UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 125.3

FINAL EXAMINATION

April 23, 2022 Instructor: Y. Yao Time: 180 minutes

NAME: _____ STUDENT NUMBER: _____

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

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), a formula sheet, and an OMR (OpScan) sheet. The test paper consists of 9 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 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.
5. Enter your name and code your NSID on the OMR sheet.
6. The test paper, the formula sheet and the OMR sheet must all be submitted.

ONLY THE FOUR PART B QUESTIONS THAT YOU INDICATE WILL BE MARKED

PLEASE INDICATE WHICH FOUR PART B QUESTIONS ARE TO BE MARKED

QUESTION NUMBER	TO BE MARKED	MAXIMUM MARKS	MARKS OBTAINED
A1-20	☑	20	
B1	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
B5	❑	10	
TOTAL		60	

PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET. EACH QUESTION IS WORTH 1 MARK.

A1. 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. The atmospheric pressure is P_0. Which one of the following statements is correct?

(A) $P_2 < P_1$ (B) $P_2 = 2P_1$ (C) $P_2 > 2P_1$ (D) $P_1 < P_2 < 2P_1$ (E) $P_2 = P_1 + P_0$

A2. Consider a wood block that is floating in water. The bottom of the block is a depth d_w below the surface. If the same block is floating in glycerine, the bottom of the block is a depth d_g below the surface. Given that the density of glycerine is greater than the density of water, which one of the following statements is correct?

(A) $d_w > d_g$ (B) $d_w < d_g$ (C) $d_w = d_g$
(D) The relationship between d_w and d_g cannot be determined without knowing the mass of the block.
(E) The relationship between d_w and d_g cannot be determined without knowing the volume of the block.

A3. A water supply maintains a constant volume flow rate through a hose. The water coming out of the circular hose nozzle has a speed v. You want to change the opening of the hose nozzle so that the speed of the water coming out is $3v$. What should you do?

(A) You should increase the diameter of the nozzle to 3 times its original value.

(B) You should increase the diameter of the nozzle to $\sqrt{3}$ times its original value.

(C) You should reduce the diameter of the nozzle to $1/\sqrt{3}$ times its original value.

(D) You should reduce the diameter of the nozzle to 1/3 times its original value.

(E) You should reduce the diameter of the nozzle to 1/6 times its original value.

A4. A mass is attached to a light spring on a frictionless surface and set in simple harmonic motion. The frequency of oscillation is f. If two identical springs of this kind are placed side by side, forming a new spring system of the same length, and the same mass is set in simple harmonic motion again, what is the new frequency of oscillation?

(A) $0.5f$ (B) f (C) $1.414f$ (D) $0.707f$ (E) $2f$

A5. Two simple pendulums, A and B, have the same length L, but the mass of A is twice of that mass of B, *i.e.*, $m_A = 2m_B$. Their amplitudes of oscillation are equal. Their periods are T_A and T_B, respectively, and their maximum speeds are v_A and v_B. Which one of the following statements is correct?

(A) $T_A = T_B$ and $v_A > v_B$ (B) $T_A = T_B$ and $v_A < v_B$ (C) $T_A > T_B$ and $v_A < v_B$
(D) $T_A < T_B$ and $v_A > v_B$ (E) $T_A = T_B$ and $v_A = v_B$

A6. A wave moving along a string is described by the equation,

$$y(x,t) = 10\sin\left[2\pi\left(\frac{x}{20} - \frac{t}{2}\right)\right],$$

where x and y are in centimeters and t is in seconds. Which statement below can be concluded from this equation?

(A) The wave has an amplitude of 5 cm.
(B) The wave has a wavelength of $10/\pi$ cm.
(C) The wave has a frequency of 2 Hz.
(D) The wave has a period of 2 s.
(E) The wave is propagating in the negative x direction.

A7. A sound wave in air has a frequency of 500 Hz and a wavelength of 0.68 m. What is the air temperature?

(A) –18°C (B) 0°C (C) 15°C (D) 27°C (E) 36°C

A8. You stand beside the tracks. A train **<u>decelerates</u>** down the track, coming toward you slower and slower. Which of the following do you hear?

(A) the intensity increasing and the frequency decreasing
(B) the intensity decreasing and the frequency increasing
(C) the intensity and the frequency both increasing
(D) the intensity decreasing and the frequency remaining the same
(E) the intensity increasing and the frequency remaining the same

A9. Four waves moving along a string are described by the wave functions,

Wave 1: $y(x, t) = 5\sin(\pi x + 3\pi t + \pi/2)$,
Wave 2: $y(x, t) = 5\sin(\pi x - 3\pi t - \pi/2)$,
Wave 3: $y(x, t) = 5\sin(\pi x - 3\pi t + \pi/2)$,
Wave 4: $y(x, t) = 5\sin(\pi x + 3\pi t - \pi/2)$,

where x and y are in centimeters and t is in seconds. Which statement below can be concluded?

(A) Wave 1 and Wave 4 form a constructive interference.
(B) Wave 2 and Wave 3 form a constructive interference.
(C) Wave 2 and Wave 4 form a constructive interference.
(D) Wave 1 and Wave 3 form a standing wave.
(E) Wave 2 and Wave 3 form a standing wave.

A10. A tube open at both ends has a fundamental resonant frequency of f. If you close one end of the tube, the fundamental resonant frequency becomes…

(A) $0.25f$ (B) $0.5f$ (C) $1.5f$ (D) $2f$ (E) $4f$

A11. When white light disperses as it passes through a prism, the deviation angle between the incident and outgoing light rays increases from red to yellow to green to blue to violet. For which of the following colours is the speed of the light in the prism the lowest?

(A) Violet (B) Green (C) Yellow (D) Red
(E) The speed of light in prism is the same for all colors.

A12. An object is placed 40.0 cm from a converging lens having a focal length of 10.0 cm. Which of the following statements is true regarding the image formed by the lens?

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

A13. You have a choice of two converging lenses, Lens 1 has a focal length of 10.0 cm and Lens 2 has a focal length of 7.50 cm. Which one of the following scenarios will produce the **<u>largest</u>** possible focussed image on the retina when one of the lenses is used as a simple magnifier? Suppose you have normal eye vision.

(A) Use Lens 1 and put the object at 25 cm from your eye.
(B) Use Lens 2 and put the object at 25 cm from your eye.
(C) Use Lens 1 and adjust the object position so that your eye is relaxed.
(D) Use Lens 2 and adjust the object position so that your eye is relaxed.
(E) Use Lens 2 and adjust the object position so that the image forms at 25 cm from your eye.

A14. Light of wavelength 540 nm is incident on a single slit of width 0.150 mm, and a diffraction pattern is produced on a screen that is 2.00 m from the slit. What is the width of the central bright fringe?

(A) 0.36 cm (B) 0.72 cm (C) 1.44 cm (D) 1.76 cm (E) 2.16 cm

A15. An observer on the Earth sees a spaceship at an altitude of 9.80 km moving downward toward the Earth at a speed of 0.800 c. What is the spaceship's altitude as measured by an observer in the spaceship?

(A) 5.88 km (B) 7.84 km (C) 8.93 km (D) 12.7 km (E) 16.3 km

A16. A particle has a relativistic momentum equal to p. If the particle's speed doubles, its momentum will be

(A) greater than $2p$. (B) equal to $2p$. (C) less than $2p$. (D) equal to $0.5p$. (E) equal to $0.25p$.

A17. A beam of red light strikes a metal surface and causes a stream of electrons emitted from the surface. What will happen if a beam of violet light, with the same intensity as the red light, strikes the same surface?

(A) More electrons are emitted in a given time interval.
(B) It takes shorter time for the electrons to emit from the surface.
(C) No electrons are emitted.
(D) The electrons that are emitted are more energetic.
(E) The electrons that are emitted are less energetic.

A18. One of the following nuclear reactions or decays is **not** possible. Which one?

(A) ${}^{2}_{1}\mathrm{H} + \mathrm{p} \rightarrow {}^{3}_{2}\mathrm{He} + \gamma$

(B) ${}^{14}_{7}\mathrm{N} + \alpha \rightarrow {}^{17}_{8}\mathrm{O} + \mathrm{p}$

(C) ${}^{226}_{88}\mathrm{Ra} \rightarrow {}^{223}_{86}\mathrm{Rn} + \mathrm{e}^{-} + \overline{\nu}$

(D) ${}^{214}_{82}\mathrm{Pb} \rightarrow {}^{214}_{83}\mathrm{Bi} + \mathrm{e}^{-} + \overline{\nu}$

(E) ${}^{32}_{16}\mathrm{S} + \mathrm{n} \rightarrow {}^{32}_{15}\mathrm{P} + \mathrm{p}$

A19. A particle a with kinetic energy K_a bombards a stationary target nucleus X, resulting in a daughter nucleus Y and outgoing particle b. If this reaction is **endothermic**, which relation between K_a and the Q value of the reaction can be concluded?

(A) $K_a < -Q$ (B) $K_a = Q$ (C) $K_a < Q$ (D) $K_a = -Q$ (E) $K_a > -Q$

A20. An ideal gas in an enclosed container at 3.0 atm and 10°C is heated to 150°C. If the volume is held constant during the heating, what is the final pressure?

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

PART B

ANSWER FOUR OF THE PART B QUESTIONS ON THE FOLLOWING PAGES AND INDICATE YOUR CHOICE OF QUESTIONS ON THE COVER PAGE.

FOR EACH OF YOUR CHOSEN PART B QUESTIONS, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWERS IN THE BOXES PROVIDED.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES.

SHOW AND EXPLAIN YOUR WORK – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY.

EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

B1. A certain pipe has two successive resonant frequencies at 315 Hz and 405 Hz. The speed of sound in air is 343 m/s.

(a) What is the fundamental frequency of this pipe? (Hint: determine the type of pipe using two given frequencies) [4 marks]

Hz

(b) What is the length of this pipe? [3 marks]

m

(c) You cut this pipe into two **unequal** pieces, giving you two shorter pipes. To your surprise, these two pipes have the same fundamental frequency. Determine the fundamental frequency. If you did not get an answer for part (b) use a value of 2.00 m. [3 marks]

Hz

B2. Consider two lenses: a converging lens whose focal points are a distance of 10.0 cm from the centre of the lens; and a diverging lens whose focal points are a distance of 16.7 cm from the centre of the lens. Suggestion: Draw a diagram to justify your answer. **Express your answers with correct sign conventions.**

(a) An object is placed a distance of 25.0 cm in front of the converging lens. Determine the distance of the image from this lens. [3 marks]

cm

(b) Without changing the position of the object or converging lens, the diverging lens is now placed between the object and the converging lens, a distance of 10.0 cm from the object. Determine the magnification produced by the diverging lens. [3 marks]

(c) For the situation in (b), determine the distance of the **final** image from the converging lens. [4 marks]

cm

B3. X-rays with the energy 11.7 keV are shone on a crystal, which acts like a diffraction grating. The spacing of this crystal "grating" is the spacing between planes of atoms in the crystal. After passing through the crystal, it is observed that the first order maximum occurs at an angle of 25.0°.

(a) Determine the wavelength of the X-ray, in nm. [2 marks]

nm

(b) Determine the crystal plane spacing, in nm. [4 marks]

nm

(c) Determine the highest order of constructive interference that can be observed with this arrangement. [4 marks]

m_{max} =

B4. In an inertial reference frame S, a red light flashes at location $x_1 = +3.00$ m and time $t_1 = 1.00$ ns, and a blue light flashes at $x_1 = +5.00$ m and $t_2 = 9.00$ ns. Reference frame S' moves in $+x$ direction with speed v relative to S, and at $t = t' = 0$ the origins of the two frames coincide. Both flashes are observed to occur at the same location in S'.

(a) What is the relative speed between S and S'? [3 marks]

m/s

(b) Find the location of the two flashes in frame S'. [4 marks]

m

(c) What is the separation in time, if any, between the two flashes in frame S'? Express your answer in ns. [3 marks]

ns

B5. $^{239}_{94}\text{Pu}$ has an atomic mass of 239.052156 u. This isotope is radioactive and decays to $^{235}_{92}\text{U}$ with a half-life of 2.40×10^4 years. Consider a sample of 1.00 kg of pure $^{239}_{94}\text{Pu}$ at time $t = 0$. Use 365.25 days for the average length of a year.

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

(b) Calculate the number of $^{239}_{94}\text{Pu}$ nuclei present in the sample at $t = 0$. ($1\text{ u} = 1.660\,539 \times 10^{-27}$ kg) [3 marks]

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

Bq

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

years