UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
Physics for the Life Sciences

FINAL EXAMINATION

April 19, 2010 Time: 3 hours

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

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 Dr. A. Robinson
- ❑ C16 F. Dean

INSTRUCTIONS:

1. You should have a test paper, a formula sheet, and an OMR sheet. The test paper consists of 11 pages. **It is the responsibility of the student to check that the test paper is complete.**
2. Enter your name and STUDENT NUMBER on the OMR sheet.
3. The test paper, the formula sheet and the OMR sheet must all be submitted.
4. None of the test materials will be returned.
5. This is a closed book examination.
6. Only Hewlett-Packard HP 10S or 30S or Texas Instruments TI-30X series calculators may be used.

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	

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PART A

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

$\sum\tau = I\alpha \Rightarrow \alpha = \frac{\sum\tau}{I}$; $\alpha_2 = \frac{R_2F_2}{\frac{1}{2}M_2R_2^2} = \frac{F_2}{\frac{1}{2}M_2R_2} = \frac{F_1}{\frac{1}{2}(2M_1)(2R_1)} = \frac{F_1}{\frac{1}{2}(4M_1R_1)}$

D

A1. Consider two solid disks. Each disk is mounted on an axle through its centre so that it is free to rotate without friction. The masses and radii of the disks are related by $M_2 = 2M_1$ and $R_2 = 2R_1$. A force of constant magnitude F_1 is now applied tangent to the rim of disk 1 and a force of constant magnitude F_2 is applied tangent to the rim of disk 2. $F_2 = F_1$. How do the torques, τ_1 and τ_2, exerted on each disk and their angular accelerations, α_1 and α_2, compare? $\alpha_2 = \frac{1}{4}\alpha_1$

(A) $\tau_2 = \tau_1$; $\alpha_2 = \alpha_1$
(B) $\tau_2 = \tau_1$; $\alpha_2 = \frac{1}{2}\alpha_1$
(C) $\tau_2 = 2\tau_1$; $\alpha_2 = \frac{1}{2}\alpha_1$
(D) $\tau_2 = 2\tau_1$; $\alpha_2 = \frac{1}{4}\alpha_1$
(E) $\tau_2 = \frac{1}{2}\tau_1$; $\alpha_2 = \frac{1}{4}\alpha_1$

$\tau = rF_\perp$; $\tau_1 = R_1F_1$; $\tau_2 = R_2F_2 = 2R_1F_1 = 2\tau_1$.

E

A2. As part of a tumbling routine, a gymnast wants to increase her rotation rate while she is in the air. To do this, she pulls her arms and legs as closely as possible to her body. Her rotation rate increases because…

(A) her angular momentum increases.
(B) her angular momentum decreases.
(C) the gravitational torque on her increases.
(D) her rotational inertia increases.
(E) her rotational inertia decreases.

$L = I\omega$ is conserved $\omega\uparrow$ when $I\downarrow$

A

A3. Consider two solid cubes. The volume of cube 2 is twice that of cube 1. The cubes are floating in water and exactly the same volume of each cube is submerged. Which one of the following statements is **TRUE**?

(A) The cubes have equal masses.
(B) The cubes have equal densities.
(C) The mass of cube 2 is greater than the mass of cube 1.
(D) The mass of cube 2 is less than the mass of cube 1.
(E) The density of cube 2 is greater than the density of cube 1.

Floating, $F_B = m_{obj}g$; $\rho_f g V_f = m_{obj}g$; $V_{f_2} = V_{f_1} \Rightarrow m_{obj_2} = m_{obj_1}$

D

A4. You are trying to remove a wheel nut to change a flat tire. You apply a perpendicular force of magnitude F a distance of r from the centre of the nut but it doesn't rotate. You then obtain a longer wrench and apply a perpendicular force of magnitude $2F$ at a distance of $3r$ from the nut. By what factor has the torque that you are applying to the wheel nut increased?

(A) $\frac{2}{3}$ (B) 3 (C) 5 (D) 6 (E) 9

$\tau = rF_\perp$; $\tau' = (3r)(2F_\perp)$; $\tau' = 6rF_1$

A

A5. A constant power source is ~~emitted~~ emitting sound uniformly in all directions. The intensity at a distance of r_o from the source is I_o. What is the intensity at a distance of $3r_o$ from the source?

(A) $\frac{1}{9}I_o$ (B) $\frac{1}{6}I_o$ (C) $\frac{1}{3}I_o$ (D) $3I_o$ (E) $9I_o$

$I = \frac{P}{A} = \frac{P}{4\pi r^2}$; $I \propto \frac{1}{r^2}$, $I' = \frac{1}{3^2}I_o$

D

A6. Which one of the following statements about stress and strain is **FALSE**?

(A) Stress is a force applied per unit area.
(B) Strain is caused as a result of stress.
(C) If a material obeys Hooke's Law, then the strain is proportional to the stress.
(D) The force causing a stress is always perpendicular to the area over which it is applied.
(E) Strain is a dimensionless quantity.

for shear stress F // A.

B

A7. Which one of the following statements concerning waves on a string is **FALSE**?

(A) In a transverse wave, the oscillation direction is perpendicular to the propagation direction. T
(B) The speed of the oscillators in the wave is constant. F $v = -A\omega\sin(\omega t)$
(C) The speed of the wave depends on the tension in the string. T
(D) The speed of the wave depends on the mass per unit length of the string. T
(E) If the wave is reflected at a fixed end of the string, then the displacements of the incoming and outgoing waves are added together. T

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A8. Which one of the following statements regarding a harmonic, constant frequency, sound wave in air is **FALSE**?

C

(A) The wave transfers energy from place to place. T
(B) The air molecules vibrate with simple harmonic motion. T
(C) The vibration speed of the air molecules must be the same as the speed of the sound wave. F
(D) There is no net movement of air. T
(E) The speed of sound depends on the temperature of the air. T

A9. Consider a solid material that has a positive coefficient of thermal expansion. A hole is cut in a sheet of this material. If the sheet is now heated, what happens to the size of the hole?

A

(A)→(E)
(F) The area of the hole increases linearly with the increase in temperature.
(G) The area of the hole decreases linearly with the increase in temperature.
(H) The area of the hole does not change.
(I) The area of the hole increases exponentially with the increase in temperature.
(J) The area of the hole decreases exponentially with the increase in temperature.

$\frac{\Delta A}{A_0} = 2\alpha\Delta T$

$A - A_0 = 2A_0\alpha\Delta T$

$A = A_0 + 2A_0\alpha\Delta T$

A10. A copper rod and an iron rod, each of the same length, L, and cross-sectional area, A, are joined to form a new rod of length $2L$. The copper end of the new rod is immersed in boiling water and the iron end of the new rod is immersed in an ice bath. The temperature at the copper/iron junction is greater than 50 °C. The thermal conductivity of copper, relative to the thermal conductivity of iron, is…

A

(A) greater than that of iron.
(B) less than that of iron.
(C) equal to that of iron.
(D) indeterminable relative to that of iron without knowing the value of L.
(E) indeterminable relative to that of iron without knowing the value of A.

$P_{Cu} = P_{Fe}$

$K_{Cu} A \frac{\Delta T_{Cu}}{d} = K_{Fe} A \frac{\Delta T_{Fe}}{d}$

$K_{Cu}\Delta T_{Cu} = K_{Fe}\Delta T_{Fe}$

since $\Delta T_{Cu} < \Delta T_{Fe}$, $K_{Cu} > K_{Fe}$

A11. Which one of the following statements concerning ideal gases is **FALSE**?

D

(A) The average translational kinetic energy of the ideal gas is directly proportional to the absolute temperature. T
(B) The interatomic or intermolecular forces in the ideal gas are negligible. T
(C) The root mean square speed of the atoms/molecules is proportional to the square root of the absolute temperature. T
(D) If the number of atoms/molecules and the temperature remain constant, then the pressure is directly proportional to the volume occupied. F $PV = NkT \Rightarrow P_1V_1 = P_2V_2 \Rightarrow P \propto \frac{1}{V}$
(E) If the number of atoms/molecules and the volume occupied remain constant, then the pressure is directly proportional to the temperature. T

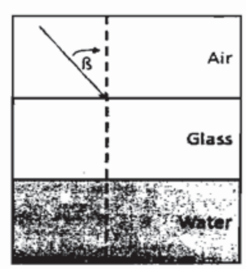
A12. A spherical balloon of radius r_1, at constant pressure, is cooled from temperature T_1 to temperature T_2. Which expression is correct for the new radius of the balloon? $PV = NkT$, $V \propto T$

E

(A) $r_2 = \left(\frac{T_2}{T_1}\right) r_1$ (B) $r_2 = \left(\frac{T_2}{T_1}\right)^2 r_1$ (C) $r_2 = \left(\sqrt{\frac{T_1}{T_2}}\right) r_1$ (D) $r_2 = \left(\frac{T_1}{T_2^3}\right) r_1$ (E) $r_2 = \left(\sqrt[3]{\frac{T_2}{T_1}}\right) r_1$

$r^3 \propto V$, $r^3 \propto T$, $r \propto \sqrt[3]{T}$

A13. Light travelling through the air (refractive index = 1.00) is incident at angle ß with respect to the surface normal on glass with a refractive index of n_g. From the glass, it passes through a layer of water, refractive index n_w. What is the angle of refraction of the light with respect to the surface normal as it passes from the glass to the water?



B

(A) $\sin^{-1}\left(\frac{\sin\beta}{n_{air} n_{water}}\right)$ (B) $\sin^{-1}\left(\frac{\sin\beta}{n_{water}}\right)$ (C) $\sin^{-1}\left(\frac{n_{air}\sin\beta}{n_{glass} n_{water}}\right)$

(D) $\sin^{-1}\left(\frac{n_{glass}\sin\beta}{n_{water}}\right)$ (E) $\sin^{-1}\left(\frac{\sin\beta}{n_{air}}\right)$

$n_a \sin\beta = n_g \sin\theta_g$

$n_g \sin\theta_g = n_w \sin\theta_w$

$n_a \sin\beta = n_w \sin\theta_w$

$\theta_w = \sin^{-1}\left(\frac{\sin\beta}{n_w}\right)$

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B

A14. Which one of these regions of the electromagnetic spectrum has the highest frequency range?

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

E

A15. Which one of the following statements concerning electromagnetic radiation is **FALSE**?

(A) The magnetic field vector is perpendicular to the propagation direction. T
(B) The electric field vector is perpendicular to the propagation direction. T
(C) The electric field, the magnetic field and the propagation direction vectors are mutually perpendicular. T
(D) The speed of light in a material is less than the speed of light in a vacuum. T
(E) The electric and magnetic field~~s are out of phase with respect to each other~~. F vectors are parallel to the propagation direction.

B

A16. Consider the image formed by a single diverging lens. Which one of the following statements is **TRUE**?

(A) The image is upright, enlarged and virtual for $p < f$.
(B) The image is upright, reduced, and virtual for all values of p.
(C) The image is inverted, enlarged, and real for $2f > p > f$.
(D) The image is inverted, reduced, and real for $p > 2f$.
(E) The image is upright, enlarged, and real for $p > f$.

A

A17. 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) 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.

q is fixed (lens-retina distance)

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \Rightarrow \frac{1}{f} - \frac{1}{p}$ constant, so as $p\downarrow$, $f\downarrow$ as well.

A

A18. Consider a double-slit experiment. Light rays from the two slits that reach the second order maximum on one side of the central maximum travel distances that differ by

(A) 2λ (B) λ (C) 0 (D) $\frac{1}{2}\lambda$ (E) $\frac{1}{4}\lambda$

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$

D

A19. Electrons with a de Broglie wavelength of λ_0 are now accelerated so that their kinetic energy becomes four times as large. The new de Broglie wavelength of the electrons is

$\lambda' = \frac{1}{2}\lambda$

(A) $4\lambda_0$ (B) $2\lambda_0$ (C) λ_0 (D) $\frac{1}{2}\lambda_0$ (E) $\frac{1}{4}\lambda_0$

E

A20. Establishing a population inversion is critical to producing the laser effect. The term "population inversion" refers to:

(A) an energy level that has less energy than the ground state.
(B) a situation where there are fewer atoms than usual in higher-energy states.
(C) a situation where most of the atoms are completely ionized.
(D) a situation where all of the atoms are in the ground state.
(E) a situation where there are more atoms in a higher-energy state than in a lower-energy state.

B

A21. A laser has a power output of P and emits pulses that have a duration time of t. The wavelength of the laser light is λ. Which one of the following is the correct expression for the number of photons in each pulse?

(A) $\frac{hc}{Pt\lambda}$ (B) $\frac{Pt\lambda}{hc}$ (C) $\frac{hcP}{t\lambda}$ (D) $\frac{hct}{P\lambda}$ (E) $hcPt\lambda$

$E_{pulse} = Pt = \frac{Nhc}{\lambda}$

$N = \frac{Pt\lambda}{hc}$

D

A22. Isotopes of the same element have:

(A) the same number of neutrons but different numbers of protons.
(B) the same number of electrons but different numbers of protons.
(C) the same number of neutrons but different numbers of electrons.
(D) the same number of protons but different numbers of neutrons.
(E) the same number of protons but different numbers of electrons.

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$A \to A-4$; $Z \to Z-2$

A23. Radium-226 ($^{226}_{88}$Ra) undergoes alpha decay to form Radon (Rn). What are the atomic number and mass number of the isotope of radon produced?

B

(A) $Z = 90, A = 220$
(B) $Z = 86, A = 222$
(C) $Z = 89, A = 226$
(D) $Z = 87, A = 226$
(E) $Z = 88, A = 222$

A24. Which one of the following statements regarding radioactive decay is **FALSE**?

D

(A) A helium nucleus is emitted when a nuclide decays by alpha emission. T
(B) A photon is emitted when a nuclide decays by gamma emission. T
(C) The proton number and mass number do not change in gamma decay. T
(D) In beta-plus decay, a neutron is converted into a proton in the nucleus. F $p \to n + \beta^+ + \nu$
(E) In beta-minus decay, an electron and an anti-neutrino are emitted. T

A25. Which one of the following statements regarding the atomic nucleus is **FALSE**?

D

(A) The nucleus is approximately spherical. T
(B) The nuclear radius is much less than the atomic radius. T
(C) The nuclear radius is proportional to the cube root of the mass number. T
(D) The mass density of the nucleus is the same as the mass density of the atom. F
(E) The total energy of the nucleus is less than the energy of the individual protons and neutrons. T

PART B

ANSWER FIVE 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 (UNLESS OTHERWISE NOTED) 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.

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B1. A hypodermic syringe is attached to a needle that has an internal radius of 0.30000 mm and a length of 3.0000 cm. The needle and syringe are filled with a solution of viscosity 2.0000×10^{-3} Pa·s and density 1.1000×10^{3} kg/m^3. The solution is to be injected into a vein where the pressure is 1.0343×10^{5} Pa.

(a) Calculate the pressure of the fluid in the syringe that is required in order to inject solution into the vein at a rate of 2.5000×10^{-7} m^3/s. _Express your answer to 5 significant figures._ (*5 marks*)

1.0815×10^5 Pa

Viscous flow ⇒ Poiseuille's Law: $\frac{\Delta V}{\Delta t} = \frac{\pi}{8} \frac{\Delta P / L}{\eta} \cdot r^4$

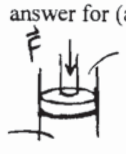
$$\Delta P = P_{syringe} - P_{vein} = \left(\frac{\Delta V}{\Delta t}\right) \cdot \frac{8 \eta L}{\pi r^4}$$

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

$$P_{syringe} = 1.0343 \times 10^5 \text{ Pa} + \frac{(2.5000 \times 10^{-7} \text{ m}^3/\text{s})(8)(2.0000 \times 10^{-3} \text{ Pa·s})(3.0000 \times 10^{-2} \text{ m})}{\pi (0.30000 \times 10^{-3} \text{ m})^4}$$

$$P_{syringe} = 1.0815 \times 10^5 \text{ Pa}$$

(b) If the cross-sectional area of the syringe is 1.0000 cm^2, calculate the force that the plunger must apply to obtain the desired pressure of the fluid in the syringe. If you did not obtain an answer for (a), use a value of 1.0800×10^5 Pa. (*2 marks*)



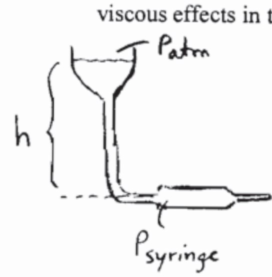
0.685 N

without pushing on the plunger, the fluid in the syringe is at atmospheric pressure

$$\frac{F}{A} + P_{atm} = P_{syringe}$$

$$F = (P_{syringe} - P_{atm})A = (1.0815 \times 10^5 \text{ Pa} - 1.013 \times 10^5 \text{ Pa})(1.0000 \text{ cm}^2)\left(\frac{1 \text{ m}}{100 \text{ cm}}\right)^2$$

(c) Now suppose that the fluid is to be delivered by a tube connected to an elevated bottle rather than by a hypodermic syringe. Calculate the required height of the fluid in the bottle relative to the fluid in the needle in order to obtain the pressure calculated in (a). You may assume that the surface of the fluid in the bottle is at atmospheric pressure and you may ignore any viscous effects in the tube. (*3 marks*)



0.635 m

$$P_{syringe} = P_{atm} + \rho g h$$

$$h = \frac{P_{syringe} - P_{atm}}{\rho g}$$

$$h = \frac{1.0815 \times 10^5 \text{ Pa} - 1.013 \times 10^5 \text{ Pa}}{(1.1000 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)} = 0.635 \text{ m}$$

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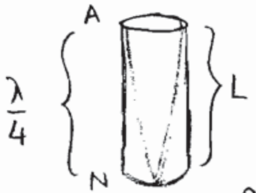
B2. The human ear can be modelled as a tube of length 2.50 cm that is closed at one end and has a cross-sectional area of 0.600×10^{-4} m^2.

(a) Calculate the frequencies of the standing waves which could exist in the ear and would be within the range of human hearing. Assume the speed of sound is 343 m/s. (*3 marks*)



At fundamental, $L = \frac{\lambda}{4}$

$$f = \frac{v}{\lambda} \Rightarrow f_1 = \frac{v}{4L}$$

$$f_1 = \frac{343\,m/s}{4(0.0250m)} = 3.43 \times 10^3\,Hz$$

3.43 kHz, 10.3 kHz, 17.2 kHz

closed tube only resonates at the odd harmonics

$$f_3 = 3f_1 = 10.3 \times 10^3\,Hz$$

$$f_5 = 5f_1 = 17.2 \times 10^3\,Hz$$

$$f_7 = 7f_1 = 24.0 \times 10^3\,Hz > 20.0 \times 10^3\,Hz$$ so outside of freq'y range of human hearing

(b) A person hears a faint noise of sound intensity level of 20.0 dB. If the source is 4.00 m from the ear, calculate the power of the source (assuming it to be spherically symmetric). (*4 marks*)

$\beta = 10\,dB \log(I/I_0)$ and $P = IA$

2.01×10^{-8} W

$$\frac{\beta}{10dB} = \log(I/I_0)$$

$$10^{\beta/10dB} = I/I_0 \Rightarrow I = I_0 \cdot 10^{\beta/10dB} = (1.00 \times 10^{-12}\,W/m^2)(10^{20.0dB/10dB})$$

$$I = 1.00 \times 10^{-10}\,W/m^2$$

$$P = IA = I \cdot 4\pi r^2$$

$$P = (1.00 \times 10^{-10}\,W/m^2)(4\pi)(4.00m)^2$$

$$P = 2.01 \times 10^{-8}\,W$$

(c) For the situation described in (b), calculate the sound energy entering the ear in a time of 1.00 minute. (If you did not obtain an answer for (b), use 2.00×10^{-8} W.) (*3 marks*)

$$P = \frac{E}{t} \Rightarrow E_{ear} = P_{ear}t = IA_{ear}t$$

3.60×10^{-13} J

$$E_{ear} = IA_{ear}t$$

$$E_{ear} = (1.00 \times 10^{-10}\,W/m^2)(0.600 \times 10^{-4}\,m^2)(1.00\,min)\left(\frac{60\,s}{min}\right)$$

$$E_{ear} = 3.60 \times 10^{-13}\,J$$

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B3. A male husky dog has ~~an~~ a ~~internal~~ skin temperature of ~~38.0~~ 32.0 °C, and a surface area of 1.31 m^2. The emissivity of the dog is assumed to be 0.970. The air temperature is –5.00 °C.

(a) Using the above information, calculate the power lost by the husky as a result of thermal radiation. (*3 marks*)

$$P_{rad} = e\sigma A T_{obj}^4$$

625 W

$$P_{rad} = (0.970)(5.670\times10^{-8}\ \tfrac{W}{m^2\cdot K^4})(1.31\ m^2)((32.0+273.15)K)^4$$

$$P_{rad} = 625\ W$$

(b) Calculate the power absorbed by the husky as a result of thermal radiation from the outside environment. (*3 marks*)

$$P_{abs} = e\sigma A T_{surr}^4$$

373 W

$$P_{abs} = (0.970)(5.670\times10^{-8}\ \tfrac{W}{m^2\cdot K^4})(1.31\ m^2)(268.15\ K)^4$$

$$P_{abs} = 373\ W$$

(c) Now consider the effect of the husky's fur. Assume that the thickness of the fur is 5.00 cm over the entire body and that its thermal conductivity is 0.0260 W/(m·K). Calculate the rate of heat loss of the husky due to thermal conduction. (*4 marks*)

$$P = kA\frac{\Delta T}{d}$$

25.2 W

$$P = (0.0260\ \tfrac{W}{m\cdot K})(1.31\ m^2)\frac{(32.0^\circ C - (-5.00^\circ C))}{0.0500\ m}$$

$$P = 25.2\ W$$

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B4. The distance from the lens to the retina in John's eyes is 2.00 cm.

(a) Assume that John can form focused images at distances between 28.0 cm and infinity. Calculate the upper and lower limits of the focal lengths of John's eyes. (*4 marks*)

q = lens-retina distance = 2.00 cm

2.00 cm to 1.87 cm

$p_1 = 28.0\,\text{cm}$

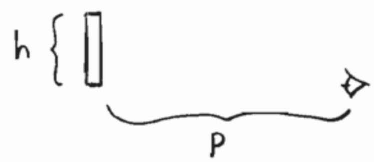
$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \Rightarrow f_1 = \left(\frac{1}{p_1} + \frac{1}{q}\right)^{-1} = \left(\frac{1}{28.0\,\text{cm}} + \frac{1}{2.00\,\text{cm}}\right)^{-1}$$

$$f_1 = 1.87\,\text{cm}$$

$$f_2 = \left(\frac{1}{p_2} + \frac{1}{q_2}\right)^{-1} = \left(\frac{1}{\infty} + \frac{1}{q}\right)^{-1} = q = 2.00\,\text{cm}$$

(b) John looks at an object 2.00 m tall that is a distance of 23.5 metres away. Calculate the size of the image on his retina. (*3 marks*)

0.170 cm



$p = 23.5\,\text{m} = 2350\,\text{cm}$

$q = 2.00\,\text{cm}$

$$m = \frac{h'}{h} = -\frac{q}{p} \Rightarrow h' = -\frac{qh}{p} = -\frac{(2.00\,\text{cm})(200\,\text{cm})}{2350\,\text{cm}}$$

$h' = -0.170\,\text{cm}$ ← inverted

(c) Thirty years later, John can no longer focus on objects closer than 75.4 cm. Calculate the refractive power of the contact lenses that will restore John's range of vision to 28.0 cm to infinity. (*3 marks*) (in diopters)

+2.25 D

Want the contact lens to form an image at 75.4 cm for an object at 28.0 cm.

Since this is a virtual image, $q_{lens} = -75.4\,\text{cm}$

$$\frac{1}{f_{lens}} = \frac{1}{p_{lens}} + \frac{1}{q_{lens}} = \frac{1}{0.280\,\text{m}} + \frac{1}{-0.754\,\text{m}}$$

$$\frac{1}{f_{lens}} = 2.25\,\text{m}^{-1} = +2.25\,\text{D}$$

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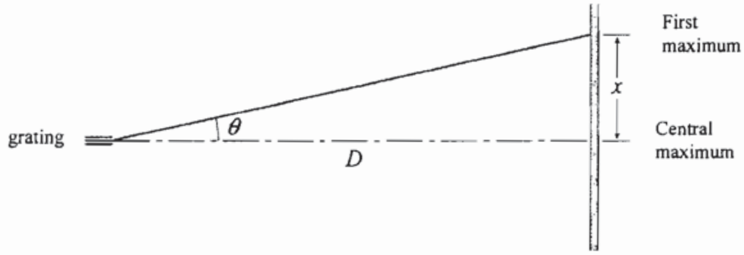
B5. The wavelength of the laser used in a CD player is 581 nm. Suppose that a diffraction grating produces a first-order tracking beam that is a distance $x = 0.625$ mm from the central bright fringe at a distance of $D = 3.00$ mm from the grating as shown in the diagram below.



(a) Calculate the angle θ shown in the diagram, i.e. calculate the angular location of the first-order bright fringe. (*3 marks*)

$$\tan\theta = \frac{x}{D}$$

11.8°

$$\theta = \tan^{-1}\left(\frac{x}{D}\right) = \tan^{-1}\left(\frac{0.625\text{ mm}}{3.00\text{ mm}}\right) = 11.8°$$

(b) Calculate the slit separation of the grating. (*4 marks*)

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

2.85×10^{-6} m

$$d = \frac{m\lambda}{\sin\theta} = \frac{(1)(581\times10^{-9}\text{ m})}{\sin(11.8°)} = 2.85\times10^{-6}\text{ m}$$

(c) Calculate the number of lines per mm of the diffraction grating. (*3 marks*)

351/mm

$$N = \frac{1}{d} = \frac{1}{2.85\times10^{-6}\text{ m}} \times \frac{1\text{ m}}{1000\text{ mm}}$$

$$N = 351/\text{mm}$$

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B6. A 1.00 gram sample of body tissue taken from the remains of an iron-age warrior found at Lindow Marsh near Manchester, England was measured to have a ^{14}C activity of 0.168 Bq. An independent measurement made by mass spectrometry reveals that the sample contains 4.39×10^{10} atoms of ^{14}C and 4.64×10^{22} atoms of ^{12}C. The ratio of ^{14}C to ^{12}C atoms in living tissue is 1.30×10^{-12}. The half-life of ^{14}C is 5730 years.

(a) Calculate the number of atoms of ^{14}C the sample would have contained, if it had been of living tissue. (~~X~~ 2 *marks*)

$$r = \frac{n_{14}}{n_{12}} = 1.30 \times 10^{-12}$$

6.03×10^{10}

$$n_{14} = (1.30 \times 10^{-12})(4.64 \times 10^{22}) = 6.03 \times 10^{10}$$

(b) Calculate the decay constant (in year^{-1}) for the radioactive decay of ^{14}C. (~~X~~ 3 *marks*)

$$T_{1/2} = 0.693\tau = \frac{0.693}{\lambda}$$

$1.21 \times 10^{-4}\,y^{-1}$

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{5730y} = 1.21 \times 10^{-4}\,y^{-1}$$

(c) Calculate the age (in years) of the remains of the warrior. (*5 marks*)

$$N(t) = N_0 e^{-t/\tau} \quad ; \quad T_{1/2} = 0.693\tau$$

$2.62 \times 10^3 y$

$$\tau = \frac{T_{1/2}}{0.693} \quad \text{so} \quad N(t) = N_0 e^{-0.693t/T_{1/2}} \quad \text{and } N_0 = n_{14} \text{ from (a)}$$

$$\frac{N(t)}{N_0} = e^{-0.693t/T_{1/2}}$$

$$\ln\left(\frac{N(t)}{N_0}\right) = -\frac{0.693t}{T_{1/2}} \Rightarrow t = -\frac{\ln\left(N(t)/N_0\right) \cdot T_{1/2}}{0.693}$$

$$t = -\frac{\ln\left(\frac{4.39 \times 10^{10}}{6.03 \times 10^{10}}\right) 5730y}{0.693} = 2.62 \times 10^3 y$$

END OF EXAMINATION