UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
FINAL EXAMINATION

April 8, 2017 Time: 180 minutes

NAME: SOLUTIONS STUDENT NO.: ____________

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

LECTURE SECTION (please check):

- ❑ 01 Dr. Y. Yao
- ❑ 02 B. Zulkoskey

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), an exam booklet, a formula sheet, a scratch card 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 name on the exam booklet and scratch card.
5. Enter your name and NSID on the OMR sheet.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR sheet must all be submitted.
7. No test materials will be returned.

QUESTION #	MAX. MARKS	MARKS
A1-20	20	
B21-24	8	
B25-28	8	
B29-32	8	
B33-36	8	
B37-40	8	
B41-44	8	
MARK	out of 60:	

PART A

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

A1. A glass is completely filled to the brim with water. An ice cube is then carefully placed in the glass, causing some of the water to spill out, leaving the ice cube floating in the water. Which one of the following statements is correct regarding the weight of the glass with the ice cube floating in the water?

C

According to Archimedes' Principle, the ice cube displaces an amount of water that has the same weight. ∴ no change in total mass.

(A) It is greater than the weight of the glass and water before the ice cube was added.
(B) It is less than the weight of the glass and water before the ice cube was added.
(C) It is the same as the weight of the glass and water before the ice cube was added.
(D) It could be either greater or less than the weight of the glass and water before the ice cube was added, depending on the weight of the ice cube.
(E) It could be either greater or less than the weight of the glass and water before the ice cube was added, depending on the volume of the ice cube above the water level.

A2. The absolute pressure at a depth of h below the surface of a lake is P_1. The absolute pressure at a depth of $2h$ below the surface of the lake is P_2. Which one of the following statements is correct?

D

(A) $P_2 < P_1$ (B) $P_2 = 2P_1$ (C) $P_2 > 2P_1$
(D) $P_1 < P_2 < 2P_1$ (E) The answer depends on the density of the water.

$P_1 = P_0 + \rho g h$
$P_2 = P_0 + 2\rho g h$
$2P_1 = 2P_0 + 2\rho g h$

A3. Due to a build-up of sludge, the effective radius of an oil pipeline becomes half the original radius. To compensate for this reduced radius, the pipeline operator increases the pressure difference across the length of the pipeline by a factor of four. If Q_1 is the original volume flow rate through the pipeline, what is the new volume flow rate, Q_2, in terms of Q_1?

E

(A) $Q_2 = 4\,Q_1$ (B) $Q_2 = 2\,Q_1$ (C) $Q_2 = Q_1$ (D) $Q_2 = ½\,Q_1$ (E) $Q_2 = ¼\,Q_1$

Poiseuille's Law:
$Q = \frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L}$
$\left(R_2 = \frac{1}{2}R_1 \text{ ; } (P_1-P_2)_2 = 4(P_1-P_2)_1\right.$
$\frac{Q_2}{Q_1} = \left(\frac{1}{2}\right)^4 \cdot 4 = \frac{4}{16} = \frac{1}{4}$

A4. When an object is moving in simple harmonic motion (SHM), which properties reach their maximum magnitudes at the same time? $F = -kx = ma$

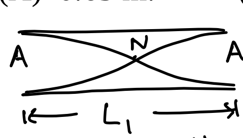
A

(A) Displacement, Acceleration, and Restoring Force
(B) ~~Speed~~, Acceleration, and Restoring Force
(C) Displacement, ~~Speed~~, and Acceleration
(D) ~~Restoring Force~~, Speed, and Kinetic Energy
(E) Displacement, ~~Speed~~, and Potential Energy

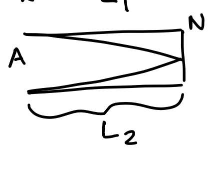
A5. An organ pipe open at both ends has a length of 1.00 m and is producing sound at its fundamental frequency. A second organ pipe sits next to the first and is closed at one end. It too is producing sound at its fundamental frequency. A beat frequency of 5 Hz is heard when the speed of sound is 343 m/s and the two pipes are played at the same time. A possible value for the length of the second pipe is

B

(A) 0.63 m. (B) 0.52 m. (C) 1.15 m. (D) 1.05 m. (E) 0.75 m.



$L_1 = \frac{\lambda_1}{2} \Rightarrow f_1 = \frac{v}{\lambda_1} = \frac{v}{2L_1} = \frac{343\text{ m/s}}{2(1.00\text{m})} = 171.5\text{ Hz}$



$L_2 = \frac{\lambda_2}{4} \Rightarrow f_2 = \frac{v}{\lambda_2} = \frac{v}{4L_2} \Rightarrow L_2 = \frac{v}{4f_2}$; and $f_2 = 176.5\text{ Hz}$ or 166.5 Hz

$\therefore L_2 = 0.486\text{m}$ or 0.515m

A6. Consider two speakers, separated by a distance d. The speakers produce sound waves of wavelength λ that are identical, coherent, and in phase. Suppose a microphone is placed at a location that is a distance r_1 from one speaker and a distance r_2 from the other speaker. Which one of the following conditions will result in the microphone detecting a large amplitude sound wave?

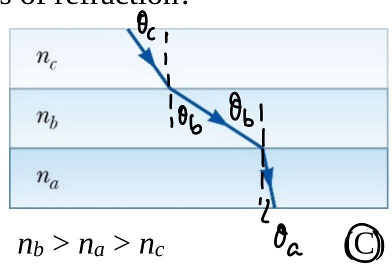
A

Constructive Interference $\Rightarrow |r_1 - r_2| = n\lambda$; $n = 0, 1, 2, 3, \ldots$

(A) $r_1 - r_2 = \lambda$ (B) $r_1 - r_2 = d + \lambda$ (C) $r_1 - r_2 = d$
(D) $r_1 - r_2 = d - \lambda$ (E) $r_1 - r_2 = d\lambda$

A7. A light ray travels through three parallel slabs having different indices of refraction as shown in the figure below. Only the refracted rays are shown. Which one of the following relations is correct regarding the three indices of refraction?

C



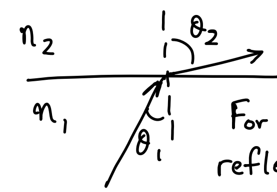
Snell's Law:
$n_c \sin\theta_c = n_b \sin\theta_b = n_a \sin\theta_a$
$\theta_a < \theta_c < \theta_b$
$\therefore n_a > n_c > n_b$

(A) $n_a > n_b > n_c$ (B) $n_b > n_a > n_c$ (C) $n_a > n_c > n_b$
(D) $n_c > n_b > n_a$ (E) $n_c > n_b > n_a$

A8. 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 $n_2 < n_1$.
(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 refraction angle.



For total internal reflection to occur, $\theta_2 > \theta_1$
$\therefore n_2 < n_1$

A9. A converging lens has a focal distance f. An object is placed on the lens's principal axis at a distance from the lens that is less than f. The image formed will be

B

(A) virtual and inverted. (B) virtual and upright. (C) real and upright.
(D) real and inverted. (E) real and larger than the object.

A10. A pair of closely-spaced slits is illuminated by monochromatic light and an interference pattern forms on a screen a few meters away. Which one of the following colours of light would produce bright fringes separated by the largest distance?

E

$m\lambda = d\sin\theta \Rightarrow \theta \uparrow$ as $\lambda \uparrow$

(A) violet (B) blue (C) green (D) yellow (E) red

A11. Consider a wave passing through a single narrow slit. What happens to the width of the central maximum of the diffraction pattern if the slit is made half as wide?

D

(A) It becomes one-fourth as wide. (B) It becomes half as wide.
(C) Its width does not change. (D) It becomes twice as wide.
(E) It becomes four times as wide.

1ST minimum occurs at $a\sin\theta = \lambda$
$\sin\theta = \dfrac{\lambda}{a}$

$a_2 = \frac{1}{2}a_1 \Rightarrow \sin\theta_2 = 2\sin\theta_1 \Rightarrow \theta_2 > \theta_1$

$\therefore$ width of central max. increases
using small angle approx., $\theta_2 = 2\theta_1$

A12. Why is it advantageous to use a large-diameter objective lens in a telescope?

C

(A) It diffracts the light more effectively than smaller-diameter lenses.
(B) It increases the magnification.
(C) It increases the resolution.
(D) It enables you to see more objects in the field of view.
(E) It reflects unwanted wavelengths.

Same explanation as for A11.

For a larger opening, the diffraction pattern is narrower, so the patterns of separate objects are distinguishable.

A13. Two moles of an ideal gas at 3.0 atm and 10°C are heated to 150 °C. If the volume is held constant during this heating, what is the final pressure?

B

$PV = nRT \Rightarrow P = nRT/V \Rightarrow P \propto T$

(A) 45 atm (B) 4.5 atm (C) 1.8 atm (D) 1.0 atm (E) 0.45 atm

$P \propto T \Rightarrow P_2 = P_1 \left(T_2/T_1\right) = 3.0\,\text{atm}\left(\frac{150+273}{283}\right) = 4.48\,\text{atm} = 4.5\,\text{atm}$

A14. Which one of the following changes will increase the average kinetic energy of the molecules in an ideal gas?

B

$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}k_B T \;;\; PV = Nk_BT$

(A) reducing the volume, keeping pressure and number of molecules constant $\Rightarrow T\downarrow$
(B) increasing the volume, keeping pressure and number of molecules constant $\Rightarrow T\uparrow \Rightarrow \frac{1}{2}mv_{rms}^2 \uparrow$
(C) reducing the volume, keeping temperature and number of molecules constant T constant
(D) increasing the pressure, keeping temperature and volume constant T constant
(E) increasing the number of molecules, keeping volume and temperature constant T constant

A15. A 100-g block of an unknown substance with a temperature of 70.0°C is placed in 200 g of water at 20.0°C. The system reaches an equilibrium temperature of 30.0°C. Assume no thermal energy is transferred to/from the environment. Which one of the following relations is correct regarding the specific heats of the block (c_{block}) and water (c_{water})?

D

$\sum Q = 0 \Rightarrow m_w c_w|\Delta T_w| = m_b c_b|\Delta T_b|$

(A) $c_{block} = 4c_{water}$ (B) $c_{block} = 2c_{water}$ (C) $c_{block} = c_{water}$
(D) $c_{block} = 0.5\, c_{water}$ (E) $c_{block} = 0.25\, c_{water}$

$200\,g\, c_w (10.0°C) = 100\,g\, c_b (40°C)$

$\therefore c_b = \frac{1}{2} c_w$

A16. A window conducts energy from a house to the cold outdoors at a rate P. At what rate is energy conducted through a window of half the area and half the thickness? (Assume that both windows are made of the same type of glass.)

C

$P = kA\frac{\Delta T}{L}$ $\quad A_2/L_2 = \frac{1}{2}A_1 / \frac{1}{2}L_1 = A_1/L_1$

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

A17. In a Compton scattering experiment, X-rays are incident on a carbon block. At larger scattering angles, what happens to the magnitude of the difference between the incident and scattered X-ray wavelengths?

A

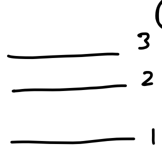
$\lambda - \lambda_0 = \frac{h}{m_e c}(1-\cos\theta)$; as $\theta\uparrow$, $\cos\theta\downarrow$, so $(1-\cos\theta)\uparrow$, so $(\lambda-\lambda_0)\uparrow$

(A) The difference increases.
(B) The difference decreases.
(C) The difference remains constant.
(D) The difference is maximum at a 45° scattering angle.
(E) The difference is minimum at a 90° scattering angle.

A18. Consider an atom having three distinct energy levels. If an electron is able to make transitions between any two levels, how many different wavelengths of radiation could the atom emit?

B

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



$3\rightarrow 2$, $3\rightarrow 1$, $2\rightarrow 1$ are the possible transitions

A19. Which one of the following units is appropriate for the decay constant λ?

D

(A) s (B) Ci (C) J (D) s^{-1} (E) MeV

A20. Radioactive ${}^{215}_{83}\mathrm{Bi}$ decays into ${}^{215}_{84}\mathrm{Po}$. Which one of the following particles is released in the decay?

B

(A) a proton (B) an electron (C) a positron
(D) a neutron (E) an alpha particle

$${}^{215}_{83}\mathrm{Bi} \rightarrow {}^{215}_{84}\mathrm{Po} + {}^{A}_{Z}? \qquad A = 215 - 215 = 0, \quad Z = 83 - 84 = -1 \Rightarrow {}^{0}_{-1}? = {}^{0}_{-1}e$$

PART B

WORK OUT THE ANSWERS TO THE FOLLOWING PART B QUESTIONS.

WHEN YOU HAVE AN ANSWER THAT IS ONE OF THE OPTIONS AND ARE CONFIDENT THAT YOUR METHOD IS CORRECT, SCRATCH THAT OPTION ON THE SCRATCH CARD. IF YOU REVEAL A STAR ON THE SCRATCH CARD THEN YOUR ANSWER IS CORRECT (FULL MARKS, 2/2).

IF YOU DO NOT REVEAL A STAR WITH YOUR FIRST SCRATCH, TRY TO FIND THE ERROR IN YOUR SOLUTION. IF YOU REVEAL A STAR WITH YOUR SECOND SCRATCH, YOU RECEIVE HALF-MARKS (1/2).

IF YOU STILL DO NOT HAVE THE CORRECT ANSWER, BUT REWORK YOUR SOLUTION AND REVEAL A STAR WITH YOUR THIRD SCRATCH, THEN YOU RECEIVE 0.2/2.

REVEALING THE STAR WITH YOUR FOURTH OR FIFTH SCRATCHES DOES NOT EARN YOU ANY MARKS, BUT IT DOES GIVE YOU THE CORRECT ANSWER.

YOU MAY ANSWER ALL SIX PART B QUESTION GROUPINGS (21-24, 25-28, 29-32, 33-36, 37-40, AND 41-44) AND YOU WILL RECEIVE THE MARKS FOR YOUR BEST 5 GROUPINGS.

USE THE PROVIDED EXAM BOOKLET FOR YOUR ROUGH WORK.

A U-tube open at both ends is partially filled with water (Fig. a). The length of the water column L_1 is 20.0 cm. The two arms have the same cross sectional area. The atmospheric pressure is $P_0 = 1.013 \times 10^5$ Pa.

B21. Calculate the **gauge pressure** at the bottom of the tube in Fig. a.

$$P_{abs} = P_0 + \rho_w g L_1 \; ; \quad P_{gauge} = P_{abs} - P_0 = \rho_w g L_1$$
$$= (1.00 \times 10^3 \,\mathrm{kg/m^3})(9.80\,\mathrm{m/s^2})(0.200\,\mathrm{m}) = \boxed{1.96\,\mathrm{kPa}}$$

B22. Oil ($\rho = 750$ kg/m^3) is then poured into the right arm (Fig. b). The difference h in the heights of the two liquid surfaces is 1.25 cm. Determine the length of the oil column L_2. The figure is not plotted to scale.

$$P_A = P_B \Rightarrow P_0 + \rho_w g(L_2 - h) = P_0 + \rho_o g L_2 \Rightarrow \rho_w g(L_2 - h) = \rho_o g L_2$$
$$\rho_w L_2 - \rho_w h = \rho_o L_2 \Rightarrow \rho_w L_2 - \rho_o L_2 = \rho_w h \Rightarrow L_2 = \left(\frac{\rho_w}{\rho_w - \rho_o}\right) h = \boxed{5.00\,\mathrm{cm}}$$

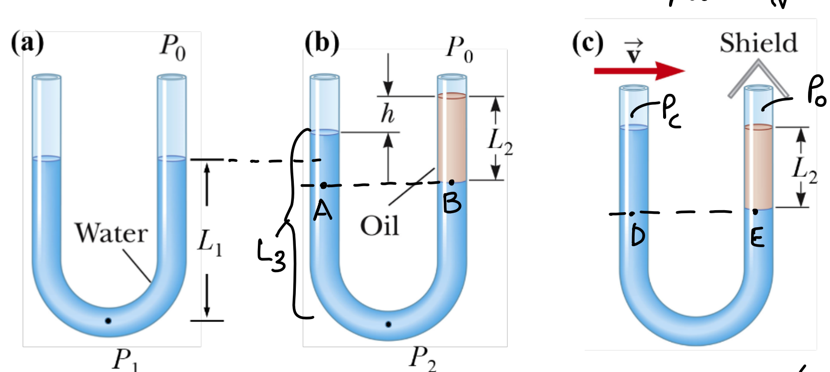
B23. Calculate the **gauge pressure** at the bottom of the tube in Fig. b.

$$P_{gauge} = \rho_w g L_3 = (1.00 \times 10^3 \,\mathrm{kg/m^3})(9.80\,\mathrm{m/s^2})(0.21875\,\mathrm{m}) = \boxed{2.14 \times 10^3\,\mathrm{Pa}}$$

(see L_3 calculation on diagram)

B24. The right arm is then shielded from any air motion while air is blown across the top of the left arm until the surfaces of the two liquids are at the same height (Fig. c). Determine the speed of the air being blown across the left arm. Assume the density of air is 1.29 kg/m^3.

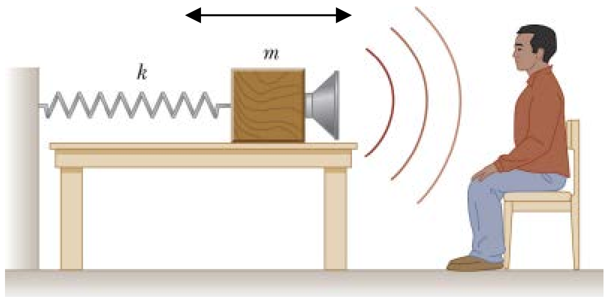
$$\text{Bernoulli's Principle} \Rightarrow P_c + \tfrac{1}{2}\rho_a v^2 = P_0 \Rightarrow v = \sqrt{\frac{2(P_0 - P_c)}{\rho_a}} = \sqrt{\frac{2(\rho_w - \rho_o) g L_2}{\rho_a}} = \boxed{13.8\,\mathrm{m/s}}$$



$$P_D = P_E$$
$$P_c + \rho_w g L_2 = P_0 + \rho_o g L_2$$
$$P_0 - P_c = (\rho_w - \rho_o) g L_2$$

$$L_3 = L_1 + \tfrac{1}{2}(L_2 - h) = 20.0\,\mathrm{cm} + \tfrac{1}{2}(5.00\,\mathrm{cm} - 1.25\,\mathrm{cm})$$
$$L_3 = 21.875\,\mathrm{cm}$$

A block with a speaker bolted to it is connected to a spring with a spring constant of 768 N/m, as shown below. The block and speaker are in simple harmonic motion on the frictionless table. The total mass of the block and speaker is 0.400 kg, and the amplitude of the unit's motion is 0.500 m. The speaker emits sound waves of frequency 896 Hz. The speed of sound is 343.0 m/s.



B25. At what point in the speaker's motion does the person sitting to the right of the speaker hear the highest frequency? Person hears highest freq'y when speaker is moving at max. speed towards person.

B26. Calculate the highest frequency heard by the person sitting to the right of the speaker.

Doppler shift, moving source ; Cons. of Energy : $\frac{1}{2}mv_{s_{max}}^2 = \frac{1}{2}kA^2$

$$f_{o_{max}} = \left(\frac{v}{v - v_{s_{max}}}\right) f_s = \left(\frac{343.0\text{ m/s}}{343.0\text{ m/s} - 21.9\text{ m/s}}\right) 896\text{ Hz} = 957\text{ Hz}$$

$$v_{s_{max}} = A\sqrt{\frac{k}{m}} = 21.9\text{ m/s}$$

B27. Calculate the frequency of the speaker's back and forth motion.

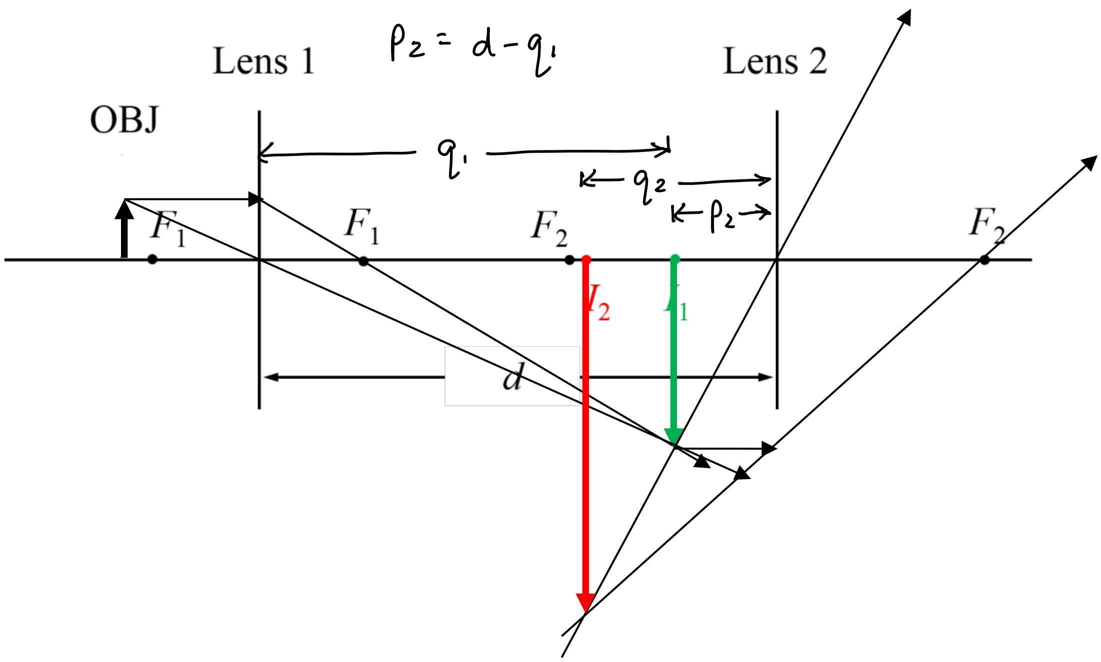
$$\omega = \sqrt{\frac{k}{m}} \Rightarrow f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{768\text{ N/m}}{0.400\text{ kg}}} = 6.97\text{ Hz}$$

B28. If the speaker is producing sound energy at a rate of 1.25 W, calculate the sound intensity level at the location of the listener when the listener is a distance of 2.00 m from the speaker.

$$I = \frac{P}{A} = \frac{P}{4\pi r^2} = \frac{1.25\text{ W}}{4\pi(2.00\text{m})^2} = 2.487\times10^{-2}\text{ W/m}^2$$

$$\beta = 10\log_{10}\left(\frac{I}{I_0}\right) = 10\log_{10}\left(\frac{2.487\times10^{-2}\text{ W/m}^2}{1.00\times10^{-12}\text{ W/m}^2}\right) = 104\text{ dB}$$

Two lenses (lens 1 and lens 2) are placed d = 50.0 cm apart. An object is placed 13.3 cm to the left of lens 1. The image formed by lens 1 is located at point I_1. The final image is located at the point I_2. The focal points for the two lenses are indicated as F_1 and F_2. F_1 is 10.0 cm from lens 1. F_2 is 20.0 cm from lens 2.



B29. Which one of the following statements is correct for lens 1 and for the image formed by lens 1?

Converging; Larger than the object

B30. If the height of the object is h, what is the height of the image formed by lens 1?

$$h' = Mh = -\frac{q}{p}h \; ; \; q = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1} = \left(\frac{1}{10.0\text{cm}} - \frac{1}{13.3\text{cm}}\right)^{-1} = 40.3\text{cm} \Rightarrow h' = -\frac{40.3\text{cm}}{13.3\text{cm}}h$$

$$h' = -3.03h$$

B31. Which one of the following statements is correct for lens 2 and for the final image? (Orientations are relative to original object.)

Converging, Virtual

B32. Calculate the overall magnification of the two-lens system.

$$M_{tot} = M_1 M_2 = \left(-\frac{q_1}{p_1}\right)\left(-\frac{q_2}{p_2}\right) \; ; \; p_2 = d - q_1 = 50.0\text{cm} - 40.3\text{cm} = 9.7\text{cm}$$

$$q_2 = \left(\frac{1}{f_2} - \frac{1}{p_2}\right)^{-1} = \left(\frac{1}{20.0\text{cm}} - \frac{1}{9.7\text{cm}}\right)^{-1} = -18.83\text{cm}$$

$$M_{tot} = (-3.03)\left(-\frac{(-18.83\text{cm})}{9.7\text{cm}}\right) = -5.88$$

A certain child's range of distinct vision is 10.0 cm to 125 cm. For the child's eyes, each lens is 1.80 cm from the retina, and the child's vision is to be corrected using eyeglasses that will be worn 2.00 cm from the eyes.

Child can't see long distances
∴ need to "bring distant objects closer"

B33. Which one of the following statements is correct?

The child is nearsighted and the corrective eyeglass lenses should be diverging.

B34. The child's range of distinct vision is due to the ability of the eyes to adjust their focal lengths. Calculate the range of focal lengths for the child's eyes.

$q = 1.80\,\text{cm}$ $p = 10.0\,\text{cm}$

$f = \left(\frac{1}{p} + \frac{1}{q}\right)^{-1} = 1.53\,\text{cm}$

$q = 1.80\,\text{cm}$, $p = 125\,\text{cm} \Rightarrow f = 1.77\,\text{cm}$

B35. Calculate the power of the corrective eyeglass lenses required so that the child's range of vision includes the normal range of vision. Want $p = \infty$ to form image at 125 cm from eye

$\therefore p = \infty$, $q = -123\,\text{cm}$

$$f = \left(\frac{1}{p} + \frac{1}{q}\right)^{-1} = \left(\frac{1}{\infty} + \frac{1}{-123\,\text{cm}}\right)^{-1} = -123\,\text{cm} = -1.23\,\text{m}\ ; \quad P = -\frac{1}{1.23}$$

$P = -0.813$ diopters

B36. Calculate the child's new near point when she is wearing her eyeglasses.

Want object distance (from eye) at which the corrective lens forms an image at a distance of 10.0 cm (from eye).

$q = -8.00\,\text{cm}$ $f = -123\,\text{cm}$

$$p = \left(\frac{1}{f} - \frac{1}{q}\right)^{-1} = \left(\frac{1}{-123\,\text{cm}} - \frac{1}{-8.00\,\text{cm}}\right)^{-1} = 8.56\,\text{cm}$$

∴ distance from eye of new near point is 10.6 cm

B37. Windows consisting of two panes of glass separated by an air gap are more energy-efficient than windows consisting of a single pane of glass. The main reason for this increase in efficiency is that…

the thermal conductivity of air is much less than the thermal conductivity of glass.

The following information applies to the next three questions. The thermal conductivity of glass is 0.840 W/m·K and the thermal conductivity of air is 0.0230 W/m·K. The inside surface temperature is 15.0°C and the outside surface temperature is −10.0°C.

B38. Calculate the rate of energy transfer through a single-paned glass window that has an area of 1.50 m^2 and is 1.60 cm thick.

$$P = kA\frac{(T_h - T_c)}{L} = \left(0.840\ \frac{W}{m\cdot K}\right)\frac{(1.50\ m^2)(15.0°C - (-10.0°C))}{1.60\ cm \times \frac{1\ m}{100\ cm}} = 1.97\times 10^3\ W$$

B39. A double-paned window has an area of 1.50 m^2 and is made of two panes of 0.800-cm-thick glass separated by a 1.00 cm air gap. Calculate the drop in temperature that occurs across the air gap.

P is the same for the glass and air $\Rightarrow k_g A\frac{\Delta T_g}{L_g} = k_a A\frac{\Delta T_a}{L_a} \Rightarrow \Delta T_g = \frac{L_g k_a}{L_a k_g}\Delta T_a$

$$\Delta T = \Delta T_g + \Delta T_a + \Delta T_g = 2\Delta T_g + \Delta T_a = 2\left(\frac{L_g k_a}{L_a k_g}\right)\Delta T_a + \Delta T_a$$

$$\Delta T = \left[2\left(\frac{(0.800\ cm)(0.0230\ W/m\cdot K)}{(1.00\ cm)(0.840\ W/m\cdot K)}\right) + 1\right]\Delta T_a = 1.0438\,\Delta T_a$$

$$\Delta T_a = \frac{25.0°C}{1.0438} = 24.0°C$$

B40. Calculate the rate of energy transfer through the double-paned window described in B39 by calculating the rate of energy transfer through the air gap.

$$P = P_a = \frac{k_a A \Delta T_a}{L_a} = \frac{(0.0230\ W/m\cdot K)(1.50\ m^2)(24.0°C)}{1.00\times 10^{-2}\ m} = 82.8\ W$$

B41. In analyzing data from a hydrogen spectrum experiment, the inverse of each experimentally-determined wavelength of the Balmer series ($n_f = 2$) is plotted versus $1/(n_i^2)$, where n_i is the initial energy level from which a transition to the $n_f = 2$ level occurs, and a straight line is obtained. The slope of the line is

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\underbrace{\frac{1}{\lambda}}_{y} = \underbrace{-R_H}_{m}\underbrace{\left(\frac{1}{n_i^2}\right)}_{x} + \underbrace{R_H\left(\frac{1}{n_f^2}\right)}_{b}$$

$-R_H$ where R_H is the Rydberg constant.

Light from a hydrogen source passes through a diffraction grating that has 605 lines per mm. The second order maximum of the hydrogen spectral line corresponding to the $n = 5$ to $n = 2$ transition shines on a photocell and electrons are ejected.

B42. Calculate the wavelength of the hydrogen spectral line corresponding to the $n = 5$ to $n = 2$ transition.

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{5^2}\right) \Rightarrow \lambda = R_H^{-1}\left(\frac{1}{2^2} - \frac{1}{5^2}\right)^{-1} = (1.097\times10^7\ \text{m}^{-1})^{-1}\left(\frac{1}{4} - \frac{1}{25}\right)^{-1} = 434\ \text{nm}$$

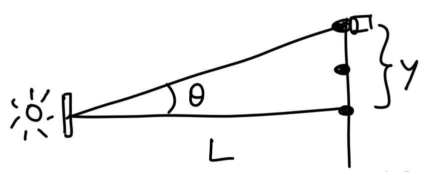
B43. A screen is placed a distance of 50.0 cm from the diffraction grating. Calculate the distance along the screen, as measured from the central maximum, that the photocell should be placed so that it is illuminated by the second order maximum of the spectral line corresponding to the $n = 5$ to $n = 2$ transition.

$\lambda = 434\ \text{nm}$

$m = 2$

$d = \frac{1}{605/\text{mm}} = 1.65\times10^{-6}\ \text{m}$

$d = 1650\ \text{nm}$



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

$y = L\tan\theta$

$y = 50.0\text{cm}\tan(31.74°) = 30.9\text{cm}$

$m\lambda = d\sin\theta \Rightarrow \theta = \text{invsin}\left(\frac{2(434\text{nm})}{1650\text{nm}}\right) = 31.74°$ (too large for small angle approx.)

B44. If the maximum kinetic energy of the electrons ejected in the photocell is 0.623 eV, calculate the work function of the illuminated metal plate in the photocell.

$$KE_{max} = \frac{hc}{\lambda} - \phi \Rightarrow \phi = \frac{hc}{\lambda} - KE_{max} = \frac{(4.136\times10^{-15}\text{eV}\cdot\text{s})(2.998\times10^8\text{m/s})}{434\times10^{-9}\text{m}} - 0.623\text{eV}$$

$$\phi = 2.23\text{eV}$$

END OF EXAMINATION