Concepts of Physics: Test 3

4 December 2023

Name: _____ **Total:** /50

Instructions

- There are 15 questions on 8 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

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

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

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

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

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

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

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

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

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

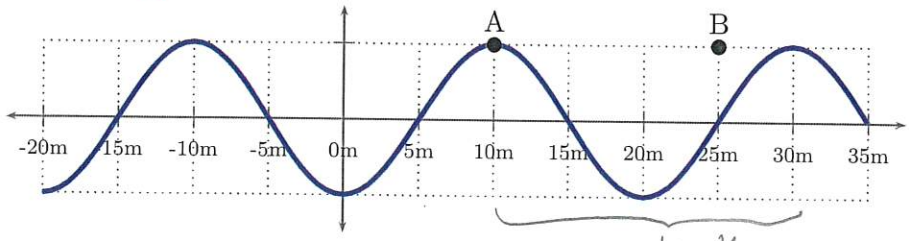
$$\text{total energy} = \text{number of photons} \times \text{photon energy} \qquad E = N \times E_{\text{photon}}$$

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

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

Question 1

A snapshot of a wave on a string is illustrated below. The point on the string marked A moves up and down ~~20~~ 5 times per second.



a) Determine the wavelength of the wave.

crest to crest 20m.

b) Determine the wavespeed.

speed = wavelength × freq

= 20m × 5 Hz

= 100 m/s

frequency = 5 Hz (times up down / second)

c) The wave travels to the right. Determine the time taken for the crest at A to reach the location labeled B.

$$\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{15\text{m}}{100\text{m/s}} = 0.15\text{s}$$

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Question 2

A pulse travels to the right along a string. A snapshot at one moment is as indicated. A bead is stuck to a particular point on the string. Which of the following (choose one) describes how the bead moves as the pulse passes its location?

i) First right then left.

ii) First left then right.

iii) First down then up.

iv) First up then down.

As pulse peak approaches bead moves up then down.

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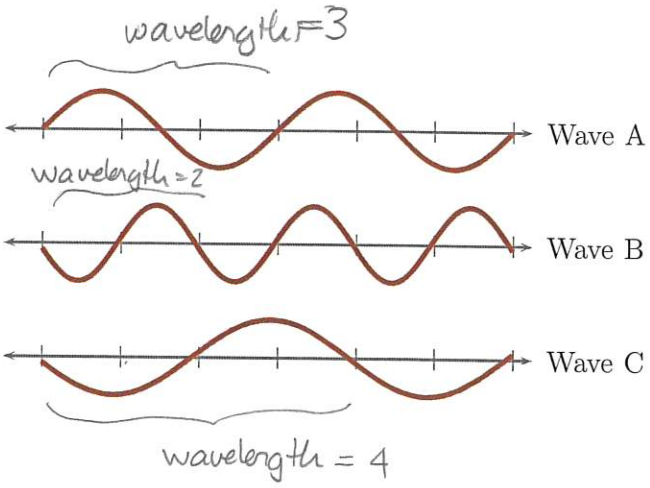
Question 3

Snapshots of three waves on strings are illustrated. The speeds of the waves are all the same.



a) Rank the waves in order of increasing wavelength. Explain your answer.

The wavelengths are indicated on the diagram.

B < A < C

b) Rank the waves in order of increasing frequency. Explain your answer.

frequency = $\frac{\text{speed}}{\text{wavelength}}$

As wavelength increases dividing by larger number so freq decreases.

C < A < B

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Question 4

A radio-controlled car is control by electromagnetic waves that travel from the controller device to the car.

a) Determine the time taken for the signals to travel when the controller and the car are 30 ~~40~~ m apart.

time = $\frac{\text{distance}}{\text{speed of light}}$ = $\frac{30\text{m}}{3\times10^8\text{ m/s}}$ = 1×10^{-7}s

b) Suppose that the car were on Mars and the controller on Earth. These are separated by 225×10^{9}m. Describe why it would be difficult to control the car on Mars regardless of how powerful the controller's signal is.

the time would be

time = $\frac{225\times10^9\text{m}}{3\times10^8\text{m/s}}$ = 750s

This is about 13 minutes

It would take too long for the controlling signals to arrive.

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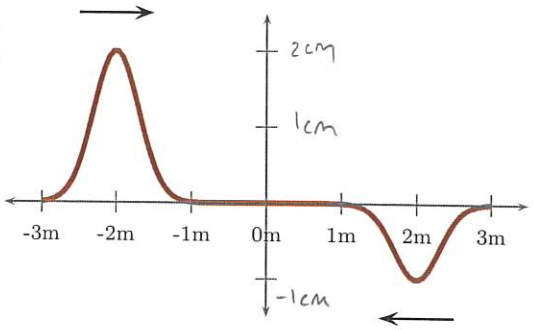
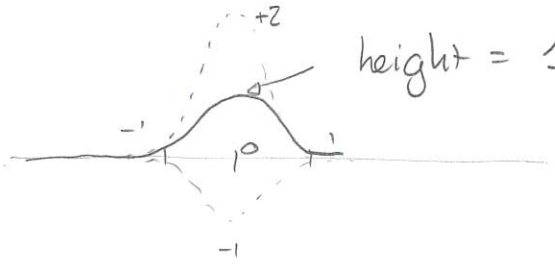
Question 5

Two pulses each travel along a string toward each other with speed 2m/s. Sketch the shape of the string at an instant 1s later. When the pulses overlap exactly, what is the peak height of the string?





height = 1cm

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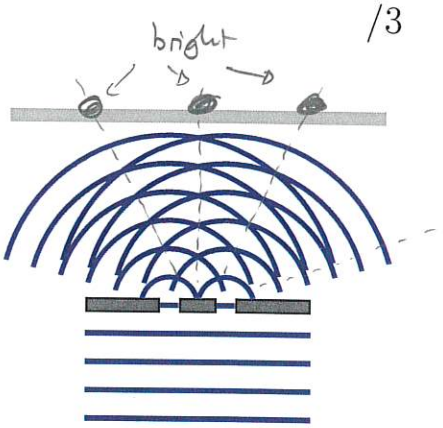
Question 6

Light is incident on two closely spaced slits. The diagram illustrates the crests of the waves beyond the slits. Indicate the locations on the screen where bright spots appear. How many bright spots will appear on the screen? Explain your answers.



Constructive interference → bright spots

↳ occurs along lines where crests meet

There will be three spots

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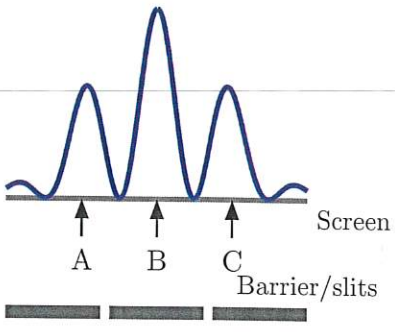
Question 7

Light travels toward an arrangement of barriers and slits as illustrated. The intensity profile of the light on the screen is as illustrated. Three points are marked on the screen. Which of the following (choose one) is true?



i) Each photon that hits the screen moves from left to right across the screen with a wavy pattern.

ii) Any photon that reaches the screen will hit the screen and move toward point B.

iii) Each photon that hits the screen arrives at point A and also point B and also point C.

(iv) A photon that hits point A on the screen will not also hit point B.

A photon can only arrive at one point.

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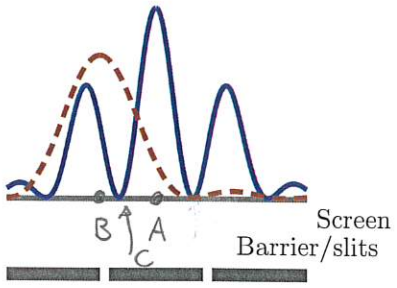
Question 8

Light travels toward an arrangement of barriers and slits as illustrated. There is a gate over the right slit which enables the right slit to be opened or closed. When both slits are open, the intensity profile for the light is illustrated by the solid blue curve. When just the left slit is open, it is illustrated by the dashed red curve.



a) Indicate the location on the screen (with the symbol "A", in the diagram) where the photon is most likely to arrive when both slits are open. highest point solid.

b) Indicate the location on the screen (with the symbol "B", in the diagram) where the photon is most likely to arrive when only the left slit is open. highest point dashed

c) An experimenter thinks that when both slits are open there are more ways for any photon to reach the screen than with just one slit open. Thus he says that, with both slits open, the photon will be able to arrive at any location where it could have arrived with just the left slit is open. Is this true or false? Explain your answer.

False. Consider location C. A photon is fairly likely to arrive here when the left is open but very unlikely to arrive here when both are open

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Question 9

Red light has a frequency of 4.6×10^{14}Hz and ultraviolet light has a frequency of 1.9×10^{16}Hz. Which of the following (choose one) is true?

i) The energy of a photon of red light is *always* larger than that of a photon of ultraviolet light.

ii) The energy of a photon of red light is *always* smaller than that of a photon of ultraviolet light.

iii) The energy of a photon of red light is larger than that of a photon of ultraviolet light *only if* the intensity of the red light is larger than the intensity of the ultraviolet light.

iv) The energy of a photon of red light is smaller than that of a photon of ultraviolet light *only if* the intensity of the red light is smaller than the intensity of the ultraviolet light.

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

only depends on frequency → smaller for red.

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Question 10

A yellow light produces electromagnetic radiation of wavelength 6.0×10^{-7}m.

a) Determine the energy of each photon of the yellow light.

Energy $= 6.63 \times 10^{-34}$ Js $\times$ freq.

freq $=$ $\frac{\text{speed}}{\text{wavelength}}$

$= \frac{3.0 \times 10^{8}\ \text{m/s}}{6.0 \times 10^{-7}\ \text{m}}$

$= 5 \times 10^{14}$ Hz

$= 6.63 \times 10^{-34}$ Js 5×10^{14} Hz

$= 3.3 \times 10^{-19}$ J

b) The light produces 5.0×10^{20} photons every second. Determine the total energy produced by the light in one second.

Total energy = energy one $\times$ number

$= 3.3 \times 10^{-19}$ J $\times$ 5×10^{20}

$= 166$ J

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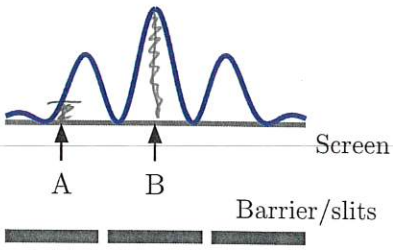
Question 11

Neutrons are fired, one at a time, directly toward a barrier which contains two slits. The probability distribution (profile) for the arrival of neutrons at a screen (of neutron detectors) is illustrated in the diagram. Which of the following (choose one) is true?



i) Neutrons must arrive directly opposite the slits so none will arrive at A or at B.

ii) Every neutron will arrive at A and at B.

iii) Any neutron could arrive at B but it is just as likely to arrive at A.

iv) Any neutron could arrive at B but it is more likely to arrive at A.

v) Any neutron could arrive at B but it is less likely to arrive at A.

B higher prob than A.

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Question 12

There are two types of stable helium atom, called helium-3 and helium-4. Helium-3 has two protons, one neutron and two electrons. Helium-4 has two protons, two neutrons and two electrons. A mixture of these types all travel in the same direction and with the same speed. Which of the following (choose one) is true?

wavelength = $\frac{6.63 \times 10^{-34}}{\text{mass} \times \text{speed}}$ ↑ smaller He-3.

i) The wavelengths of each type is 0 m.

ii) The wavelength of helium-3 is the same as helium-4 and both are non-zero.

iii) The wavelength of helium-3 is larger than that of helium-4 and both are non-zero.

iv) The wavelength of helium-3 is smaller than that of helium-4 and both are non-zero.

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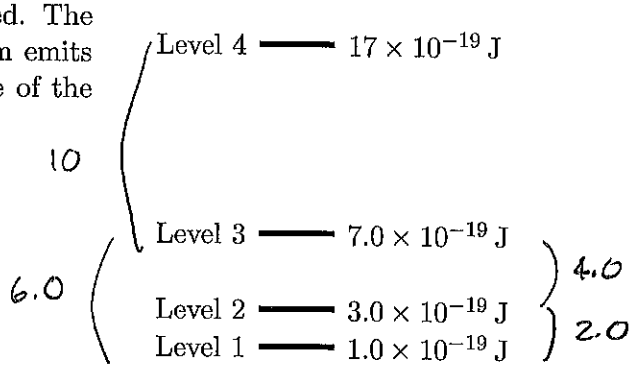
Question 13

The energy level diagram for an atom is as illustrated. The energies are indicated alongside the levels. The atom emits light. Which of the following (choose one) are some of the possible energies of the emitted photons?



i) 1.0×10^{-19} J and 3.0×10^{-19} J

ii) 1.0×10^{-19} J and 4.0×10^{-19} J

iii) 2.0×10^{-19} J and 3.0×10^{-19} J

iv) 2.0×10^{-19} J and 4.0×10^{-19} J

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Question 14

You are given a tube that either contains helium or else neon gas. The gas can be excited so that it emits light. Explain how you could use the emitted light to determine which type of gas the tube contains.

* Break the light into colors (spectrum)
* Measure wavelengths of each color
* Compare spectrum / wavelengths to those known for helium and neon (will be different)
  ↳ this will tell which matches

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Question 15

An artificial atom has four energy levels as illustrated.

Level 4 —— 13.5×10^{-19} J

Level 3 —— 9.0×10^{-19} J

Level 2 —— 4.0×10^{-19} J

Level 1 —— 1.5×10^{-19} J

a) Determine the smallest energy that any photon emitted by this atom could have. Determine the frequency of the associated light.

smallest energy ⇝ smallest atom energy change

⇝ from 2→1 energy lost $= 2.5 \times 10^{-19}$ J

frequency = $\frac{\text{energy lost}}{6.63 \times 10^{-34}\ \text{J s}}$

$= \frac{2.5 \times 10^{-19}\ \text{J}}{6.63 \times 10^{-34}\ \text{J s}} = 3.8 \times 10^{14}\ \text{Hz}$.

b) Assuming that these are the only energy levels that the atom could have, how many different frequencies of light could it produce? Explain your answer.

Consider all drops

drop	energy lost
4-3	4.5×10^{-19} J
4-2	9.5×10^{-19} J
4-1	12×10^{-19} J
3→2	7.5×10^{-19} J
3→1	8.0×10^{-19} J
2→1	2.5×10^{-19} J

↙ each different one gives a different freq.

⇝ 6 possible

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