4.5 atm (C) 1.8 atm (D) 1.0 atm (E) 0.14 atm

$P_2 = (T_2/T_1)P_1 = \left(\frac{150+273}{10+273}\right) \cdot 3.0\text{atm} = 4.5\text{atm}$

A22. Let V_O be the volume of the ${}^{16}_{8}O$ nucleus and V_S be the volume of the ${}^{32}_{16}S$ nucleus. Which one of the following statements is correct? Volume ∝ nucleon number

C

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

A23. Let N_P and Z_P be the neutron number and atomic number of a parent nucleus that undergoes alpha decay, becoming a daughter nucleus. Let N_D and Z_D be the neutron number and atomic number of the daughter nucleus. Which one of the following statements is correct?

D

(A) $N_D = N_P + 2$ (B) $N_D = N_P$
(C) $N_D + Z_D = N_P + Z_P$ (D) $N_D = N_P - 2$
(E) $N_D = N_P - 4$

$^{A}_{Z}P \rightarrow {}^{A-4}_{Z-2}D + \underbrace{{}^{4}_{2}He}_{\text{alpha}}$

$A \downarrow 4$ and $Z \downarrow 2 \Rightarrow N \downarrow 2$

A24. A hydrogen atom in the ground state absorbs a 12.75-eV photon. To which level is the electron promoted?

C

(A) $n = 2$ (B) $n = 3$ (C) $n = 4$ (D) $n = 5$ (E) $n = 6$

$E_1 = -13.6\text{eV}$

$E_n = -13.6\text{eV} + 12.75\text{eV}$

$E_n = -0.850\text{eV}$

$\frac{-13.6\text{eV}}{n^2} = -0.850\text{eV}$

$n^2 = \sqrt{\frac{13.6}{0.850}} = 4$

A25. The binding energy of a nucleus is equal to…

D

(A) the energy needed to remove one of the nucleons.
(B) the energy needed to add one more nucleon.
(C) the average energy with which any nucleon is bound in the nucleus.
(D) the energy needed to separate all the nucleons from each other.
(E) the mass of the nucleus multiplied by c^2.

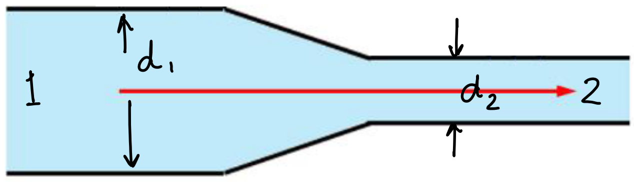
PART B

ANSWER FIVE 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.**

B1. A liquid of density 7.00×10^2 kg/m^3 flows through a horizontal pipe of varying cross section as shown in the diagram below. The inside diameter of the larger section of the pipe is 2.50 cm, and the flow speed in this region is 275 cm/s. The inside diameter of the smaller section of the pipe is 2.30 cm. (The diagram is not to scale.)



(a) Calculate the flow speed in the smaller section. (3 marks)

$\boxed{3.25\ \text{m/s}}$

$$A_1 v_1 = A_2 v_2$$

$$\pi \frac{d_1^2}{4} v_1 = \pi \frac{d_2^2}{4} v_2 \Rightarrow v_2 = \left(\frac{d_1}{d_2}\right)^2 v_1$$

$$v_2 = \left(\frac{2.50\text{cm}}{2.30\text{cm}}\right)^2 (2.75\,\text{m/s}) = 3.25\,\text{m/s}$$

(b) Calculate the mass flow rate of the fluid. If you did not obtain an answer for (a), use a value of 3.50 m/s. (3 marks)

$\boxed{0.945\ \text{kg/s}}$

$$\frac{\Delta m}{\Delta t} = \rho A v = \left(700\,\frac{\text{kg}}{\text{m}^3}\right)\pi \frac{d_1^2}{4} v_1$$

$$= \left(700\,\frac{\text{kg}}{\text{m}^3}\right)\pi \frac{(0.0250\text{m})^2}{4} \cdot 2.75\,\text{m/s} = 0.945\,\text{kg/s}$$

(c) Calculate the difference in pressure between the larger section and the smaller section of the pipe. If you did not obtain an answer for (a), use a value of 3.50 m/s. (4 marks)

$\boxed{1.05 \times 10^3\ \text{Pa}}$

Bernoulli's Principle: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

horizontal pipe $\Rightarrow y_1 = y_2$

$$\therefore P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

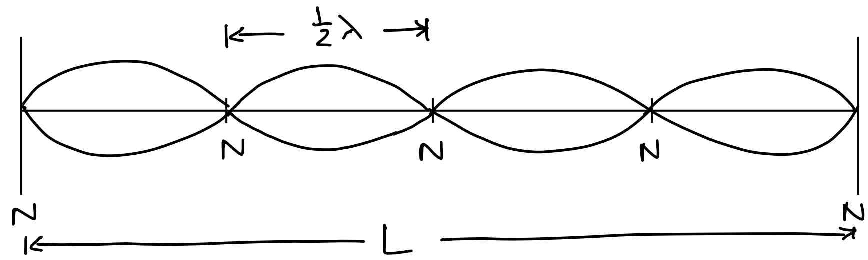
$$P_1 - P_2 = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right) = \frac{1}{2}\left(700\,\text{kg/m}^3\right)\left((3.25\,\text{m/s})^2 - (2.75\,\text{m/s})^2\right)$$

$$P_1 - P_2 = 1.05 \times 10^3\,\text{Pa}$$

Student No.: ______________________

B2. A steel wire with mass 25.0 g and length 1.35 m is fixed at both ends and vibrating at its fourth harmonic, a frequency of 223 Hz.

(a) Draw a diagram showing the wire vibrating at its fourth harmonic. (1 mark)



(b) Calculate the tension in the wire that is required to produce a frequency of 223 Hz for the fourth harmonic. (4 marks)

$\boxed{4.20 \times 10^2\,\text{N}}$

From diagram, $L = 4\left(\frac{1}{2}\lambda\right) \Rightarrow \lambda = \frac{1}{2}L$

$$v = f\lambda = \sqrt{\frac{F}{\mu}} \Rightarrow f^2\lambda^2 = \frac{F}{\mu} \Rightarrow F = \mu f^2 \lambda^2 = \frac{m}{L} \cdot f^2 \cdot \left(\frac{1}{2}L\right)^2$$

$$F = \frac{mf^2L}{4} = \frac{(25.0\times 10^{-3}\,\text{kg})(223\,\text{Hz})^2(1.35\,\text{m})}{4} = 4.20\times 10^2\,\text{N}$$

(c) Calculate the wavelength of the sound wave produced in air at a temperature of 35.0°C when the wire is vibrating at a frequency of 223 Hz. (3 marks)

$\boxed{1.58\,\text{m}}$

$$f_{sound} = f_{wire} = 223\,\text{Hz} \; ; \; v = f\lambda \Rightarrow \lambda_{sound} = \frac{v_{sound}}{f_{sound}}$$

$$\lambda_{sound} = \frac{1}{f_{sound}}(331\,\text{m/s})\sqrt{\frac{273+35}{273}} = 1.58\,\text{m}$$

(d) Calculate the frequencies of the fundamental and second harmonic of the wire. (2 marks)

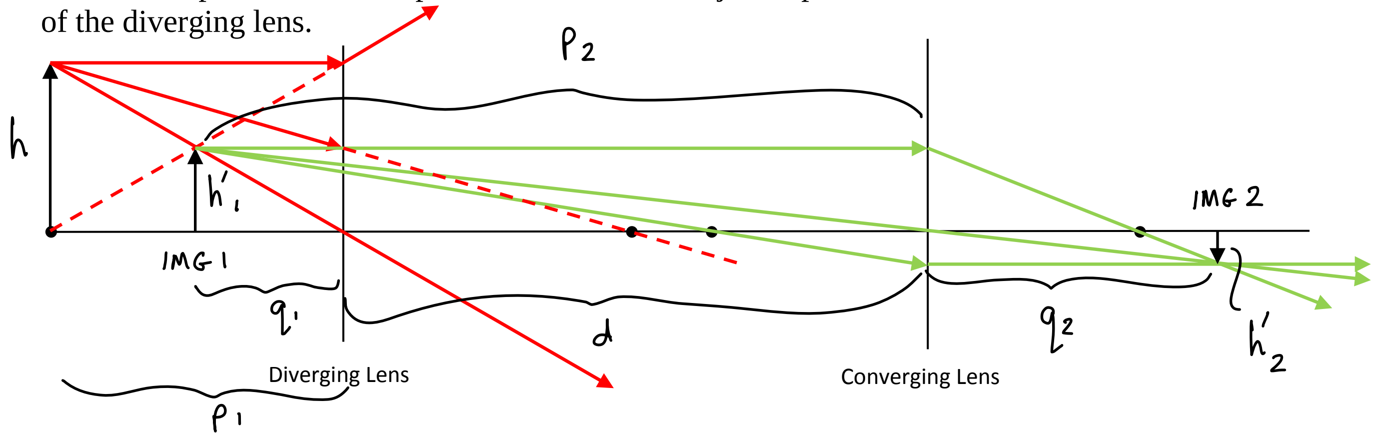
$\boxed{55.8\,\text{Hz},\ 112\,\text{Hz}}$

A wire fixed at both ends resonates at all the harmonics.

$$\therefore f_1 = \text{fundamental} = \frac{1}{4}f_4 = \frac{223\,\text{Hz}}{4} = 55.8\,\text{Hz}$$

$$f_2 = 2f_1 = 2(55.8\,\text{Hz}) = 112\,\text{Hz}$$

B3. A diverging lens with a focal distance of 20.0 cm and a converging lens with a focal distance of 15.0 cm are placed 40.0 cm apart. A 5.00-cm-tall object is placed a distance of 20.0 cm to the left of the diverging lens.



(a) The above diagram shows the object, the two lenses, and their focal points. Draw the ray diagram to locate the position of the final image. (4 marks)

(b) Calculate the position of the final image relative to the converging lens. (3 marks)

$\boxed{21.4\text{ cm to right}}$

$f_1 = -20.0\text{ cm}$ diverging $\qquad f_2 = +15.0\text{ cm}$ converging

$$q_1 = \left(\frac{1}{f_1} - \frac{1}{p_1}\right)^{-1} = \left(\frac{1}{-20.0\text{ cm}} - \frac{1}{20.0\text{ cm}}\right)^{-1} = -10.0\text{ cm}$$

$$p_2 = |q_1| + d = 10.0\text{ cm} + 40.0\text{ cm} = 50.0\text{ cm}$$

$$q_2 = \left(\frac{1}{f_2} - \frac{1}{p_2}\right)^{-1} = \left(\frac{1}{+15.0\text{ cm}} - \frac{1}{50.0\text{ cm}}\right)^{-1} = +21.4\text{ cm}$$

The final image occurs 21.4 cm to the right of the converging lens.

(c) Calculate the size of the final image. If you did not obtain an answer for (b), use a value of 20.0 cm to the right. (3 marks)

$\boxed{1.07\text{ cm}}$

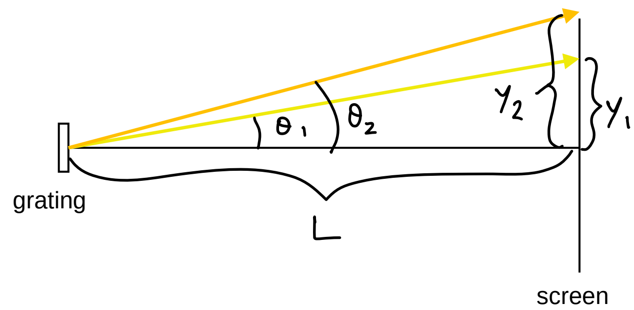
$$h'_2 = m_2 h'_1 = m_2 (m_1 h) = \left(-\frac{q_2}{p_2}\right)\left(-\frac{q_1}{p_1}\right) h$$

$$h'_2 = \left(-\frac{21.4\text{ cm}}{50.0\text{ cm}}\right)\left(-\frac{(-10.0\text{ cm})}{20.0\text{ cm}}\right)(5.00\text{ cm})$$

$$h'_2 = -1.07\text{ cm} \; ; \quad \text{size} = 1.07\text{ cm}$$

inverted

B4. When yellow light of wavelength 589 nm from a sodium source illuminates a diffraction grating, the first-order line on a screen 60.0 cm away appears 33.2 cm from the central zeroth-order line. A second light source produces a first-order line on the screen that appears 37.1 cm from the central line.



(a) Calculate the number of lines per cm on the grating. (3 marks)

$\boxed{8.22 \times 10^3 \text{ lines/cm}}$

$m\lambda = d\sin\theta \Rightarrow d = \frac{m\lambda}{\sin\theta}$; $\theta_1 = \text{invtan}\left(\frac{y_1}{L}\right)$

$$\theta_1 = \text{invtan}\left(\frac{33.2\text{cm}}{60.0\text{cm}}\right) = 28.96°$$

$$d = \frac{1\,(589\text{nm})}{\sin(28.96°)} = 1.217 \times 10^3 \text{nm}$$

$$N = \frac{1}{d} = \frac{1}{1.217 \times 10^3 \text{nm}} \times \frac{10^7 \text{nm}}{\text{cm}} = 8.22 \times 10^3 \text{ lines/cm}$$

(b) Calculate the wavelength of the light emitted by the second source. (3 marks)

$\boxed{639 \text{ nm}}$

$m\lambda = d\sin\theta$

$$\lambda_2 = \frac{d\sin\theta_2}{1}$$

$$\theta_2 = \text{invtan}\left(\frac{y_2}{L}\right) = \text{invtan}\left(\frac{37.1\text{cm}}{60.0\text{cm}}\right) = 31.7°$$

$$\lambda_2 = (1.217 \times 10^3 \text{nm}) \sin(31.7°)$$

$$\lambda_2 = 639\text{ nm}$$

Without having a value for d:

$$d = \frac{m\lambda}{\sin\theta} \Rightarrow \frac{m_1\lambda_1}{\sin\theta_1} = \frac{m_2\lambda_2}{\sin\theta_2} \Rightarrow \lambda_2 = \frac{m_1\lambda_1\sin\theta_2}{m_2\sin\theta_1}$$

$$\lambda_2 = \frac{(589\text{nm})\sin(31.7°)}{\sin(28.96°)}$$

$$\lambda_2 = 639\text{ nm}$$

(c) For the yellow light from the sodium source, calculate the order of the spectral line that appears on the screen and has the largest angular location. (4 marks)

$\boxed{2}$

Not given screen size, so assume that θ can be up to 90°

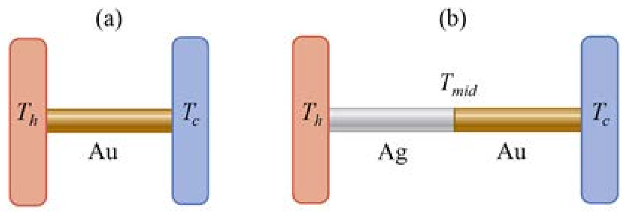
$m_{max}\lambda_1 = d\sin\theta_{1max}$ and $d = \frac{m_1\lambda_1}{\sin\theta_1}$

$$m_{max} = \frac{d\sin\theta_{1max}}{\lambda_1} = \frac{m_1\lambda_1\sin\theta_{1max}}{\lambda_1\sin\theta_1} = \frac{1 \cdot \sin 90°}{\sin\theta_1}$$

$$m_{max} = \frac{1}{\sin(28.96°)} = 2.07$$; m must be an integer,

$\therefore m_{max} = 2$

B5. A gold (Au) rod has one end maintained at T_h = 80.0°C and the other at T_c = 20.0°C. The length of the rod is 0.250 m and the diameter is 2.00 mm. The thermal conductivity of gold is 314 W/(m·K).



(a) Calculate the rate of energy transfer as heat along the gold rod. (3 marks)

$\boxed{0.237\ \text{W}}$

$$P = \frac{kA(T_h - T_c)}{L} = \frac{k\left(\frac{\pi d^2}{4}\right)(T_h - T_c)}{L}$$

$$P = \frac{\left(314\ \frac{\text{W}}{\text{m}\cdot\text{K}}\right)\left(\frac{\pi}{4}(2.00\times10^{-3}\ \text{m})^2\right)(80.0°\text{C} - 20.0°\text{C})}{0.250\ \text{m}} = 0.237\ \text{W}$$

(b) A silver (Ag) rod of the same length and diameter as the gold rod is placed end-to-end with the gold rod (see diagram). Calculate the temperature T_{mid} at the interface between the two rods. The thermal conductivity of silver is 427 W/(m·K). (4 marks)

$\boxed{54.6°\text{C}}$

Rate of heat transfer is the same for both materials.

$$P = \frac{k_{Ag}A(T_h - T_{mid})}{L} = \frac{k_{Au}A(T_{mid} - T_c)}{L}$$

$$k_{Ag}T_h - k_{Ag}T_{mid} = k_{Au}T_{mid} - k_{Au}T_c$$

$$k_{Ag}T_h + k_{Au}T_c = (k_{Ag} + k_{Au})T_{mid}$$

$$T_{mid} = \frac{k_{Ag}T_h + k_{Au}T_c}{k_{Ag} + k_{Au}} = \frac{(427\ \text{W}/_{\text{m}\cdot\text{K}})(80.0°\text{C}) + (314\ \text{W}/_{\text{m}\cdot\text{K}})(20.0°\text{C})}{(427\ \text{W}/_{\text{m}\cdot\text{K}} + 314\ \text{W}/_{\text{m}\cdot\text{K}})}$$

$$T_{mid} = 54.6°\text{C}$$

(c) Calculate the rate of energy transfer as heat along the two rods. If you did not obtain an answer for (b), use a value of 55.0°C (3 marks)

$\boxed{0.136\ \text{W}}$

$$P = P_{Au} = P_{Ag} = \frac{k_{Ag}A(T_h - T_{mid})}{L}$$

$$P = \frac{(427\ \text{W}/_{\text{m}\cdot\text{K}})\left(\frac{\pi}{4}(2.00\times10^{-3}\ \text{m})^2\right)(80.0°\text{C} - 54.6°\text{C})}{0.250\ \text{m}} = 0.136\ \text{W}$$

CHECK: $P_{Au} = \frac{k_{Au}A(T_{mid} - T_c)}{L} = 0.137\ \text{W}$ ✓ (round-off accounts for discrepancy)

B6. $^{239}_{94}Pu$ has an atomic mass of 239.052156 u. This isotope is radioactive and decays to $^{235}_{92}U$ with a half-life of 2.40×10^4 years. Consider a sample of 1.00 kg of pure $^{239}_{94}Pu$ at time $t = 0$.

(a) Identify the type of decay that $^{239}_{94}Pu$ undergoes. (1 mark)

$\boxed{\text{alpha}}$

$$^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{A}_{Z}X \qquad A = 239 - 235 = 4 \qquad Z = 94 - 92 = 2$$

$$^{4}_{2}X \Rightarrow {}^{4}_{2}He : \text{alpha particle}$$

(b) Calculate the number of $^{239}_{94}Pu$ nuclei present in the sample at $t = 0$. ($1\ u = 1.661 \times 10^{-27}$ kg) (3 marks)

$\boxed{2.52 \times 10^{24}}$

$$m_{tot} = \#\text{nuclei} \times \frac{\text{mass}}{\text{nucleus}} \Rightarrow N_0 = \frac{m_{tot}}{\text{mass}/\text{nucleus}} = \frac{1.00\ kg}{239.052156\,u}$$

$$N_0 = \frac{1.00\ kg}{239.052156\,u} \times \frac{1\ u}{1.661 \times 10^{-27}\ kg} = 2.52 \times 10^{24}$$

(c) Calculate the initial activity of the sample. Express your answer in Becquerels (decays/s). If you did not obtain an answer for (b), use a value of 2.25×10^{24} nuclei. (3 marks)

$\boxed{2.31 \times 10^{12}\ Bq}$

$$\lambda = \frac{\ln 2}{2.40 \times 10^4\ y} = 2.89 \times 10^{-5}/y \times \frac{1\ y}{365\ d} \times \frac{1\ d}{24\ h} \times \frac{1\ h}{3600\ s} = 9.16 \times 10^{-13}/s$$

$$R = \lambda N \Rightarrow R_0 = \lambda N_0$$

$$R_0 = (9.16 \times 10^{-13}/s)(2.52 \times 10^{24}) = 2.31 \times 10^{12}\ Bq$$

(d) Calculate the number of years required for the activity of the sample to decrease to a safe activity of 0.100 Bq. If you did not obtain an answer for (c), use a value of 2.25×10^{12} Bq. (3 marks)

$\boxed{1.07 \times 10^{6}\ y}$

$$R = \lambda N, \quad N = N_0 e^{-\lambda t} \Rightarrow R = R_0 e^{-\lambda t}$$

$$\frac{R}{R_0} = e^{-\lambda t} \Rightarrow -\lambda t = \ln\left(\frac{R}{R_0}\right) \Rightarrow t = \frac{-\ln(R/R_0)}{\lambda}$$

$$t = \frac{-\ln\left(0.100\ Bq / 2.31 \times 10^{12}\ Bq\right)}{2.89 \times 10^{-5}\ y} = 1.07 \times 10^{6}\ y$$

END OF EXAMINATION