.

University of Calgary

Physics 369

Midterm Examination

October 21, 2010. 6:45-8:15 p.m.

QUESTION BOOKLET AND FORMULA SHEET

INSTRUCTIONS (read carefully):.

Time: 90 minutes. Mark values of questions are indicated in the left margin. **Total mark 40.** CLOSED BOOK EXAMINATION. Formula sheet provided with this Question Booklet. No other books or notes allowed. Only Faculty of Engineering sanctioned student calculators are allowed.

To write this exam you need the following:

1. **THIS DOUBLE-SIDED QUESTION BOOKLET**, which contains the exam questions and the Formula Sheet (last page).

2. A **STAPLED SET of FOUR ANSWER SHEETS** which you will use to enter all answers for marking. Check that this contains a scoring form (top page) and three additional pages for your detailed solutions to Problems 12, 13, 14.

   (If are missing anything from the above items, raise your hand and ask an exam supervisor to supply what is missing.)

Total mark for this exam is 40. 10 marks are allotted to the ten multiple-choice questions of Part A, and 30 marks are allotted to the three long-answer problems of Part B.

All Answers to the Multiple Choice Questions of PART A must be entered by blacking out the appropriate character (choose one of a, b, c, d, e) beside the question number in the grid provided in the upper right quadrant of PAGE 1 of the answer sheets. Make sure you darken the entire interior of the circle around the character.

Your solutions to the long-answer problems of Part B must be written out in the spaces provided on PAGES 2–4 of the answer sheets. Be sure to show all important steps in your solutions and underline final answers (answers should also include physical units where applicable). Indicate where sub-sections of your solution (e.g., 12 (a), (b), (c), etc.) begin.

ANYTHING THAT YOU WRITE IN THIS QUESTION BOOKLET WILL BE TREATED AS "ROUGH WORK" AND WILL NOT BE MARKED. Limited space is provided in the Question Booklet for rough calculations, but **remember to enter your answers in the answer sheets.** Only the material in the answer sheets will be marked.

IMPORTANT: Start by entering your **ID NUMBER** in the space provided at the top of **all four answer sheets**. Also, using pen, black out the corresponding numbers below your ID on Page 1.
DO THIS NOW. Then wait for the Exam Supervisor to signal when to start the test.

PART A: MULTIPLE CHOICE QUESTIONS. Enter answers on the Answer Sheets in the area provided at the **upper right of Page 1**. Black out the letter corresponding to your selected answer for each question. **Each correct answer is worth 1 mark.** Selecting the wrong answer, or multiple answers, for a question will result in a 0 mark for that question.

[1] **1.** Light travels in a medium of refractive index n_1, in which its wavelength is λ_1. It then enters a medium of refractive index n_2, in which its wavelength is λ_2. Select the correct expression for λ_2:

(a) λ_1/n_2 (b) $n_2\lambda_1/n_1$ (c) $n_2\lambda_1$ (d) λ_1/n_1 (e) $n_1\lambda_1/n_2$

[1] **2.** **Figure 2** shows a light ray passing through a plane interface between two transparent optical media. (The arrow indicates the direction of light travel.) From the list below, select the value of the angle of incidence on the interface.

(a) 30° (b) 40° (c) 50° (d) 60° (e) 90°

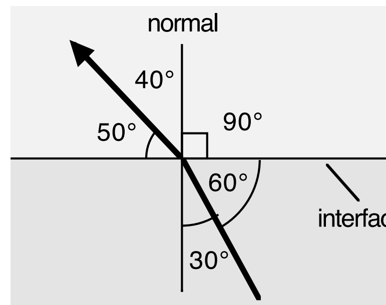


Figure 2

[1] **3.** A person stands on the horizontal optic axis of a large convex spherical mirror of radius R (in this case R is negative). Starting at distance $|R|$ from the mirror vertex, she walks towards the mirror vertex until she stops a distance $|R|/2$ from the vertex. While she is walking, her image

(a) moves to infinity

(b) moves towards her through a distance $|R|/4$

(c) moves towards her through a distance $|R|/6$

(d) moves towards her through a distance $|R|/12$

[1] **4.** A person looks directly at a small air bubble located at the exact center of a glass block of refractive index 1.50 and thickness 12.0 cm as shown in **Figure 4**. As it appears to the viewer, the bubble is:

(a) 4.0 cm behind the near surface of the block

(b) 4.5 cm behind the near surface of the block

(c) 6.0 cm behind the near surface of the block

(d) 9.0 cm behind the near surface of the block

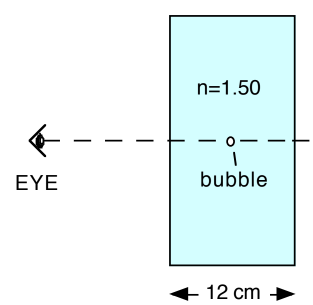


Figure 4

Part A continued on next page...

[1] **5.** In **Figure 5** a diverging lens producing a virtual image of a real object. **When the direction of travel of the light is reversed** in Figure 5 (simply reverse the directions of the small arrowheads on the light rays) then the diverging lens produces

(a) a virtual image of a virtual object

(b) a real image of a virtual object

(c) a real image of a real object

(d) a virtual image of a real object

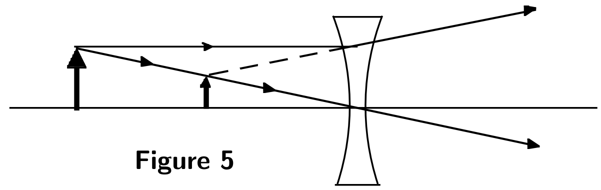


Figure 5

[1] **6.** As shown in **Figure 6**, a gerbil in a pet shop is looking at a fish in a large spherical transparent tank of radius 0.333 m. The gerbil is 0.250 m from the near surface of the tank, and the fish is 0.50 m behind the surface. The tank is filled with water (n=4/3). Optical effects of the glass wall of the spherical tank can be neglected. As seen by the fish, the apparent distance of the gerbil from the fish is closest to

(a) 0.44 m (b) 0.67 m (c) 0.85 m (d) 0.94 m (e) 1.03 m

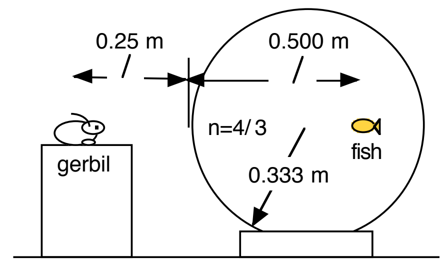


Figure 6

[1] **7.** A concavo-convex lens has radii of curvature 10 cm and 20 cm respectively, as shown in **Figure 7**. The index of refraction of the lens is 1.60. The optical power of this lens in dioptres (1 D=1 m^{-1}) is closest to

(a) −9.00 D (b) −3.00 D (c) −0.9 D (d) +1.75 D

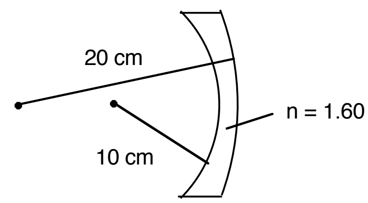


Figure 7

[1] **8.** In **Figure 8** the piston in an internal combustion engine is driving a rotating crankshaft at 3000 rpm. (1 rpm = 1 revolution per minute.) The piston executes one cycle of simple harmonic motion for each revolution of the crankshaft. The range of motion of the piston (from its lowest to highest position) is 2.5 cm. The maximum acceleration experienced by the piston is closest to

(a) 10 m/s^2 (b) 30 m/s^2

(c) 530 m/s^2 (d) 1200 m/s^2

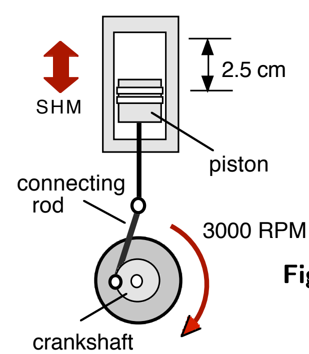


Figure 8

Part A continued on next page...

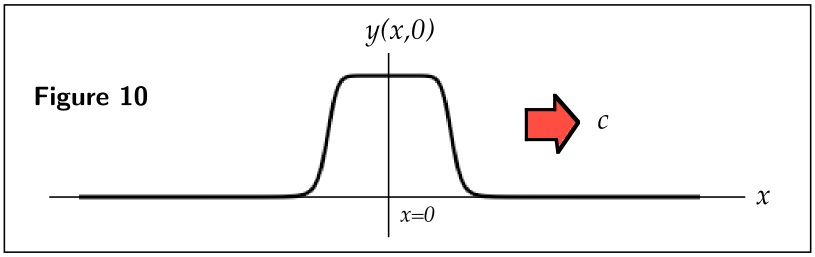
[1] **9.** A simple harmonic motion is represented by the complex phasor quantity $\tilde{A} = (-6 + 2i)$ m. The amplitude and initial phase angle of this simple harmonic motion are

(a) 5.66 m and -0.32 radians

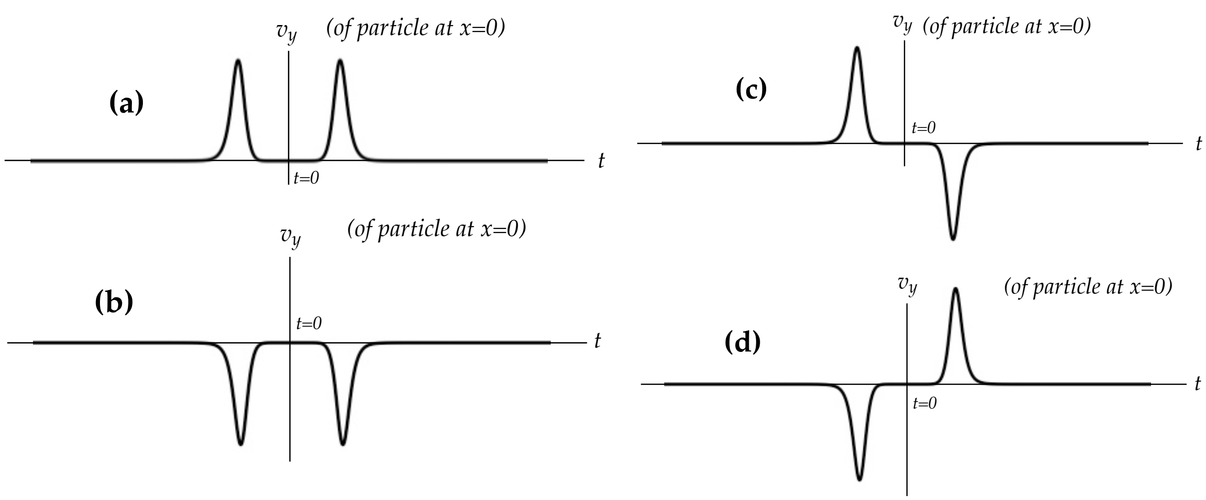
(b) 5.66 m and 2.82 radians

(c) 6.32 m and -0.32 radians

(d) 6.32 m and 2.82 radians



[1] **10**. A snapshot of a transverse wave pulse on a stretched string, taken at $t = 0$, is shown in **Figure 10**, directly above. The pulse moves in the positive x-direction at constant wave speed c. Which of the figures below most accurately represents the velocity of the particle of the string located at $x = 0$, **as a function of time**?



[0] **11.** This is VERSION C of the examination. **IMPORTANT**: Please black out (c) for Question 11 ("Version") on Page 1 of the Answer Sheets to ensure you are given credit for your correct multiple choice answers.

(a) A (b) B (c) C (d) D (e) E

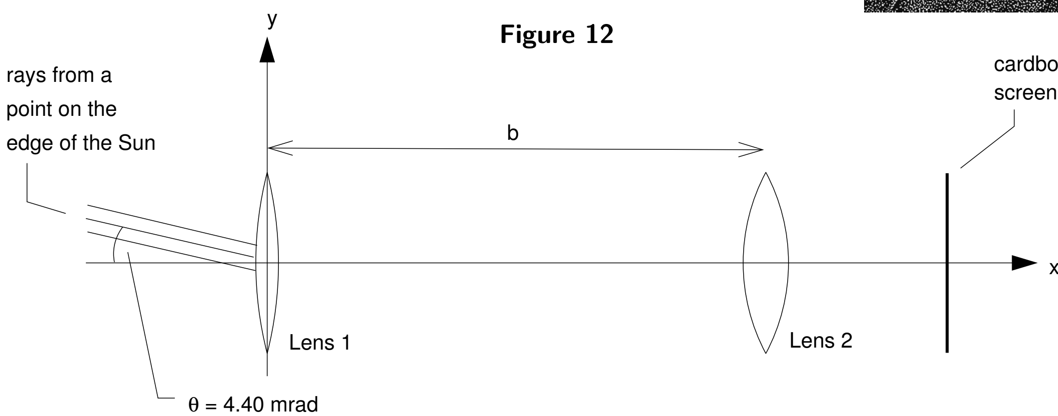
END OF PART A.

PART B: THREE LONG-ANSWER PROBLEMS. Use blank spaces in this booklet for rough work that will not be looked at by the markers. **YOUR COMPLETE FINAL SOLUTIONS SHOULD BE ENTERED ON THE SEPARATE ANSWER SHEETS.** Each problem is worth 10 marks. Part mark values are shown in the left margin.

12. The photograph at right shows a telescope being used to project an image of the Sun on a cardboard screen. This is a two-lens system, sketched in **Figure 12** below. The focal length of lens 1 is $f_1 = +50.0$ cm, and that of lens 2 is $f_2 = +5.00$ cm. The distance between the two lenses is $b = 55.5$ cm.

The diagram also shows a beam of parallel rays coming from a point at the top edge of the Sun, forming an angle $\theta = 4.40$ mrad with the optical axis (1 mrad = 10^{-3} radian). An xy coordinate system is included in the figure, with the origin at the position of lens 1.

Figure 12



[3] (a) The rays shown in the figure converge to a point image after passing through lens 1. What are the x and y coordinates of this image?

[1] (b) The image formed by lens 1 is an object for lens 2. Is it a real or a virtual object?

[3] (c) How far from lens 2 should the cardboard screen be placed to form a sharp image of the Sun?

[3] (d) What is the radius of the final image?

ROUGH WORK ONLY in the space below. Your solution to be marked goes on Page 2 of the Answer Sheets. Nothing you write in the space below will be seen by the markers.

Part B continued on next page...

13. (In the following problem, all phase angles are specified in *radians*.) Two simple harmonic motions of the same angular frequency ω are given by

$$x_1(t) = (3.0 \text{ cm}) \cos(\omega t - \pi/3)$$
$$x_2(t) = (4.0 \text{ cm}) \sin(\omega t + 3\pi/2)$$

[1] (a) The second of these simple harmonic motions can be written identically in terms of the cosine function as $x_2(t) = (4.0 \text{ cm}) \cos(\omega t + \phi)$. What is the necessary value of ϕ? (Restrict your answer to the range $0 \leq \phi < 2\pi$.)

[3] (b) When x_1 is at its maximum value of +3.0 cm, it is found that the velocity of the other simple harmonic motion, $\frac{dx_2}{dt}$, is equal to +15.0 m/s. Use this information to find the value of ω.

[3] (c) Use complex phasor addition techniques to find the amplitude A and phase θ of the resultant simple harmonic motion $x(t) = x_1(t) + x_2(t) = A\cos(\omega t + \theta)$. Again, express θ in the range $0 \leq \theta < 2\pi$.

[2] (d) Draw the phasor diagram (to reasonable accuracy) for the addition of phasors of part (c).

[1] (e) Again consider the resultant $x(t) = x_1(t) + x_2(t)$. With all else held constant, the phase of $x_2(t)$ is now adjusted through all possible values until the resultant amplitude is minimized. What is that minimum resultant amplitude?

ROUGH WORK ONLY in the space below. Your solution to be marked goes on Page 3 of the Answer Sheets. Nothing you write in the space below will be seen by the markers.

Part B continued on next page...

14. A transverse wave pulse of constant shape travels at constant wave speed on a stretched string aligned with the x-axis. The shape of the pulse is specified by giving the transverse displacement y as a function of position x and time t:

$$y(x,t) = A\frac{a^2}{a^2 + (x+ct)^2} \qquad (A,\ a \text{ and } c \text{ are positive constants.})$$

[2] (a) Find the corresponding expressions for the partial derivatives $\frac{\partial y}{\partial x}$ and $\frac{\partial y}{\partial t}$.

[2] (b) Find the expression for the slope of the string at $x = -a$ and $t = 0$.

[2] (c) Find the expression for the velocity of the particle of the string at $x = 0$ and $t = a/c$.

[2] (d) At what values of x does $y(x, 0) = A/101$?

[2] (e) You are standing at the point $x = +4a$. You are measuring the transverse displacement of the string with an optical device that responds only when the displacement $y(x,t)$ at your location exceeds $A/101$. As the pulse passes you, your detector starts responding at $t = t_1$ and stops responding at $t = t_2$. What are t_1 and t_2 (expressed as multiples of a/c)?

ROUGH WORK ONLY in the space below. Your solution to be marked goes on Page 4 of the Answer Sheets. Nothing you write in the space below will be seen by the markers.

END OF PART B; END OF TEST

Trigonometry

$\sin^2\theta + \cos^2\theta = 1$ $\quad \tan\theta = \frac{\sin\theta}{\cos\theta}$ $\quad \sin 2\theta = 2\sin\theta\cos\theta$ $\quad \cos 2\theta = cos^2\theta - \sin^2\theta$

$\tan 2\theta = \frac{2\tan\theta}{1-\tan^2\theta}$ $\quad \sin(\alpha\pm\beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$ $\quad \cos(\alpha\pm\beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$

Physical constants

speed of light in vacuum $= 3.00\times10^8$ m/s absolute zero $= 0$ K $= -273.15$ C

ideal gas constant$= 8.314$ J/mol·K $\quad \gamma = \frac{c_p}{c_v} = \begin{cases} 5/3 \text{ monatomic gas} \\ 7/5 \text{ diatomic gas} \end{cases}$ $\quad$ 1 atm$= 1.01325\times10^5$ Pa

Mean molar mass of air = 28.8 g/mol Density of dry air (1 atm, 20° C)$= 1.20$ kg/m^3

Formulas

$n = c/v$ $\quad \theta_r = \theta_a$ $\quad n_a\sin\theta_a = n_b\sin\theta_b$ $\quad c = f\lambda$ $\quad \lambda = \lambda_o/n$ $\quad \sin\theta_{crit} = \frac{n_a}{n_b}$

$s = -s'$ $\quad m = \frac{y'}{y}$ $\quad \frac{n_a}{s} + \frac{n_b}{s'} = \frac{n_b - n_a}{R}$ $\quad m = -\frac{n_a s'}{n_b s}$ $\quad \frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ $\quad f = \frac{R}{2}$

$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $\quad m = -\frac{s'}{s}$ $\quad f$-number$= f/D$ $\quad M = \frac{\theta'}{\theta}$ $\quad M = \frac{25 \text{ cm}}{f}$

$M = m_1 M_2$ $\quad M = -\frac{f_1}{f_2}$ $\quad \frac{d^2x}{dt^2} = -\omega^2 x$ $\quad x(t) = A\cos(\omega t + \phi_o)$ $\quad y(t) = A\sin(\omega t + \phi_o)$

$\omega^2 x^2 + v_x^2 = \omega^2 A^2$ $\quad T = \frac{1}{f} = \frac{2\pi}{\omega}$ $\quad e^{\pm i\theta} = \cos\theta \pm i\sin\theta$ $\quad Ae^{i(\omega t + \phi_o)} = Ae^{i\phi_o}e^{i\omega t} = \tilde{A}e^{i\omega t}$

$\tilde{A} = a + ib$ $\quad A = |\tilde{A}| = \sqrt{a^2 + b^2}$ $\quad \tan\phi_o = \frac{b}{a}$ $\quad \tilde{A} = \sum_i \tilde{A}_i$ $\quad a = \sum_i a_i$ $\quad b = \sum_i b_i$

$y(x,t) = y(u) = y(x \pm ct)$ $\quad \frac{\partial y}{\partial x} = \pm\frac{1}{c}\frac{\partial y}{\partial t}$ $\quad \frac{\partial^2 y}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 y}{\partial t^2}$ $\quad y(x,t) = f(x - ct) + g(x + ct)$

$y(x,t) = A\sin[kx - \omega t + \phi] = -A\sin[\omega t - kx - \phi] = A\cos(\omega t - kx - \phi + \pi/2)$ $\quad c = f\lambda = \frac{\omega}{k}$

$Ae^{i(kx - \omega t + \theta)} = Ae^{i\theta}e^{i(kx - \omega t)} = \tilde{A}e^{i(kx - \omega t)} = \tilde{A}e^{ikx}e^{-i\omega t}$ $\quad k = \frac{2\pi}{\lambda}$ $\quad T = \frac{1}{f} = \frac{2\pi}{\omega}$

$c = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$ $\quad PV = nRT$ $\quad PV =$ constant $\quad PV^\gamma =$ constant.

Max 20; RBH 2010-10-07