Phys 100
Fall 2024

Concepts of Physics: Test 3

15 November 2024

Name: SOLUTION **Total:** /60

Instructions

- There are 13 questions on 7 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

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

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

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

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

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

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

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

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

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

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

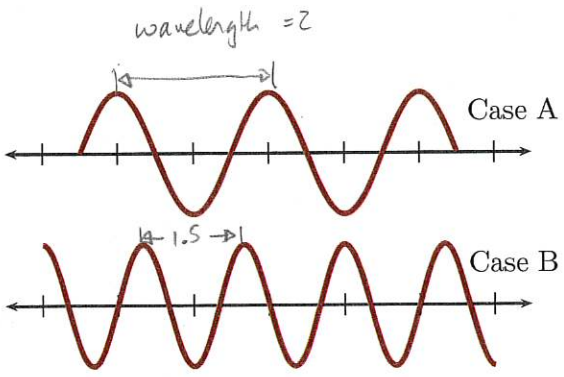
$$\text{total energy} = \text{number of photons} \times \text{photon energy} \qquad E = N \times E_{\text{photon}}$$

$$\text{probability} = \frac{\text{number that arrive}}{\text{total number that could arrive}}$$

$$\text{number that arrive} = \text{probability} \times (\text{total number that could arrive})$$

Question 1

Two waves travel on the same type of string and their speeds are identical. Snapshots of sections of the string at one moment are illustrated.



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

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

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

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

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

i) The frequency of A is larger than the frequency of B.

ii) The frequency of A is smaller than the frequency of B.

iii) The frequency of A is the same as the frequency of B.

frequency = speed / wavelength

larger for A

smaller for A

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Question 2

Cell phones transmit electromagnetic waves, which travel with the speed of light, and have frequency 9.00×10^8 Hz. Determine the wavelength of these waves.

$$\text{wavelength} = \frac{\text{speed}}{\text{frequency}} = \frac{3.0 \times 10^8 \text{ m/s}}{9.0 \times 10^8 \text{ Hz}}$$

$$= 0.33 \text{ m}$$

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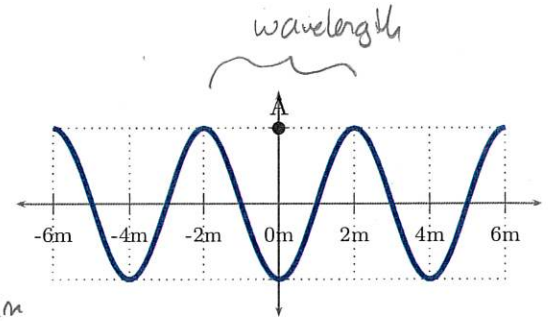
Question 3

A snapshot of a wave on a slinky is illustrated. The wave travels right with speed 12 m/s.



a) Determine the wavelength and frequency of the wave.

From the graph wavelength = 4m

$$\text{frequency} = \frac{\text{speed}}{\text{wavelength}} = \frac{12\,\text{m/s}}{4\,\text{m}} = 3\,\text{Hz}$$

b) How many crests pass point A in 5.0 s? Explain your answer.

The frequency is 3Hz ⇒ 3 crests pass every second

⇒ in 5s 3×5 crests = 15 crests

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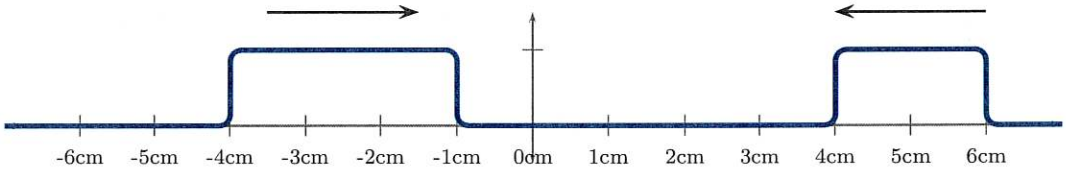
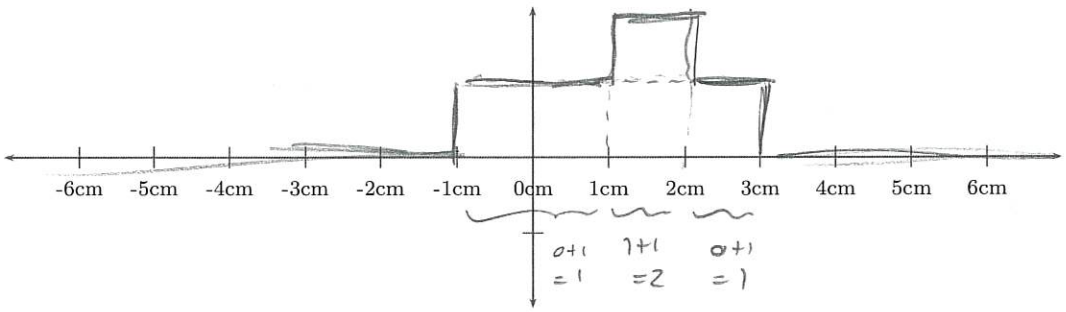
Question 4

Two rectangular wave pulses move along a string, each with speed 1 cm/s. Initially the string appears as illustrated.



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

each moves 3cm



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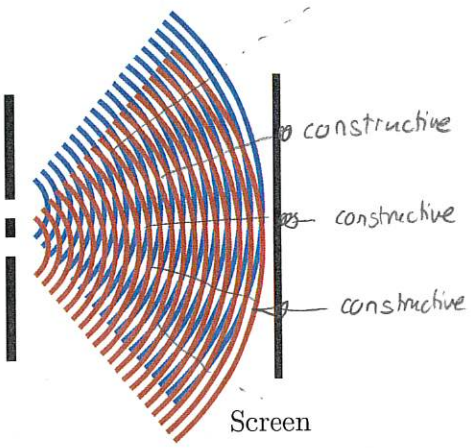
Question 5

Light passes through two closely spaced slits. The waves beyond the slits are illustrated. The light eventually arrives at the illustrated screen. How many bright spots appear on the screen?

i) None.
ii) Exactly 1.
iii) Exactly 2.
(iv) Exactly 3.
v) Exactly 4.
vi) Exactly 5.
vii) More than 5.

Bright where there is constructive interference.



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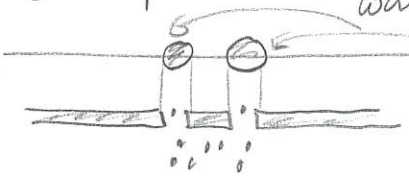
Question 6

Light is incident on a barrier which contains two narrow slits. The pattern on a screen placed beyond the barrier is illustrated.

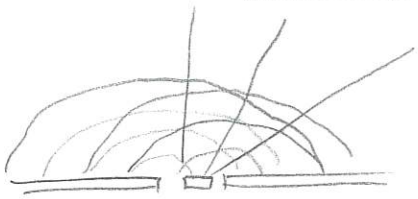
a) Assume that light arriving at the barrier and slits consists of a stream of particles. Each particle is either absorbed by the barrier or else passes through one slit without any disturbance to its motion. Would this be able to describe the pattern that is observed? Explain your answer.

NO If they were particles + passed straight through, there would be two bright spots



b) Assume that light arriving at the barrier and slits consists of a wave. Would this be able to describe the pattern that is observed? Explain your answer.

Yes constructive interference from two overlapping waves gives many bright spots.



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Question 7

Bright laser light shines on a barrier that with a single narrow slit. The light arrives at a screen beyond the barrier and it produces a pattern of bright and dark regions. The intensity of the light is reduced to the point where only one photon passes from the slit to the screen in any single second. Which of the following (choose one) is true for such low intensity light?

photons arrive one location at a time randomly.

i) The pattern looks similar to before but is just a lot dimmer.
ii) The pattern is replaced by a single tiny bright spot at the center.
iii) The pattern is replaced by a series of tiny spots that are evenly spaced.
iv) The pattern is replaced by a series of tiny spots that are located randomly.

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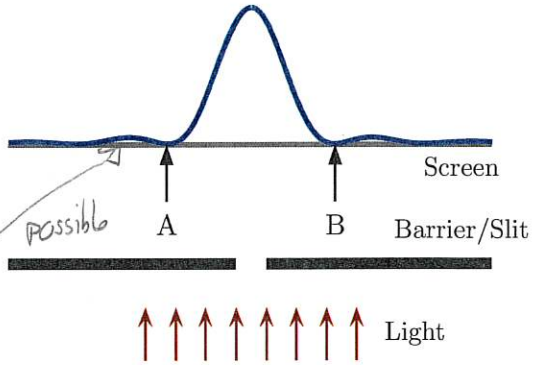
Question 8

Light is fired toward a single slit in an opaque barrier. The intensity of the light pattern is as illustrated. Which (choose one) of the following is true?



Particles will arrive at random locations, most between A and B and some beyond

i) Each particle of light will hit exactly the same point on the screen, somewhere between A and B.
ii) Particles of light will hit different points on the screen, with all arriving between A and B.
iii) Particles of light will hit different points on the screen, with most, but not all, arriving between A and B.
iv) Any single particle of light will arrive at different locations on the screen.

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Question 9

Light is fired toward a screen that contains a small detector. The probability that a photon arrives in the detector is 0.50. Determine the number of photons that will arrive in the detector if 60000 photons are fired toward the screen.

number arriving = total number x prob

= 60000 x 0.5

= 30000

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Question 10

Hydrogen gas produces light with various wavelengths. This light is filtered so that the only wavelength present is 656×10^{-9} m. This corresponds to frequency 4.57×10^{14} Hz.

a) Determine the energy of a single photon of this light.

energy $= 6.63 \times 10^{-34}$ J·s $\times$ frequency

$= 6.63 \times 10^{-34}$ J·s $\times$ 4.57×10^{14} Hz

$= 3.02 \times 10^{-19}$ J

b) Is it possible to arrange for this light to deliver only a quarter of the energy contained in a single photon? Briefly explain your answer.

No, cannot split a photon

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Question 11

A light source produces green light with exactly one frequency. The intensity of this light can be reduced. As the intensity is reduced which of the following (choose one) is true?

i) The energy of each photon stays the same. The number of photons produced per second stays the same.

ii) The energy of each photon stays the same. The number of photons produced per second decreases.

iii) The energy of each photon decreases. The number of photons produced per second stays the same.

iv) The energy of each photon decreases. The number of photons produced per second decreases.

energy (one photon) only depends on frequency

$\Rightarrow$ same per photon

need fewer photons to make less.

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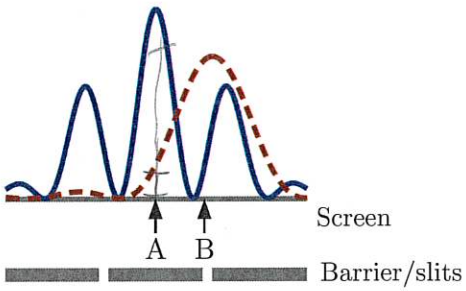
Question 12

Light travels toward an arrangement of barriers and slits as illustrated. When both slits are open, the intensity profile for the light is illustrated by the solid blue curve. When just the left slit is blocked, the intensity profile is indicated by the dashed red line.



a) Consider photons arriving at the location labeled A. Does blocking the left slit increase, decrease or not affect the probability of a photon arriving at location A? Explain your answer.

Probability drops when opening slit ⇒ decreases
↳ blue curve higher

b) Consider photons arriving at the location labeled B. Does blocking the left slit increase, decrease or not affect the probability of a photon arriving at location B? Explain your answer.

The red curve is higher ⇒ probability increases

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Question 13

A laser produces light with wavelength 5.6×10^{-7} m. The energy of a single photon is 3.5×10^{-19} J. The laser produces total energy 0.0020 J each second. Which of the following (choose one) is the approximate number of photons produced by this laser every second?

i) 7.0×10^{-22}
ii) 1.75×10^{-16}
iii) 3571
iv) 5.7×10^{15}
v) 2.8×10^{18}

$\frac{0.0020\,\text{J}}{3.5 \times 10^{-19}\,\text{J}} = 5.7 \times 10^{15}$

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