

Last Name: Kwiat First Name _____ NetID _____
Discussion Section: _____ Discussion TA Name: _____

Instructions—

Turn off your cell phone and put it away.

Keep your calculator on your own desk. Calculators may not be shared.

This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil; do **not** use a mechanical pencil or a pen. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner.
2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.
3. Print your NetID in the **NETWORK ID** boxes, and then mark the corresponding circle below each of the letters or numerals. Note that there are different circles for the letter “I” and the numeral “1” and for the letter “O” and the numeral “0”. **Do not** mark the hyphen circle at the bottom of any of these columns.
4. **This Exam Booklet is Version A.** Mark the **A** circle in the **TEST FORM** box at the bottom of the front side of your answer sheet.
5. Stop **now** and double-check that you have bubbled-in all the information requested in 2 through 4 above and that your marks meet the criteria in 1 above. Check that you do not have more than one circle marked in any of the columns.
6. Do **not** write in or mark any of the circles in the STUDENT NUMBER or SECTION boxes.
7. On the **SECTION line**, print your **DISCUSSION SECTION**. (You need not fill in the COURSE or INSTRUCTOR lines.)
8. Sign (**DO NOT PRINT**) your name on the **STUDENT SIGNATURE line**.

*Before starting work, check to make sure that your test booklet is complete. You should have 12 **numbered** pages plus two Formula Sheets at the end.*

Academic Integrity—Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including expulsion.

Exam Grading Policy—

The exam is worth a total of xxx points, composed of two types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*

Partial credit will be granted as follows.

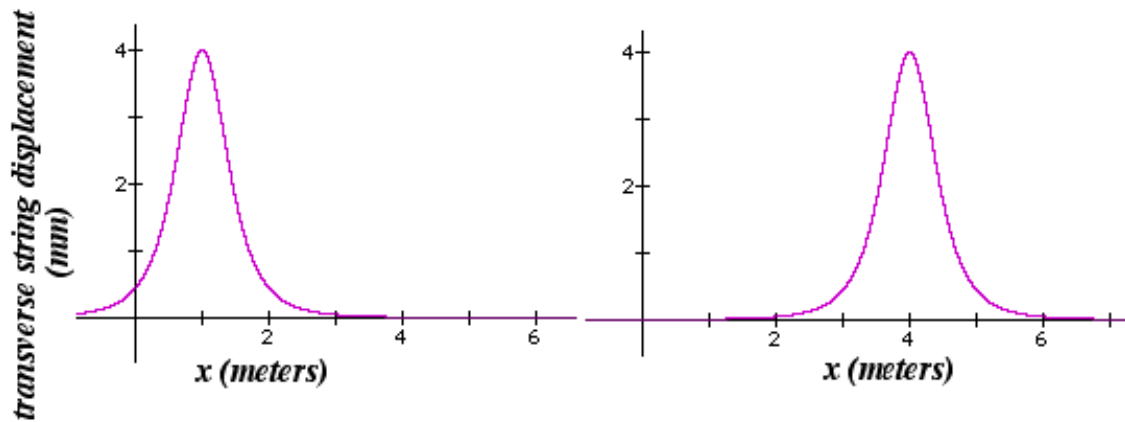
- (a) If you mark only one answer and it is the correct answer, you earn **6** points.
- (b) If you mark *two* answers, one of which is the correct answer, you earn **3** points.
- (c) If you mark *three* answers, one of which is the correct answer, you earn **2** points.
- (d) If you mark no answers, or more than *three*, you earn **0** points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*

No partial credit.

- (a) If you mark only one answer and it is the correct answer, you earn **3** points.
- (b) If you mark a wrong answer or no answers, you earn **0** points.

1 A transverse wave pulse traveling in the $+x$ direction in a string is observed at time $t=0$ and $t = 7$ sec to look like:



At what speed does this wave travel?

- 0.43 m/s
- 2.33 m/s
- 3.00 m/s

2. Two waves

$$y = A \cos(200t - 10x)$$

$$y = A \cos(200t - 10x + \pi/4)$$

are superposed. What is the resulting wave?

- $2A \cos(200t - 10x + \pi/8)$
- $\sqrt{2} A \cos(200t - 10x + \pi/8)$
- $4A \cos(200t - 10x + \pi/8)$
- $1.85 A \cos(200t - 10x + \pi/8)$
- none of these

3. Two waves

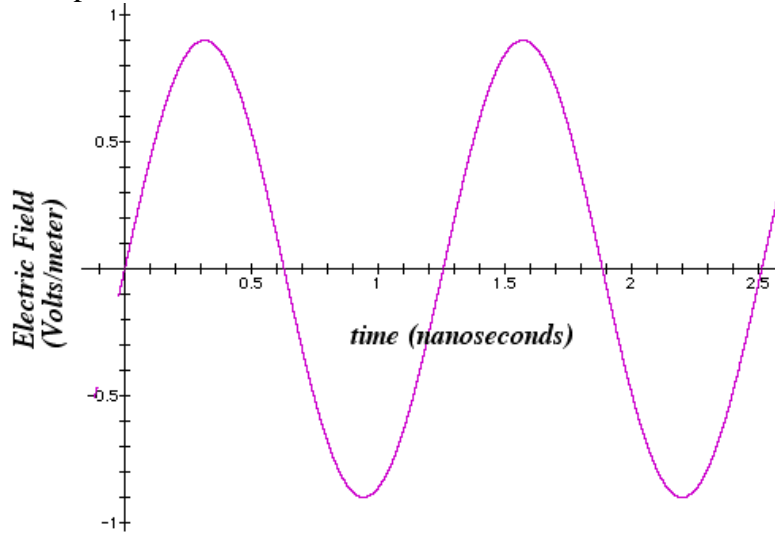
$$y = A \cos(200t - 10x)$$

$$y = 2A \cos(200t - 10x - \pi/4)$$

are superposed. What is the resulting wave?

- $3A \cos(200t - 10x - \pi/8)$
- $\sqrt{5} A \cos(200t - 10x - \pi/8)$
- $2.80 A \cos(200t - 10x - 0.53)$

The next two problems concern the following plot of the field strength of an electromagnetic wave as a function of time and at a fixed position in space. Its wavespeed is 3×10^8 m/second.



4. What is its amplitude?

- a. 0.9 V/m
- b. 1.8 V/m
- c. 3.6 V/m
- d. 0
- e. 1.25 V/m

5. What is its wavelength?

- a. 0.38 meters
- b. 1.25 meters
- c. 0.62 meters

The next three questions are related:

Two acoustic speakers are arranged as shown. Each emits a harmonic wave at (circular) frequency $\omega = 1200$ rad/second. A phase delay ϕ can be inserted in the signal to the lower speaker. The sound speed in this air is 340 m/s



6. What is the wavelength of these waves?
- 1.8 m
 - 0.9 m
 - 3.6 m
 - 0.28 m
 - 0.56 m
7. We are now told that each speaker, when driven without the other, emits a wave that has intensity $I_0 = 0.4$ Watt/m² at the receiver (the grey circle)

When driven together with $\phi = 0$, what is the intensity at the receiver?

- 0.4 Watt/m²
 - 0.8 Watt/m²
 - 1.6 Watt/m²
 - 1.2 Watt/m²
 - 0 Watt/m²
8. What phase difference ϕ will cause the intensity at the receiver to be $I_0/2$, i.e. 0.2 Watt/m²?
- 120 degrees
 - 60 degrees
 - 150 degrees
 - 139 degrees
 - 360 degrees

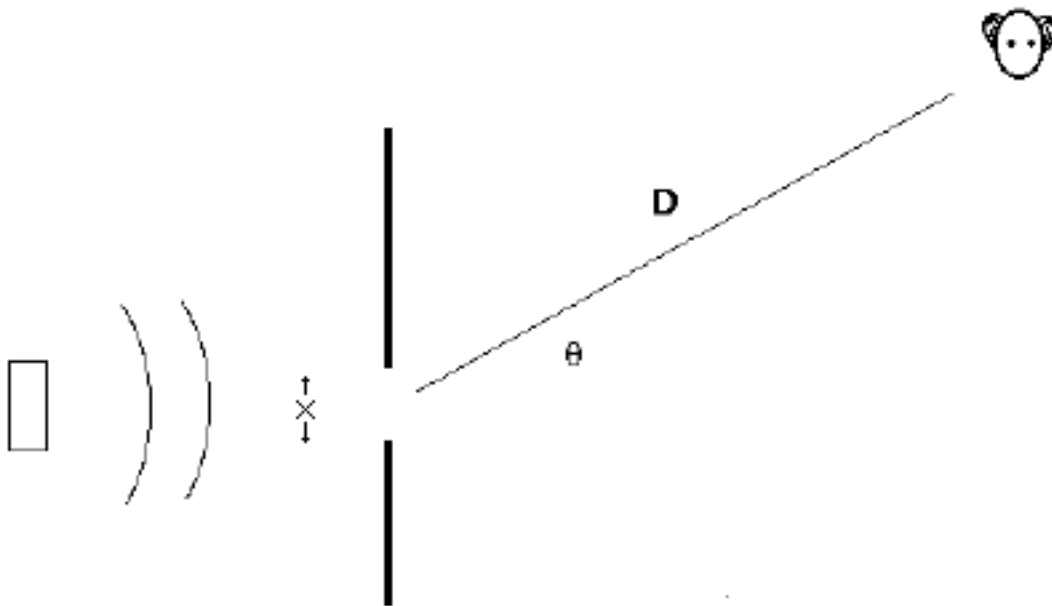
9. An array of four identical emitters of radio waves separated by distances d is as pictured. A receiver is placed at position R far from the array. The emitters radiate waves of frequency 15 MHz and wavelength 20 meters and separately generate the same intensity at R. There is no phase difference between the emitters.



There are many choices for separation d that will result in there being no intensity at position R. Two of these are:

- $d = 5$ meters and 10 meters
- $d = 20$ meters and 40 meters
- $d = 10$ meters and 20 meters
- $d = 6.67$ meters and 13.33 meters
- none of these

10. Sound waves in air ($c = 340$ m/s, frequency $f = 800$ Hz) are incident normally upon an $x = 0.7$ meter wide door in a rigid wall. A person listens at a large distance D from the door. A top view is indicated.

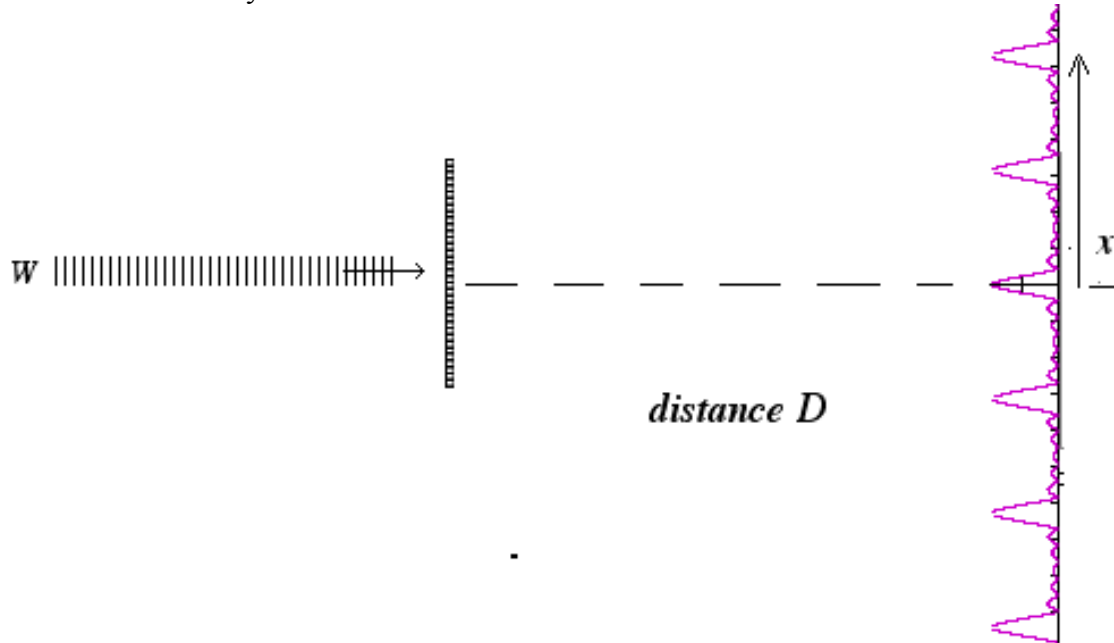


At which of these angles θ will the person hear the least sound intensity?

- 17°
- 37°
- 66°

The next two questions are related:

Light of wavelength 560 nm is incident normally upon a grating of 40 lines/ mm. The beam has a width $W = 1$ mm. An interference pattern is observed on a screen a distance $D = 0.7$ meters away.



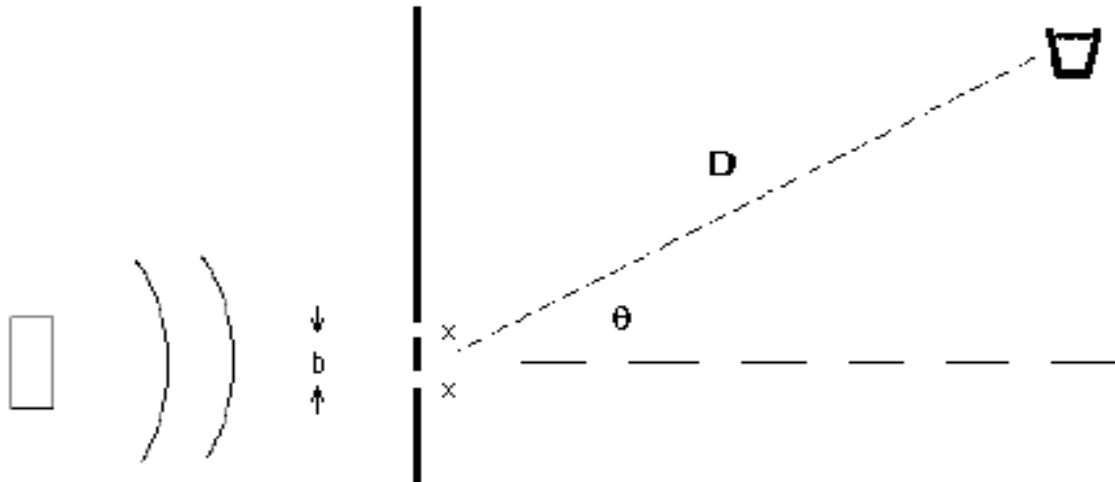
11. At what position x does the second principle interference maximum appear? (We do not count the maximum at $x = 0$)

- a. $x = 3.1$ cm
- b. $x = 1.6$ cm
- c. $x = 0.8$ cm
- d. $x = 2.4$ cm
- e. $x = 4.0$ cm

12. How many secondary (little) maxima should appear between the first and second principle maxima? (The sketch shows five, which is not correct.)

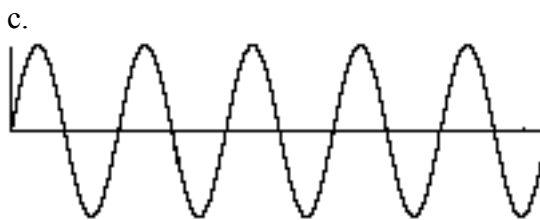
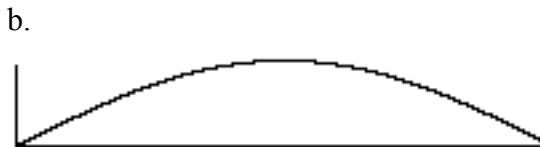
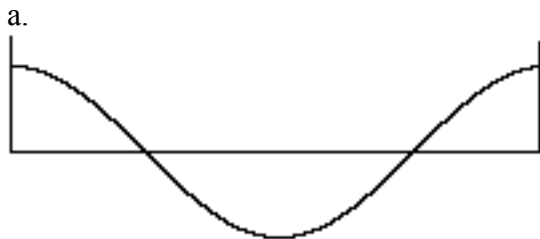
- a. 10
- b. 19
- c. 38

13. Microwaves of wavelength 1.5 cm are radiated towards a metal wall with two small holes, each of width $x = 2$ mm, separated by a distance $b = 4$ cm. At which of these angles θ will the water boil the most quickly?



- a. $\theta = 22^\circ$
- b. $\theta = 11^\circ$
- c. $\theta = 32^\circ$

14. Which of these three *cannot* be a wave-function for a particle in an infinite well?



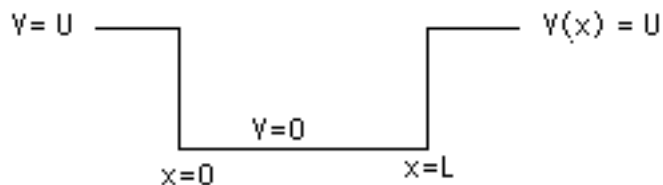
15. You are trying to resolve two pairs of two dots on a painting in a museum. One pair is red and the other is blue. Which pair requires you to be closer in order for you to be able to resolve?

- a. Red pair
- b. Blue pair
- c. Same

16. A particle is trapped in a 1-D infinite potential well from $x=0$ to $x=100$ pm and it is in its ground state. What is the probability of finding this particle in an interval of width 1 pm, centered at $x=25$ pm? Note, since the interval is much smaller than the length scale of the variation of the wave function, you can assume that the wave function is approximately constant within that interval: you do not have to do an integral.

- a. 0.010
- b. 0.10
- c. 0.02
- d. 0.014
- e. 0

17. Consider a finite potential well from $x=0$ to $x=L$ of depth U . In what region is $\psi(x) = D \exp(+\alpha x)$, with $\alpha = \{2m(U-E)/\hbar^2\}^{1/2}$ and $U > E$, and D some constant, an acceptable solution to the time-independent Schrodinger equation?



- a. $x < 0$
- b. $0 < x < L$
- c. $x > L$

18. In a 1-D infinite square well of length 1 nm, an electron is in the $n = 5$ state. At some point, the particle goes to a lower energy state and emits a photon with wavelength $\lambda = 1.57 \times 10^{-7}$ m. To which energy state did the electron go?

- a. $n=1$ state
- b. $n = 2$ state
- c. $n = 3$ state
- d. $n = 4$ state
- e. $n = 6$ state

19. What is the normalization constant A of the function which is zero for negative x and exponentially diminishing for positive x ? (a is a positive constant.)

$$\begin{aligned}\psi(x) &= 0 \quad (x < 0) \\ \psi(x) &= A \exp(-ax) \quad (x > 0)\end{aligned}$$

- a. $A = a$
- b. $A = 2a$
- c. $A = a^{1/2}$
- d. $A = (2a)^{1/2}$
- e. $A = (2a)^{-1/2}$

20. In a single-slit experiment, if the slit width is halved, the diffraction pattern on the screen will

- a. become half as wide
- b. become twice as wide
- c. stay the same

21. A virus particle of 22 nanometer diameter and mass 10 atto-grams ($\text{atto} = 10^{-18}$) is moving at a speed of 2 microns/ second. What is its wavelength?

- a. 11 nm
- b. 33 nm
- c. 82 nm
- d. 600 nm
- e. 2000 nm

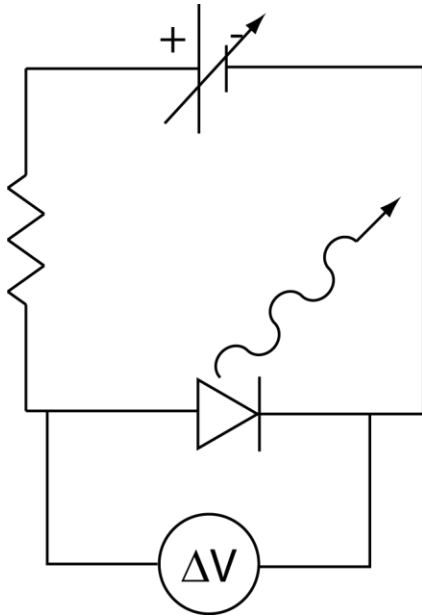
22. An ant whose mass is $0.5 \text{ mg} = 5 \times 10^{-7} \text{ kg}$ appears to be stationary. You are able to measure the position of this ant within an uncertainty of 0.7 micron . Which of the following comes closest to the least possible uncertainty in its speed?

- a. $\Delta v = 2 \times 10^{(-22)} \text{ m/s}$
- b. $\Delta v = 2 \times 10^{(-24)} \text{ m/s}$
- c. $\Delta v = 2 \times 10^{(-26)} \text{ m/s}$
- d. $\Delta v = 2 \times 10^{(-28)} \text{ m/s}$
- e. $\Delta v = 0$

23. Collimated light from a Na lamp illuminates a grating with 4000 slits/cm . How wide does the beam have to be in order to resolve the Na doublet transitions ($\lambda_1 = 589 \text{ nm}$ and $\lambda_2 = 589.6 \text{ nm}$) if we are operating in the third order ($m=3$)?

- a. 0.27 mm
- b. 0.51 mm
- c. 0.82 mm

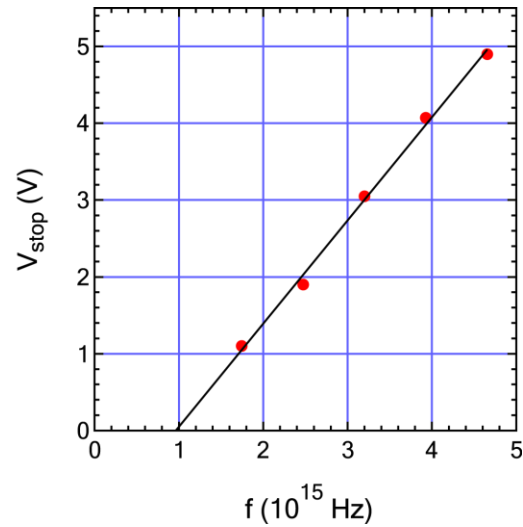
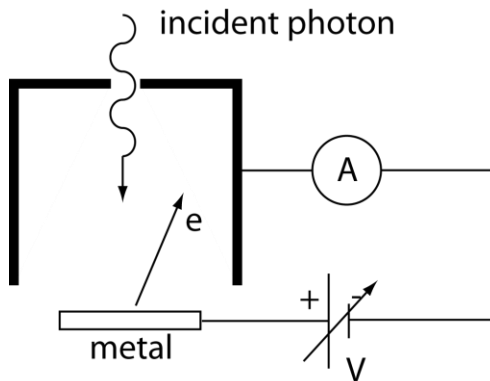
24. An LED emits $\lambda = 600 \text{ nm}$ light. At what voltage ΔV does the LED turn on?



- a. $\Delta V = 0.3 \text{ V}$
- b. $\Delta V = 1.0 \text{ V}$
- c. $\Delta V = 2.1 \text{ V}$

The next two questions are related.

In an alternate universe, where Planck's constant is different than in our universe, a measurement of the photoelectric effect yields the following data. With the exception of Planck's constant, all other physical quantities, e.g., electron charge, speed of light, etc. are the same.



25. Based on this data, what is the value of Planck's constant?

- $h = 2,2 \times 10^{-34} \text{ J s}$
- $h = 1.3 \times 10^{-34} \text{ J s}$
- $h = 6.6 \times 10^{-34} \text{ J s}$
- $h = 9.1 \times 10^{-34} \text{ J s}$
- can't be determined

26. What is the work function of the metal?

- $\Phi = 0.8 \text{ eV}$
- $\Phi = 1.4 \text{ eV}$
- $\Phi = 2.5 \text{ eV}$
- $\Phi = 4.1 \text{ eV}$
- can't be determined