UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
Physics for the Life Sciences

FINAL EXAMINATION

April 22, 2014 Time: 3 hours

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

LECTURE SECTION (please check):

- ❑ 01 Mr. B. Zulkoskey
- ❑ 02 Dr. J.-P. St. Maurice
- ❑ C16 Mr. 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 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	

continued on page 2...

Student No.: ______________________

PART A

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

A

A1. Consider two steel wires, each of length L. The radius of wire A is r and the radius of wire B is $2r$. Equal weights are hung from each wire. If wire A stretches by an amount ΔL, then the amount that wire B stretches is…

(A) ¼ ΔL (B) ½ ΔL (C) ΔL (D) $2\Delta L$ (E) $4\Delta L$

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

$\Delta L = \frac{FL_o}{AY}$

$\Delta L = \frac{FL_o}{\pi r^2 Y}$

E

A2. Suppose you are near the bottom of a deep swimming pool. Which one of the following statements is correct concerning the pressure on the palm of your hand?

(A) The pressure on your palm is independent of the depth below the surface and the orientation of your hand.
(B) The pressure on your palm is greatest when your palm is facing downward.
(C) The pressure on your palm is greatest when your palm is facing sideways.
(D) The pressure on your palm is greatest when your palm is facing upward.
(E) The pressure on your palm depends only on depth below the surface, not on how your palm is oriented.

$P_2 = P_1 + \rho g(y_1 - y_2)$

E

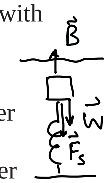
A3. Consider a horizontal pipe carrying an ideal fluid (an incompressible, non-viscous fluid). What will be the effect on the fluid flow in a section of pipe where the radius is half the radius of the rest of the pipe?

$A_1 v_1 = A_2 v_2 \Rightarrow v_2 = A_1 v_1 / A_2 = \pi r^2 v_1 / \pi (r/2)^2 = 4v_1$

(A) The flow speed in the narrower section will be one-quarter of the flow speed in the rest of the pipe.
(B) The flow speed in the narrower section will be one-half of the flow speed in the rest of the pipe.
(C) The flow speed will be the same in all sections of the pipe.
(D) The flow speed in the narrower section will be twice the flow speed in the rest of the pipe.
(E) The flow speed in the narrower section will be four-times the flow speed in the rest of the pipe.

C

A4. A light spring of negligible mass and volume has a force constant k. The spring rests vertically and is attached to the bottom of a large tub. A piece of wood of mass m_w, area A, and height H is attached to the top of the spring. The density of the wood is less than the density of water. At first the tub is empty and the spring is compressed by some value ΔL_1. The tub is then filled with water to the point that the water completely covers the spring and its attached piece of wood. Which one of the following statements is **TRUE**?



(A) The spring becomes more compressed in proportion *only* to the height filled by the water above the piece of wood.
(B) The spring becomes more compressed in proportion to both the height filled by the water above the piece of wood and the area A of the piece of wood.
(C) The spring goes from being compressed to being extended with the extension being proportional to the mass of the piece of wood.
(D) The compression of the spring does not change.
(E) The spring compression will increase if there is a lot of water, but will be extended instead of compressed if, in the final state, there is just enough water to cover the piece of wood and not more.

$\rho_{H_2O} g \frac{m_w}{\rho_w} - m_w g = k\Delta L_2$

E

A5. A mass m, hanging from a spring with force constant k, is set into an up-and-down simple harmonic motion. If the mass is initially displaced from equilibrium by an amount x_0 and released from rest, which one of the following statements concerning the speed of the mass when moving through the equilibrium point is **TRUE**? The speed is…

(A) 0. (B) proportional to x_0^2 only.
(C) proportional to $x_0 k/m$. (D) proportional to $x_0^2 k/m$.
(E) proportional to $\sqrt{k/m}$.

Energy is conserved:

$\frac{1}{2}kx_0^2 = \frac{1}{2}mv^2$

$v = x_0\sqrt{\frac{k}{m}}$

continued on page 3...

A6. The fundamental frequency of a resonating pipe is 150 Hz, and the next higher resonant frequencies are 450 Hz and 750 Hz. From this information what can you conclude?

A

(A) The pipe is open at one end and closed at the other.
(B) The pipe could be open at each end or closed at each end.
(C) The pipe must be open at each end.
(D) The pipe must be closed at each end.
(E) The pipe is open at both ends for the lowest frequency only.

$f' = 3f_1 \Rightarrow$ closed at one end, open at other end

A7. Consider a mass-spring system that moves in simple harmonic motion in the absence of friction. Which one of the following statements is **FALSE**?

D

(A) The total energy of the system remains constant. T
(B) The energy of the system is continually transformed between kinetic and potential energy. T
(C) The total energy of the system is proportional to the square of the amplitude of the motion. T
(D) The potential energy stored in the system is greatest when the mass passes through the equilibrium position. F
(E) The velocity of the mass has its maximum value when the mass passes through the equilibrium position. T

A8. A point source broadcasts sound into a uniform medium. If the distance from the source is tripled, how does the intensity change?

A

(A) It becomes one-ninth as large.
(B) It becomes one-third as large.
(C) It is unchanged.
(D) It becomes three times as large.
(E) It becomes nine times as large.

$I = P/A = P/4\pi r^2 \Rightarrow I \propto \frac{1}{r^2}$

A9. You are driving on the highway and coming toward you is an ambulance. Both you and the ambulance are moving at the same speed, but in opposite directions. The ambulance siren is producing sound of frequency *f*. Which one of the following statements is **TRUE** regarding the frequency of sound heard from the siren?

$f_o = \left(\frac{v + v_o}{v - v_s}\right) f_s$

B

(A) Both you and the ambulance driver hear a frequency of *f*.
(B) You hear a frequency higher than *f*, the ambulance driver hears a frequency of *f*.
(C) You hear a frequency lower than *f*, the ambulance driver hears a frequency of *f*.
(D) You hear a frequency higher than *f*, the ambulance driver hears a frequency lower than *f*.
(E) Both you and the ambulance driver hear a frequency higher than *f*.

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 $n_2 > n_1$.
(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 is less than the critical angle.
(E) The angle of incidence equals the angle of refraction.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_1 \sin\theta_c = n_2 \sin 90^\circ$

$\sin\theta_c = \frac{n_2}{n_1} \Rightarrow \frac{n_2}{n_1} < 1$

$\Rightarrow n_2 < n_1$

A11. A light source is placed at the focal point of a converging lens and after passing through the lens the rays of light are parallel to the principal axis. The light source is then moved closer to the lens. Which one of the following statements concerning the light rays emerging from the lens is **TRUE**?

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ and $p < f$ $\quad q = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1}$

A

(A) The light rays diverge.
(B) The light rays converge.
(C) The light rays still emerge parallel to the principal axis.
(D) The light rays emerge parallel to each other but not parallel to the principal axis.
(E) No light rays emerge from the lens.

$p < f \Rightarrow q < 0 \Rightarrow$ virtual image

$\Rightarrow$ diverging rays

A12. Which one of the following statements concerning electromagnetic (EM) waves is **FALSE**?

E

(A) The electric and magnetic fields in EM waves are always perpendicular to each other. T
(B) Higher frequency waves have more energy than lower frequency waves. T
(C) EM waves move slower in high-index-of-refraction media. T
(D) The index of refraction of a medium varies with the wavelength of the incident EM wave. T
(E) The frequency of EM waves decreases in regions with higher index of refraction. F

continued on page 4...

A13. A lens is made of plastic with an index of refraction equal to *n*. As illustrated in the accompanying diagram, the lens is convex with a radius of curvature *R* on one side and flat on the other side. Which one of the following statements is **FALSE**?

A

(B) is also false

(A) The lens is convergent if light enters from one side but divergent if it enters from the other side. F
(B) If *n* is 1.5, the focal distance in water is smaller than if the lens is in air. T $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
(C) The lens is convergent when used in air. T
(D) If *n* is less than 1.2, and the lens is immersed in water then the lens becomes divergent if it was convergent with *n* = 1.5, but convergent if it was divergent with *n* = 1.5. T
(E) The focal distance increases if *R* increases. T

A14. In a double-slit experiment, the light rays from the two slits that reach the second maximum on one side of the central maximum have traveled distances that differ by $m=1 \Rightarrow r_2 - r_1 = \lambda$

C

(A) ½ λ (B) λ (C) 2 λ (D) 3 λ (E) 4 λ

$m=2 \Rightarrow r_2 - r_1 = 2\lambda$

A15. A compound microscope is made with two lenses: an objective lens that is closer to the object and an eyepiece lens. Which one of the following statements concerning the operation of the compound microscope is **TRUE**?

C

(A) Both lenses form real images. F
(B) Both lenses form virtual images. F
(C) The objective lens forms a real image and the eyepiece lens forms a virtual image. T
(D) The objective lens forms a virtual image and the eyepiece lens forms a real image. F
(E) The objective lens must be a diverging lens. F

A16. A nearsighted (myopic) person wears corrective lenses. Where should one of the focal points of the corrective lenses be located? want $q = -F$ when $p = \infty$

E

(A) at infinity (B) at the cornea (C) at the retina (D) at the near point (E) at the far point

A17. When a hole is drilled in a metal plate, the drill bit and plate become hot due to friction between the drill bit and the plate. What happens to the diameter of the hole after the plate cools to room temperature?

A

(A) It decreases. $\Delta L = \alpha L_0 \Delta T$
(B) It increases.
(C) It remains the same.
(D) The answer depends on whether the initial temperature of the metal plate is above 0°C.
(E) The answer depends on the size of the hole.

A18. A thermally-isolated system consists of an initially-hot piece of aluminum and an initially-cold piece of copper; the aluminum and copper pieces are in thermal contact. The aluminum and copper pieces are the same mass. The specific heat of aluminum is more than double the specific heat of copper. Which one of the following statements is **TRUE** after the pieces reach thermal equilibrium? $Q = mc\Delta T$

B

(A) The temperature change of the aluminum is greater than the temperature change of the copper. F
(B) The temperature change of the aluminum is less than the temperature change of the copper. T
(C) Each piece undergoes the same change of temperature. F
(D) The temperature of the aluminum does not change; the copper piece reaches the same temperature as the aluminum. F
(E) The temperature of the copper does not change; the aluminum piece reaches the same temperature as the copper. F

A19. A window conducts energy from the inside of a house to the cold outdoors at a rate of *P*. What is the rate of energy conduction through a window that has half the area and is half as thick?

C

(A) ¼ *P* (B) ½ *P* (C) *P* (D) 2*P* (E) 4*P*

$P = kA\frac{\Delta T}{L}$ $A_2 = \frac{1}{2}A_1$; $L_2 = \frac{1}{2}L_1 \Rightarrow P_2 = P_1$

continued on page 5…

A20. In a photoelectric effect experiment, light of a single wavelength is incident on a metal surface and electrons are ejected. If the intensity of the incident light is increased, which one of the following statements is **TRUE**?

C

I ↑ so # of photons/s ↑ so # electrons ejected/s ↑

(A) The stopping potential increases.
(B) The stopping potential decreases.
(C) The rate of ejection of electrons increases.
(D) The rate of ejection of electrons decreases.
(E) The work function of the metal decreases.

A21. A sample of a radioactive isotope initially contains N_0 nuclei. This isotope becomes stable after one alpha decay. If the half-life of the radioactive isotope is two days, how many radioactive nuclei remain after four days?

A

4 days $= 2T_{1/2} \Rightarrow N = N_0\left(\frac{1}{2}\right)^2 = \frac{1}{4}N_0$

(A) $\frac{1}{4}N_0$ (B) $\frac{1}{3}N_0$ (C) $\frac{1}{2}N_0$ (D) $\frac{2}{3}N_0$ (E) $\frac{3}{4}N_0$

A22. Which one of the following statements regarding radioactive decay is **TRUE**?

D

(A) In beta-minus decay, a positron and a neutrino are emitted. F
(B) In gamma decay, a different isotope is formed. F
(C) In alpha decay, the daughter nucleus has more protons than the parent nucleus. F
(D) The decay rate (or activity, R) is proportional to the number of nuclei. T
(E) The decay rate (or activity, R) is constant with time. F

$R = \lambda N$

A23. According to the Bohr model, the radius of the lowest electron orbit is a_0. Which one of the following is the correct expression for the radius of the next allowed electron orbit?

B

$r_n = \frac{n^2}{Z} a_0$

(A) $2a_0$ (B) $4a_0$ (C) $6a_0$ (D) $8a_0$ (E) $9a_0$

A24. A massive nucleus of mass number greater than $A = 200$ undergoes alpha decay while at rest. Which one of the following statements is **TRUE** for the state of the system immediately after the alpha decay?

B

(A) The kinetic energy of the daughter nucleus is greater than the kinetic energy of the alpha particle.
(B) The kinetic energy of the daughter nucleus is less than the kinetic energy of the alpha particle.
(C) The kinetic energies of the alpha particle and of the daughter nucleus are equal.
(D) The alpha particle has all the momentum.
(E) The daughter nucleus has all the momentum.

$p_D = p_\alpha \Rightarrow \sqrt{2M_D KE_D} = \sqrt{2m_\alpha KE_\alpha}$
$\therefore KE_D = KE_\alpha (m_\alpha / M_D) << KE_\alpha$

A25. Which particle is most likely to be captured by a Uranium-235 nucleus and cause it to undergo fission?

D

(A) an energetic proton (B) a fast-moving electron
(C) an energetic neutron (D) a slow-moving neutron
(E) a fast-moving alpha particle

PART B

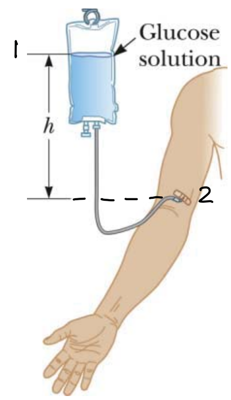
ANSWER FIVE PART B QUESTIONS AND INDICATE YOUR CHOICES ON THE COVER PAGE.

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.**

continued on page 6…

B1. A collapsible plastic bag contains a glucose solution. The density of the solution is 1.02×10^3 kg/m^3. The height difference, *h*, between the level of the glucose in the bag and the insertion point in the patient's vein is 18.1 cm. The pressure at the surface of the glucose in the bag is 1.013×10^5 Pa (atmospheric pressure).



(a) Calculate the gauge pressure in the glucose at the insertion point. You may assume a static fluid situation. (3 marks)

$P_2 = P_1 + \rho g(y_1 - y_2) = P_1 + \rho g h$

$P_2 = P_{atm} + \rho g h$

$P_{2_{gauge}} = P_2 - P_{atm} = P_{atm} + \rho g h - P_{atm} = \rho g h$

$\boxed{1.81 \times 10^3 \text{ Pa}}$

$P_{2_{gauge}} = (1.02 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(0.181 \text{ m}) = 1.81 \times 10^3 \text{ N/m}^2 = 1.81 \times 10^3 \text{ Pa}$

(b) At the insertion point, a needle is used to infuse the glucose into the vein. The needle is 1.25 cm long and has a radius of 0.250 mm. The gauge pressure in the vein is 1.33×10^3 Pa and the viscosity of the glucose solution is 1.14×10^{-3} Pa·s. Calculate the volume flow rate of glucose through the needle. If you did not obtain an answer for (a), use a value of 1.80×10^3 Pa. (5 marks)

Viscous flow ⇒ Poiseville's Law

$\boxed{5.17 \times 10^{-8} \text{ m}^3/\text{s}}$

$$\frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8 \eta L}$$

$$\frac{\Delta V}{\Delta t} = \frac{\pi (0.250 \times 10^{-3} \text{ m})^4 (1.81 \times 10^3 \text{ Pa} - 1.33 \times 10^3 \text{ Pa})}{8 (1.14 \times 10^{-3} \text{ Pa} \cdot \text{s})(1.25 \times 10^{-2} \text{ m})}$$

$$\frac{\Delta V}{\Delta t} = 5.17 \times 10^{-8} \text{ m}^3/\text{s}$$

(c) Calculate the flow speed (in m/s) of the glucose through the needle. If you did not obtain an answer for (b), use a value of 5.00×10^{-8} m^3/s. (2 marks)

$\boxed{0.263 \text{ m/s}}$

$$\frac{\Delta V}{\Delta t} = A v$$

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

$$v = \frac{5.17 \times 10^{-8} \text{ m}^3/\text{s}}{\pi (0.250 \times 10^{-3} \text{ m})^2} = 0.263 \text{ m/s}$$

continued on page 7...

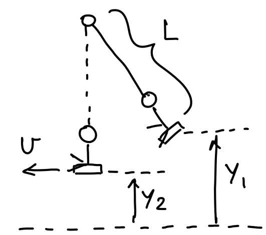
Student No.: ______________________

B2. A 30.0-kg child is swinging back and forth on a playground swing, while continuously blowing a whistle, producing sound of frequency 1.20 kHz. The child and swing may be considered to be a simple pendulum of length 2.00 m.

(a) Calculate the frequency of the oscillatory motion of the child/swing. Express your answer in Hz. (2 marks)

$\boxed{0.352\ \text{Hz}}$

Simple pendulum $\Rightarrow$ $T = 2\pi\sqrt{\frac{L}{g}}$



$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{9.80\ \text{m/s}^2}{2.00\ \text{m}}} = 0.352\ \text{Hz}$$

(b) Where, in the oscillation, is the child moving at maximum speed? (1 mark)

At the lowest point of the motion, where PE_{grav} is minimum.

(c) Calculate the maximum speed of the child if the vertical position of the swing varies between 30.0 cm and 130 cm above the ground. (3 marks)

$\boxed{4.43\ \text{m/s}}$

Energy is conserved.

$$E_1 = E_2$$

$$PE_{grav_1} + KE_1 = PE_{grav_2} + KE_2$$

$$mgy_1 + 0 = mgy_2 + \tfrac{1}{2}mv^2 \Rightarrow v = \sqrt{2g(y_1 - y_2)}$$

$$v = \sqrt{2(9.80\ \text{m/s}^2)(1.30\ \text{m} - 0.300\ \text{m})} = 4.43\ \text{m/s}$$

(d) Calculate the maximum beat frequency that a stationary observer would hear if he/she used an identical 1.20 kHz whistle. Note that the air temperature is a warm 27.0°C. If you did not obtain an answer for (c), use a value of 4.50 m/s. (4 marks)

$\boxed{15.5\ \text{Hz}}$

Doppler effect due to motion of child's whistle.

$$f_{o_{max}} = \left(\frac{v - v_o}{v - v_{s_{max}}}\right) f_s = \left(\frac{v}{v - v_{s_{max}}}\right) f_s \quad ; \quad v = 331\ \text{m/s}\sqrt{\frac{273 + 27}{273}}$$

$$v = 347\ \text{m/s}$$

$$f_{o_{max}} = \left(\frac{347\ \text{m/s}}{(347 - 4.43)\ \text{m/s}}\right)(1.20\ \text{kHz})$$

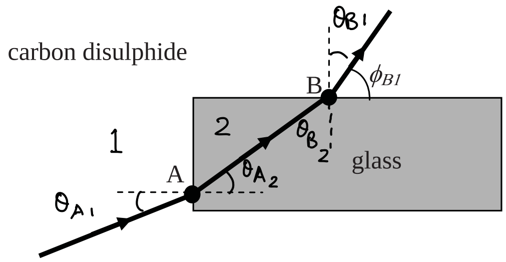
$$f_{beat_{max}} = f_{o_{max}} - 1.20\ \text{kHz} = 1.20\ \text{kHz}\left(\frac{347\ \text{m/s}}{(347 - 4.43)\ \text{m/s}} - 1\right)$$

$$f_{beat_{max}} = 15.5\ \text{Hz}$$

continued on page 8...

Student No.: ______________________

B3. The drawing shows a block of glass (index of refraction of 1.52) surrounded by carbon disulphide (index of refraction 1.63).



(a) Calculate the critical angle between glass and carbon disulphide. (2 marks)

$\boxed{68.8°}$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$1.63 \sin\theta_c = 1.52 \sin 90°$$

$$\sin\theta_c = \frac{1.52}{1.63} \Rightarrow \theta_c = \text{invsin}\left(\frac{1.52}{1.63}\right) = 68.8°$$

(b) At which point, A or B, is total internal reflection possible? (1 mark)

$\boxed{\text{A}}$

Total internal reflection is only possible when going from higher to lower index of refraction. $\therefore$ A

(c) The angle of incidence for the ray of light entering the glass block at point A is 30.0°. Calculate the angle of refraction for the ray of light inside the glass block at point A. (3 marks)

$\boxed{32.4°}$

$$n_1 \sin\theta_{A1} = n_2 \sin\theta_{A2} \Rightarrow \sin\theta_{A2} = \frac{n_1 \sin\theta_{A1}}{n_2}$$

$$\theta_{A2} = \text{invsin}\left(\frac{n_1 \sin\theta_{A1}}{n_2}\right) = \text{invsin}\left(\frac{1.63 \sin(30.0°)}{1.52}\right) = 32.4°$$

(d) Calculate the angle, ϕ_{B1}, that the light makes <u>with the glass block</u> when it leaves the block at point B. (4 marks)

$\boxed{38.1°}$

$$\theta_{B2} = 90° - \theta_{A2} = 90° - 32.4° = 57.6°$$

$$n_2 \sin\theta_{B2} = n_1 \sin\theta_{B1} \Rightarrow \theta_{B1} = \text{invsin}\left(\frac{n_2 \sin\theta_{B2}}{n_1}\right)$$

$$\theta_{B1} = \text{invsin}\left(\frac{1.52 \sin(57.6°)}{1.63}\right) = 51.9°$$

$$\phi_{B1} = 90° - \theta_{B1} = 38.1°$$

continued on page 9...

B4. An individual with a far point *F* at 1.30 m and near point *N* at 0.400 m needs corrective lenses for both situations. In the following calculations, ignore the distance between the corrective lenses and the eyes.

(a) To see objects at infinity, what kind of corrective lens does the individual need? (1 mark)

diverging

need to form a virtual image closer to the eye, ∴ diverging lens

(b) Calculate the prescription (or Power) in diopters of the corrective lens that will enable the individual to clearly see objects at infinity. (3 marks)

$- 0.769\ D$

$p = \infty$, want $q = -F$

$$\text{Power} = \frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

$$\text{Power} = \frac{1}{\infty} + \frac{1}{-F} = \frac{1}{-F} = \frac{1}{-1.30\,m} = -0.769\ D$$

(c) Calculate the prescription (again in diopters) needed to bring the near point from 40.0 cm to 20.0 cm. (3 marks)

$+2.50\ D$

When $p = 20.0\,cm$, want $q = -N$

$$\text{Power} = \frac{1}{f} = \frac{1}{p} + \frac{1}{q} \quad (p, q \text{ in metres})$$

$$\text{Power} = \frac{1}{0.200\,m} + \frac{1}{-0.400\,m} = +2.50\ D$$

(d) The individual also wants to buy off-the-shelf +2.00 Diopters reading glasses (essentially a magnifying lens) to read the fine print on some documents. When using these reading glasses without any correcting lens, calculate the maximum angular magnification that will result. (3 marks)

1.80

maximum angular magnification occurs when the image forms at the near point.

$$m = \frac{N}{p} = N\left(\frac{1}{p}\right) = N\left(\frac{1}{f} - \frac{1}{q}\right) = N\left(\frac{1}{f} - \frac{1}{-N}\right) = \frac{N}{f} + 1$$

$$m = N\left(\frac{1}{f}\right) + 1 = (0.400\,m)(+2.00\,D) + 1 = 1.80$$

continued on page 10...

B5. The area of a light bulb filament is 1.09×10^{-5} m^2. The emissivity of the filament is 0.800.

(a) Calculate the rate at which energy is radiated by the light bulb when its temperature is 2950 K. (4 marks)

$$\boxed{37.4\,\text{W}}$$

$$P = \sigma \epsilon A T^4$$

$$P = \left(5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4}\right)(0.800)(1.09 \times 10^{-5}\,\text{m}^2)(2950\,\text{K})^4$$

$$P = 37.4\,\text{W}$$

(b) Suppose that 16.7% of the energy radiated by the light bulb is in the visible part of the spectrum. Calculate the distance from the light bulb at which the intensity of visible light is 4.00×10^{-11} W/m^2. (This is the threshold intensity for human dark-adapted vision.) If you did not obtain an answer for (a), use a value of 40.0 W. (4 marks)

$$\boxed{1.12 \times 10^5\,\text{m}}$$

$$P_{vis} = 0.167P = (0.167)(37.4\,\text{W}) = 6.25\,\text{W}$$

$$I = \frac{P}{A} = \frac{P}{4\pi r^2} \Rightarrow r^2 = \frac{P}{4\pi I} \Rightarrow r = \sqrt{\frac{P}{4\pi I}}$$

$$r = \sqrt{\frac{6.25\,\text{W}}{4\pi(4.00 \times 10^{-11}\,\text{W/m}^2)}} = 1.12 \times 10^5\,\text{m}$$

(c) Using an average wavelength of 546 nm for the visible light, calculate the number of photons per second that pass through an area of 1.00 m^2 when the intensity is 4.00×10^{-11} W/m^2. (2 marks)

$$\boxed{1.10 \times 10^8/\text{s}}$$

$$P = IA = \frac{\text{Energy}}{\text{photon}} \times \frac{\text{photons}}{t}$$

$$\frac{\text{photons}}{t} = \frac{IA}{\text{Energy/photon}} = \frac{IA}{hc/\lambda} = \frac{IA\lambda}{hc}$$

$$\frac{\text{photons}}{t} = \frac{(4.00 \times 10^{-11}\,\text{W/m}^2)(1.00\,\text{m}^2)(546 \times 10^{-9}\,\text{m})}{(6.626 \times 10^{-34}\,\text{J}\cdot\text{s})(2.998 \times 10^8\,\text{m/s})} = 1.10 \times 10^8/\text{s}$$

continued on page 11...

B6. The isotope of potassium, ${}^{40}_{19}K$ (atomic mass = 39.963999 u), is unstable. If this isotope were to undergo alpha decay, the atomic mass of the isotope resulting from the decay would be 35.968307 u.

(a) If ${}^{40}_{19}K$ undergoes alpha decay, what are the atomic number, Z, and mass number, *A*, of the isotope resulting from the decay? (2 marks)

$${}^{40}_{19}K \rightarrow X + \alpha$$

$${}^{40}_{19}K \rightarrow {}^{36}_{17}X + {}^{4}_{2}He$$

Z: $\boxed{17}$

A: $\boxed{36}$

(b) Determine by calculation whether or not it is possible for ${}^{40}_{19}K$ to spontaneously undergo alpha decay. The atomic mass of the alpha particle is 4.002603 u. (3 marks)

$$Q = (m_{reactants} - m_{products})c^2$$

$\boxed{\text{not possible}}$

$$Q = (39.963999u - (35.968307u + 4.002603u))c^2$$

$$Q = -6.44\,MeV$$

indicates endothermic, energy required

$\therefore$ spontaneous alph decay cannot occur.

(c) Suppose that a bunch of bananas has an activity of 112 Bq due to ${}^{40}_{19}K$. Calculate the time (in years) for the activity of the bananas to decrease to 101 Bq. The half-life of ${}^{40}_{19}K$ is 1.28×10^9 years. (5 marks)

$\boxed{1.91 \times 10^8 y}$

$$R_0 = 112\,Bq, \quad R = 101\,Bq, \quad T_{1/2} = 1.28 \times 10^9 \text{ years}$$

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{1.28 \times 10^9 y} = 5.414 \times 10^{-10} y^{-1}$$

$$R = \lambda N \text{ and } N = N_0 e^{-\lambda t} \Rightarrow R = R_0 e^{-\lambda t}$$

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

$$t = \frac{-\ln(101\,Bq/112\,Bq)}{5.414 \times 10^{-10} y^{-1}} = 1.91 \times 10^8 y$$

END OF EXAMINATION