Phys 100
Fall 2022

# Concepts of Physics: Test 3

30 November 2022

**Name:** _____ **Total:** **/50**

## Instructions

- There are 13 questions on 9 pages.
- Show your reasoning and calculations and always explain your answers.

## Physical constants and useful formulae

$$\text{speed} = \frac{\text{distance traveled}}{\text{time elapsed}} \qquad s = \frac{d}{t}$$

$$\text{frequency} = \frac{1}{\text{time per cycle}} \qquad f = \frac{1}{T}$$

$$\text{wave speed} = \text{wavelength} \times \text{frequency} \qquad s = \lambda \times f$$

$$\text{frequency} = \frac{\text{wave speed}}{\text{wavelength}} \qquad f = \frac{s}{\lambda}$$

$$\text{wavelength} = \frac{\text{wave speed}}{\text{frequency}} \qquad \lambda = \frac{s}{f}$$

$$\text{speed of light} = 3.0 \times 10^8\,\text{m/s} \qquad c = 3.0 \times 10^8\,\text{m/s}$$

$$\text{photon energy} = 6.63 \times 10^{-34}\,\text{Js} \times \text{frequency} \qquad E_{\text{photon}} = 6.63 \times 10^{-34}\,\text{Js} \times f$$

$$\text{frequency} = \frac{\text{photon energy}}{6.63 \times 10^{-34}\,\text{Js}} \qquad f = \frac{E_{\text{photon}}}{6.63 \times 10^{-34}\,\text{Js}}$$

$$\text{number of photons} = \frac{\text{total energy}}{\text{photon energy}} \qquad N = \frac{E}{E_{\text{photon}}}$$

$$\text{total energy} = \text{number of photons} \times \text{photon energy} \qquad E = N \times E_{\text{photon}}$$

$$\text{width central region} = \frac{2 \times \text{wavelength}}{\text{slit width}} \times \text{screen distance} \qquad w = \frac{2\lambda}{a}\,d$$

$$\text{particle wavelength} = \frac{6.63 \times 10^{-34}\,\text{Js}}{\text{mass} \times \text{speed}} \qquad \lambda = \frac{6.63 \times 10^{-34}\,\text{Js}}{m \times v}$$

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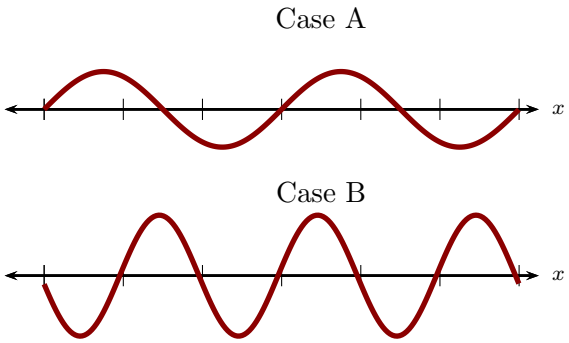
## Question 1

Two waves travel on *different* types of string. Their frequencies are identical. A snapshot of each at one moment is illustrated.




a) Which (choose one) of the following is true?

i) The wavelength of A is larger than that of B.

ii) The wavelength of A is smaller than that of B.

iii) The wavelength of A is the same as that of B.

b) Which (choose one) of the following is true?

i) The wave speed of A is larger than that of B.

ii) The wave speed of A is smaller than that of B.

iii) The wave speed of A is the same as that of B.

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## Question 2

An inventor builds a device which can detect the oscillations associated with electromagnetic waves. It only works if the frequency of the wave is less than $5.0 \times 10^6$ Hz. Will the device detect the oscillations associated with red light, which is an electromagnetic wave traveling with speed $3.0 \times 10^8$ m/s and with wavelength $6.32 \times 10^{-7}$ m? Explain your answer.

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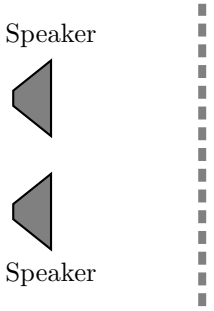
## Question 3

Two loudspeakers are situated alongside each other. Each plays the same pure note and the sound propagates away from them. A listener moves her ear from top to bottom *along the dashed line*. Which of the following is true regarding the intensity of the sound she hears as she moves her ear?




i) Same loudness at all locations along the dashed line.

ii) Loudest at the two locations on the dashed line directly opposite the speakers.

iii) Loudest midway between the speakers, softer at all other locations.

iv) Alternating loud and soft at many locations.

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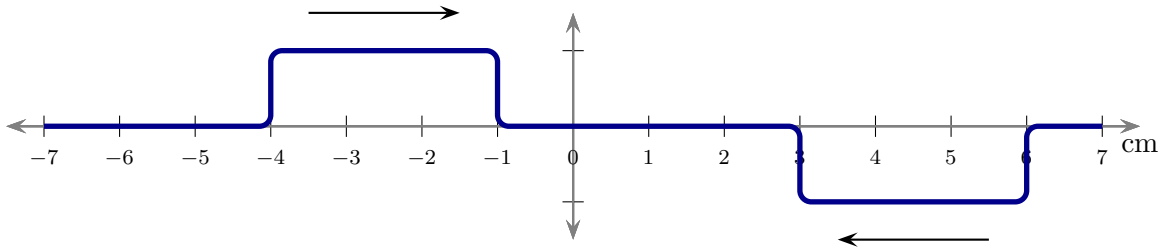
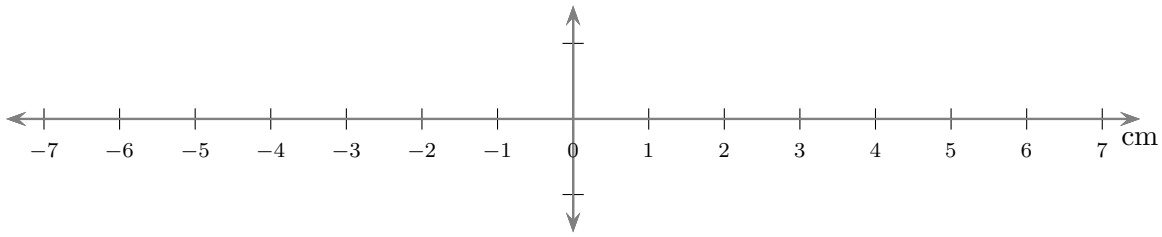
## Question 4

Two wave pulses each move along a string with speed 1 cm/s toward each other. At an initial instant the string appears as illustrated (the grid units are in cm).




Sketch the appearance of the string 3s after the initial instant, using the axes below.

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## Question 5

A laser pointer produces a beam of red light. The beam does not look like a wave. Describe how you could show that the light produced by the laser can be described in terms of waves. Your description must include: 1) what you would do to the light, 2) what would happen when you do this, 3) why waves describe what happens and 4) why particles cannot describe this.

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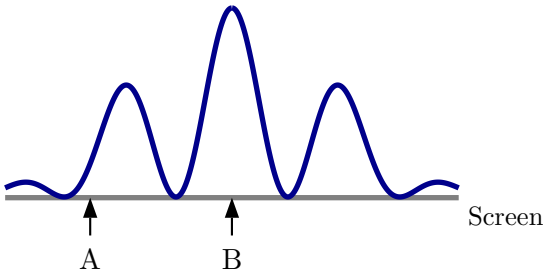
## Question 6

Light with a definite frequency is fired through a double slit arrangement toward a screen. The intensity of the light at various locations on the screen is indicated by the graph above the screen. Two locations labeled A and B on the screen are as illustrated. Which of the following (choose one) is true concerning any photons that pass through the slits?




i) Any given photon will never arrive at A but will always arrive at B.
ii) Any given photon will never arrive at B but will always arrive at A.
iii) Typically more photons will arrive at A than at B.
iv) Typically more photons will arrive at B than at A.

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## Question 7

A red laser produces light with frequency $4.74 \times 10^{14}$ Hz.

a) Determine the energy of one photon produced by this laser.

b) A green laser produces light with a wavelength which is smaller than that produced by the red laser. Describe whether the energy of a single photon produced by the green laser is the same as, smaller than or larger than that of a single photon produced by the red laser. **Explain your answer.**

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## Question 8

Two lasers produce red light with exactly the same frequency. However, the intensity (energy produced per second) of the light produced by laser A is much larger than the intensity of the light produced by laser B. Which of the following (choose one) is true?

i) The number of photons produced by A per second is larger than that produced by B; the energy of one photon of A is larger than the energy of one photon of B.
ii) The number of photons produced by A per second is larger than that produced by B; the energy of one photon of A is the same as the energy of one photon of B.
iii) The number of photons produced by A per second is the same as that produced by B; the energy of one photon of A is larger than the energy of one photon of B.
iv) The number of photons produced by A per second is the same as that produced by B; the energy of one photon of A is the same as the energy of one photon of B.

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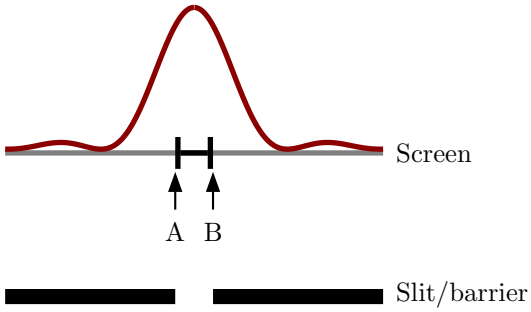
## Question 9

Neutrons are fired toward a single slit, which is wide enough to accommodate a neutron. A screen is placed beyond the slit and the locations at which neutrons arrive on the screen can be determined. The probability of arrival at various locations on the screen is graphed above the screen on the diagram. A region of the screen is marked from A to B as illustrated; this is exactly opposite the slit. Which of the following (choose one) is true?




i) Each individual neutron that passes through the slits definitely arrives in the marked region between A and B.

ii) Each individual neutron that passes through the slits arrives at many locations.

iii) Some neutrons that pass through the slits could arrive outside of the region between A and B.

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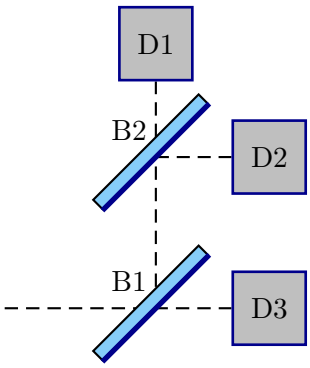
## Question 10

Laser light is fired from the left towards an arrangement of beamsplitters (labeled B1 and B2). Each beamsplitter reflects a photon with probability 1/2 and transmits it with probability 1/2. Three detectors (labeled D1, D2 and D3) are placed beyond the beamsplitters.




a) Suppose a single photon is fired toward B1 from the left. Which of the following (choose one) is true?

i) The photon will be detected in *all* of D1, D2 and D3.

ii) The photon will be detected in *both* of D1 and D2 but *not* in D3.

iii) The photon will be detected in *one* of D1 or D2 but *not* in D3.

iv) The photon will be detected in *one* of D1, D2 and D3.

b) Suppose 2000 photons are fired from the left to B1. Approximately how many do you expect to arrive at each detector?

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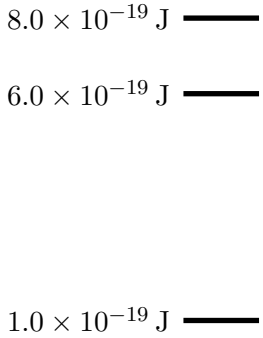
## Question 11

An artificial atom has exactly three energy levels as illustrated. The atom emits photons of light.




a) Determine the largest energy that any photon emitted by the atom could have.

b) Determine the largest frequency of the light that the atom could emit.

c) How many distinct frequencies of light could this atom emit? Explain your answer.

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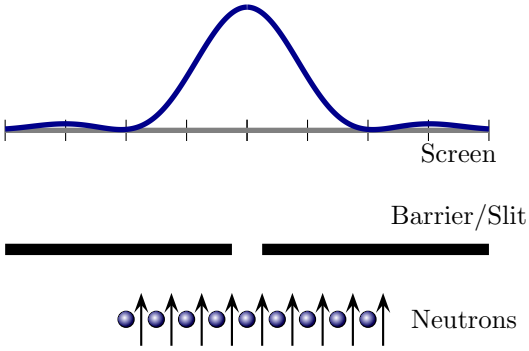
## Question 12

In an experiment, neutrons are fired, one at a time, toward a narrow single slit, which is wide enough to allow neutrons to pass. The neutrons are all fired toward the slit in precisely the same way. The probability distribution for arrival at various locations on a screen is depicted in the diagram below.




a) Suppose that the experiment is repeated with a second batch of neutrons. This time the neutrons are all fired toward the slit with a larger speed than before. Is the the wavelength of these neutrons (in the second batch) the same as, larger than or smaller than the wavelength of the neutrons in the original experiment? Explain your answer.

b) Is the region in which most neutrons arrive on the screen in the experiment with the second batch the same as, wider than or narrower than the region for the original experiment? Explain your answer.

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## Question 13

You are given the atomic spectra for several elements, including sodium, mercury and potassium. You are given an unknown powdered material which you can burn safely. Describe how you could determine whether the powder contains sodium by using the light that is produced when it burns.

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