

EXAM 3

WAVES, OPTICS AND MODERN PHYSICS worth 40% of the final grade

Fall 2017

Name: _____

Questions 1 to 15 are worth 2 points each. Only the answers are corrected.

1. An electron initially at rest is hit by a photon. After the collision, the photon goes back from whence it came. Which of the following quantities has increased due to the collision?



- a) The photon's frequency.
b) The photon's wavelength.
c) The photon's speed.
d) It's a trap! Neither the frequency, the wavelength nor the speed has changed.
2. Mathieu wants to send light through a narrow slit. He can use:
- A. a slit having a width of 0.02 mm;
B. a slit having a width of 0.1 mm;
C. a light source having a wavelength of 450 nm;
D. a light source having a wavelength of 550 nm.

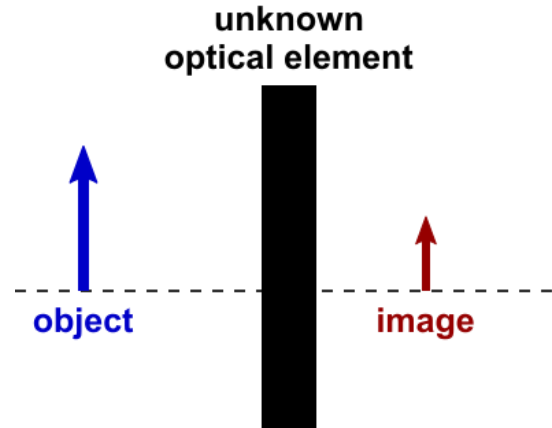
If he wants the distance between the diffraction maxima to be as large as possible, which combination should Mathieu use?

- a) A and C.
b) A and D.
c) B and C.
d) B and D.
e) It's impossible to know since Jean-Raphaël did not give us the formula for the diffraction maxima.

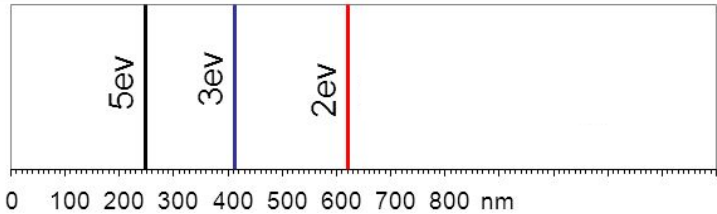
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3. Knowing the position, height and orientation of an object and its image, identify the optical element between the two.

- a) It is a converging lens.
- b) It is a diverging lens.
- c) It is a concave mirror.
- d) It is a convex mirror.
- e) It is a plane mirror.



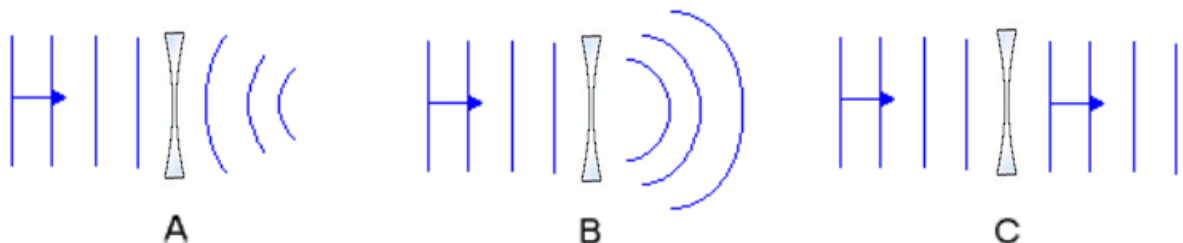
4. The following figure shows the spectral lines of a gas. The energy of the photons in each spectral line is written on the figure. This gas does not have other spectral lines; those three are the only ones.



Which of the following diagrams shows energy levels that could generate the spectral lines above? *Note: On the diagrams below, the 0 eV is only there to state where the zero is; it does not correspond to an energy level.*

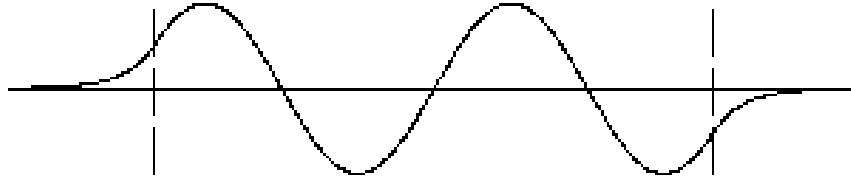
A	B	C	D
----- 0 eV	----- 0 eV	----- 0 eV	
----- -2 eV			----- 5 eV
----- -3 eV	----- -5 eV	----- -5 eV	----- 3 eV
----- -5 eV	----- -7 eV	----- -7 eV	----- 2 eV
	----- -8 eV		----- 0 eV
	----- -10 eV	----- -10 eV	

5. Which of the following figures correctly shows the wavefronts of light passing through a diverging lens?



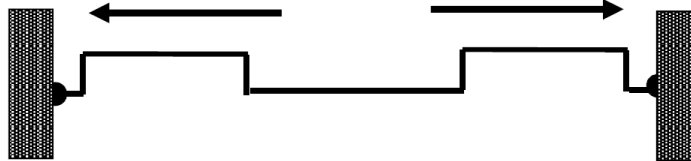
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6. Here is the wave function of a particle in a potential well. Which statement is true?

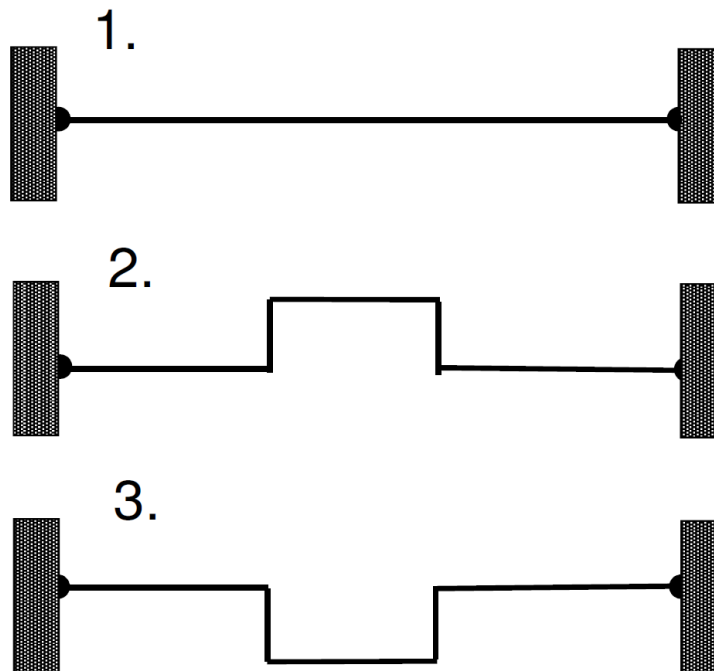


- a) The particle is on the third energy level in an infinite potential well.
- b) The particle is on the third energy level in a finite potential well.
- c) The particle is on the fourth energy level in an infinite potential well.
- d) The particle is on the fourth energy level in a finite potential well.

7. The two waves shown below propagate on a rope fixed between two walls.



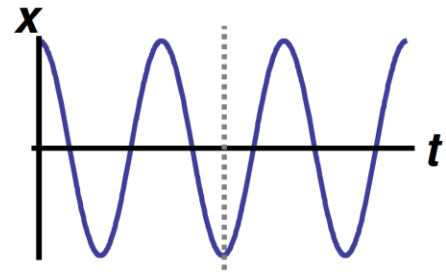
The two waves will be reflected at each end of the rope, after which they will come back and eventually meet in the middle of the rope. How will the rope be at that exact moment? *Circle the correct answer.*



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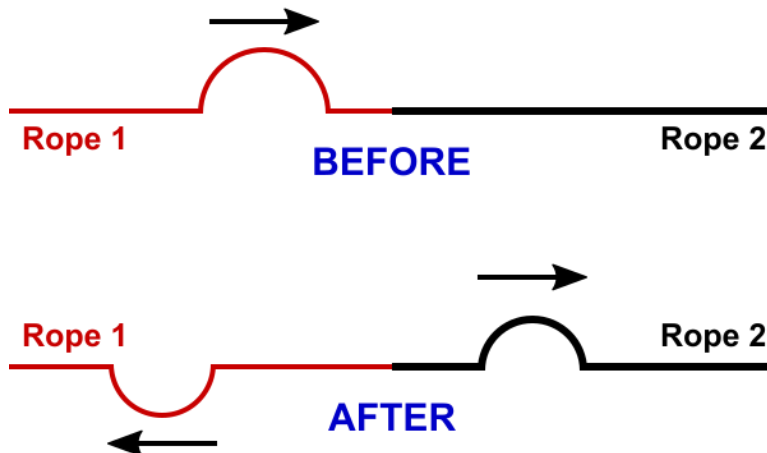
8. On the right is the graph of the position with respect to time for an object in a harmonic motion.

Complete the following sentence using the words **zero**, **positive** or **negative**.



At the instant shown by the dotted line, the object's velocity is _____ and the force acting on the object is _____.

9. We conduct Young's experiment with two narrow slits. What would happen if we increased the width of the slits while keeping the same distance between the two slits and the same wavelength?
- The number of interference maxima within the central diffraction maximum would decrease.
 - The number of interference maxima within the central diffraction maximum would stay the same.
 - The number of interference maxima within the central diffraction maximum would increase.
10. A half-circle shaped wave arrives at the junction of two ropes. After that, there is a transmitted wave and a reflected wave. According to the figure below, which of the following statements is correct?



- The tension force inside rope 2 is weaker than the tension inside rope 1.
- The impedance of rope 2 is smaller than the impedance of rope 1.
- The linear density of rope 2 is larger than the linear density of rope 1.
- The speed of the wave on rope 2 is higher than the one on rope 1.

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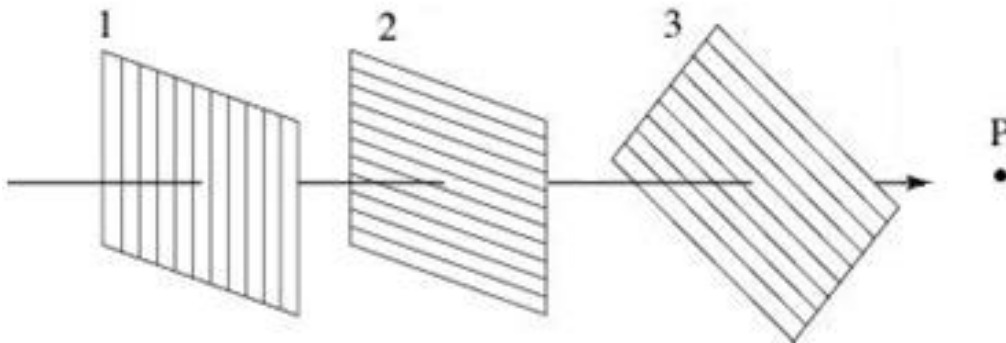
11. A sound source emits a sound at 400 Hz. However, Laurence, who is not very far from the source, hears a sound at 390 Hz. Among the following causes, which could explain this fact? You need to circle all the good answers – no more – to have all the points.

- a) The sound source is moving toward Laurence.
- b) Laurence is moving away from the source.
- c) The air is warmer near Laurence.
- d) The air is colder near Laurence.
- e) The distance between Laurence and the source causes a phase shift of 10 Hz.

12. A carbon atom undergoes a gamma decay. Which of the following quantities changes during this decay?

- a) The atomic number.
- b) The number of nucleons in the atom.
- c) The number of electrons in the atom's orbitals.
- d) The mass of the atom's nucleus.
- e) None of the above.

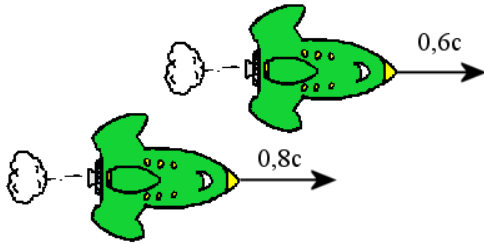
13. Three polarizing filters are placed one after the other. The polarization axes of the first two filters make an angle of 90° , while the polarization axis of the third filter makes a 45° angle with the axis of the second filter. Unpolarized light, arriving from the left, hits the polarization filter 1 first. How would the light intensity at point P change if we slightly rotated the third filter?



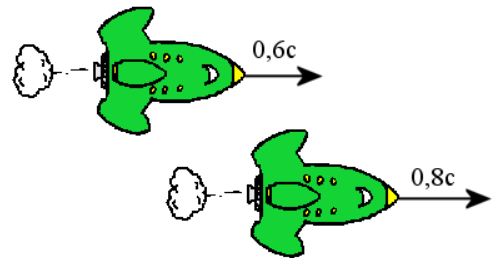
- a) The intensity would decrease.
- b) The intensity would stay the same.
- c) The intensity would increase.
- d) The intensity could decrease or increase, it depends whether the filter is rotated clockwise or counterclockwise.

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14. Ann-Julie and Marilyn are inside two identical spaceships. Marilyn first leaves the Earth at 60 % the speed of light. Ann-Julie leaves later, but with a speed of 80 % the speed of light. When Ann-Julie catches up with Marilyn, they both measure the time required for Ann-Julie's spaceship to pass in front of Marilyn's spaceship. They both start their measurement when the nose of Ann-Julie's spacecraft is aligned with the tail of Marilyn's spacecraft, and stop their measurement when the tail Ann-Julie's ship is aligned with the nose of Marilyn's ship. Who measures the longest time?



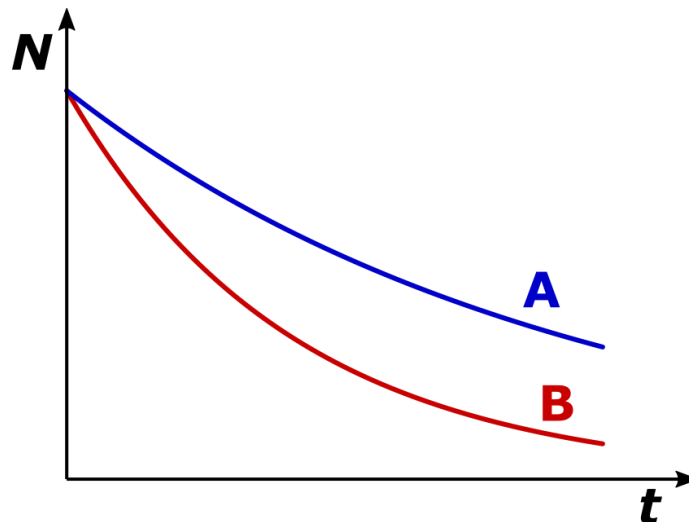
They start measuring the time.



They end their measurement.

- a) Marilyn
- b) Ann-Julie
- c) The duration is the same for both.
- d) It depends on the proper length of the two spaceships.

15. The graph below shows the number of remaining atoms as a function of time for two radioactive substances, named A and B.



Which substance has the longest half-life? _____

Which substance has the highest initial activity? _____

Answer with **A**, **B** or **the same**.

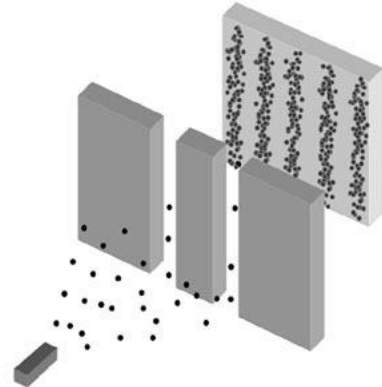
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For questions 16 to 21, the complete solutions are required. Points will be awarded (or deducted) for sketches, graphs, calculations and units, not only for the final answers.

16. (10 points)

Young's experiment is made using electrons instead of light. Knowing that the electrons go at 1 000 km/s and that the distance between the two slits is equal to $5 \mu\text{m}$, calculate the distance between the centre of the interference pattern and the order 2 interference maximum on a screen located 5 m away from the slits.

Mass of an electron = $9,11 \times 10^{-31} \text{ kg}$



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17. (14 points)

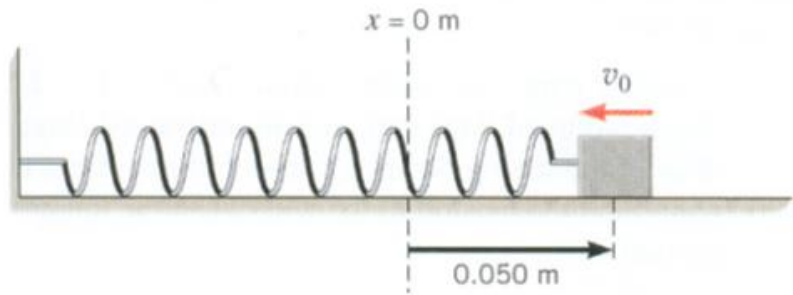
Jean-Raphaël decides to leave the Earth aboard a very fast spacecraft because he is tired of Luc's "funny" jokes. Jean-Raphaël heads for Alpha Centauri, a star system located 4 light-years away from Earth (according to Luc, who stays on Earth), with a tremendous speed of $0.8 c$.

- a) What is the duration of Jean-Raphaël's trip, according to Luc?
- b) What is the duration of Jean-Raphaël's trip, according to Jean-Raphaël?
- c) What is the distance between the Earth and Alpha Centauri, according to Jean-Raphaël?
- d) Knowing that the spaceship has a mass of 100 000 kg, what is the kinetic energy of the spacecraft according to Luc?
- e) Luc decides to send a rocket toward Alpha Centauri. The rocket has a speed of $0.3 c$ according to Luc. What is its speed according to Jean-Raphaël?
- f) Let us suppose that the star emits monochromatic light (only one wavelength). According to Luc on Earth, this wavelength is equal to 600 nm. Jean-Raphaël notices that this light is able to eject electrons from the metal of his spaceship. According to Jean-Raphaël, the maximum kinetic energy of those ejected electrons is equal to 3 eV. What is the work function of the spaceship's metal?

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18. (12 points)

A 10 kg block attached to a spring can slide on a horizontal surface without friction. We stretch the spring ($k = 490 \text{ N/m}$) by a distance of 5 cm and push the block toward the left with a given velocity v_0 .



- With what initial velocity v_0 must we push the block if we want its motion to have an amplitude equal to 13 cm?
- What is the oscillation period of the block?
- What is the block's maximum velocity?
- Give the equation of the block's motion in the form $x = A \sin(\omega t + \phi)$.

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19. (10 points)

An isotropic sound source has a power of 10 W and a frequency of 600 Hz. The surrounding air is at a temperature of 5 °C.

- a) What is the sound intensity, in decibels, 100 m away from this source?
- b) What is the perceived frequency by an observer moving toward the source at a speed of 30 m/s?

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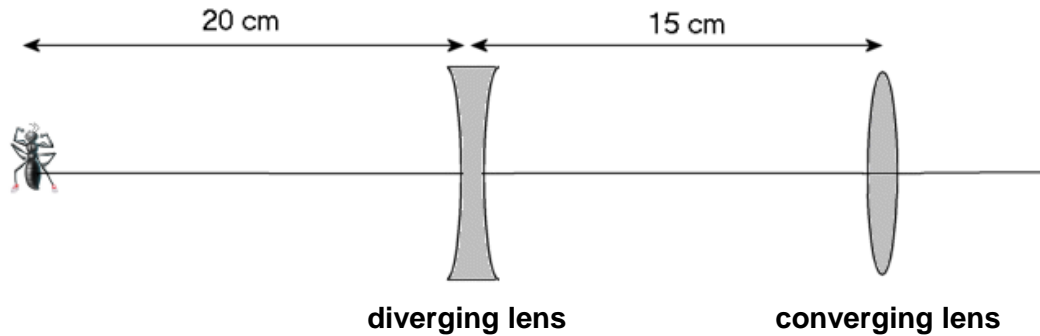
20. (14 points)

Krypton ${}_{36}^{89}\text{Kr}$ is a radioactive element whose nucleus emits electrons. The half-life of this element is 3.15 minutes.

- a) Write the complete corresponding decay reaction.
- b) What is the energy released by this reaction?
- c) What is the activity, in curies, of 20 mg of krypton 89?
- d) How long does it take for the remaining number of krypton 89 atoms to be equal to 10 % of the initial amount?

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21. (10 points)



In the situation illustrated above, the focal length of the diverging lens is equal to 30 cm, while the converging lens has a focal length of 9 cm (only the absolute values were given). The ant has a height of 7 mm.

- Where is the final image, of the ant, made by these two lenses?
- What is the height of the final image? In your answer, state whether or not this final image is inverted relative to the ant itself.

Answers

1. b 2. b 3. d 4. c 5. b 6. d
 7. 3 8. zero, positive 9. a 10. c 11. b
 12. d 13. b 14. c 15. A, B
 16. 1.455 mm
 17. a) 5 y b) 3 y c) 2.4 ly d) 5.9917×10^{21} J
 e) -1.972×10^8 m/s or -0.6579 c f) 5.126×10^{-19} J or 3.20 eV
 18. a) -0.84 m/s b) 0.8976 s c) 0.91 m/s d) $x = 13 \text{ cm} \cdot \sin\left(7 \frac{\text{rad}}{\text{s}} \cdot t + 2.7468 \text{ rad}\right)$
 19. a) 79.008 dB b) 653.84 Hz
 20. a) ${}_{36}^{89}\text{Kr} \rightarrow {}_{37}^{89}\text{Rb}^+ + \beta^- + \bar{\nu}$ b) 4.9863 MeV c) 1.3426×10^7 Ci d) 627.84 s
 21. a) 13.5 cm to the right of the converging lens b) -2.1 mm (inverted)