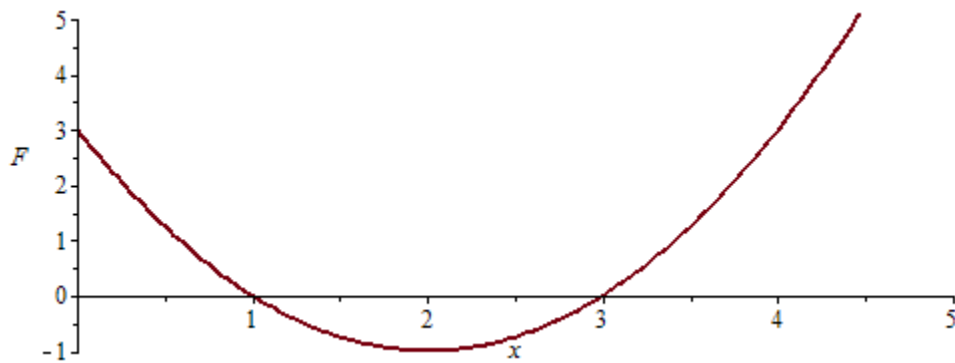# EXAM 3
Waves, optics and modern physics
40 % of the final mark

Fall 2016   Name: _____
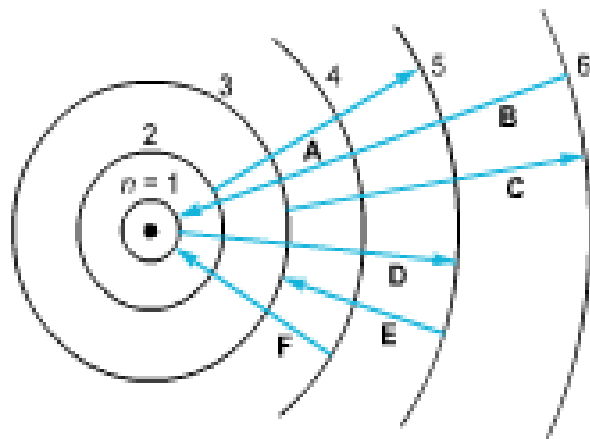

Questions 1 to 15 are worth 2 points each.

1. Here is the graph of the force acting on an object as a function of its position.

In the vicinity of which point can the object make harmonic oscillations (if the amplitude is small)?

Answer: $x =$ _____

2. Among all the transitions shown in the figure (following the Bohr atomic model), which one corresponds to the absorption line having the longest wavelength?
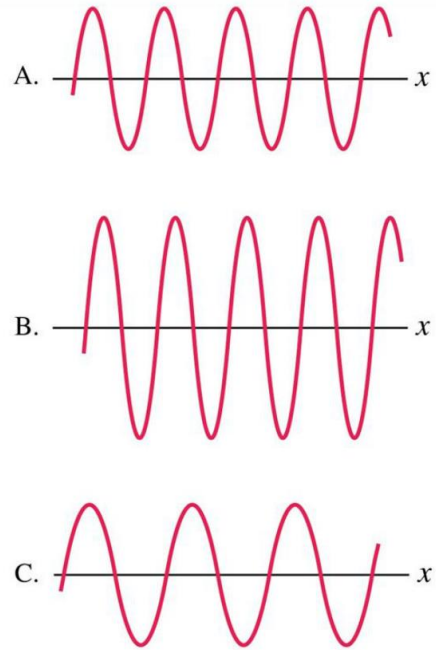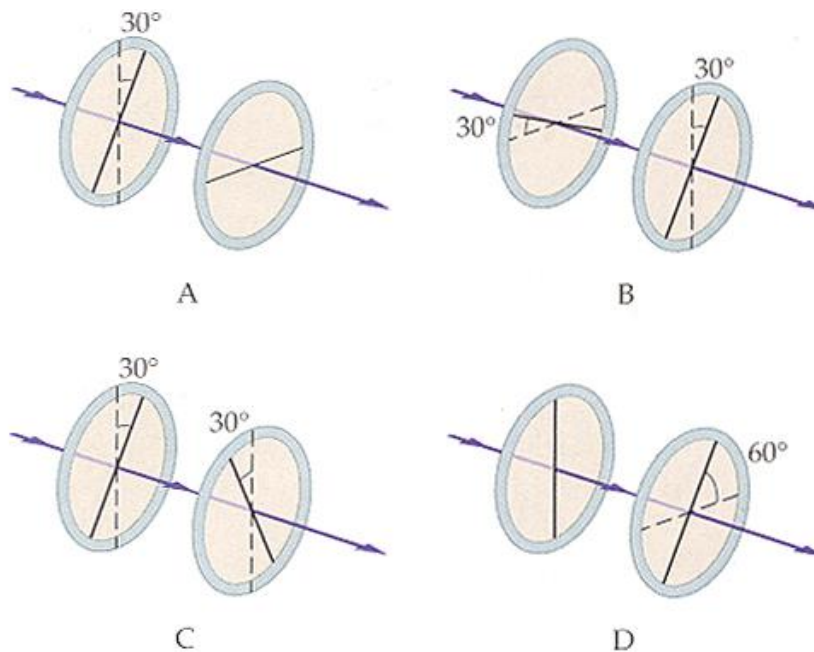

Answer: _____

3. The three graphs on the right shows the de Broglie wave of an electron. Which electron has the smallest speed?

A.

B.

❑ A
❑ B
❑ C
❑ A and B (same speed for both)
❑ A and C (same speed for both)

C.

4. Unpolarized light passes through two polarized filters. Sort these four situations according to the intensity of the transmitted light, from the highest intensity to the lowest intensity. The intensity of the unpolarized light incident on the first filter is the same in all four situations.


A

B

C

D

Answer: _____

5. Arthur looks at Claudia while she is travelling in her spaceship. He sees that inside the spaceship, there is a beam of light going from the back to the front of the spaceship. Arthur and Claudia both measure the time it takes for the beam of light to go from the back to the front of the spaceship. Which observer is measuring the proper time (Δt_0)?

❑ Arthur
❑ Claudia
❑ None of them
❑ Both

6. Here are the patterns obtained on a screen. The three lasers produce the same colour.
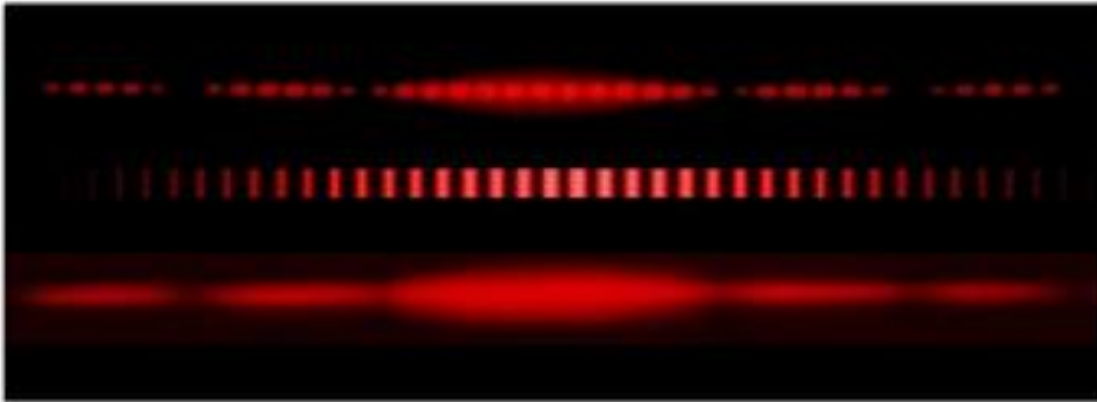
The previous patterns were obtained using these slits.

A B C
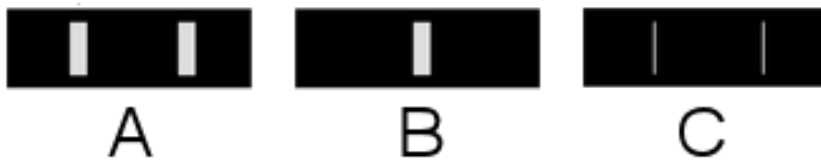
Assign the slits with the corresponding pattern.

Top figure: slit(s) _____ (A, B or C)

Middle figure: slit(s) _____ (A, B or C)

Bottom figure: slit(s) _____ (A, B or C)

7. Two radioactive substances X and Y have initially the same number of atoms. X has a half-life of 1 hour and Y has a half-life of 2 hours. After 2 hours, how is the activity of substance X compared to the activity of substance Y?

- ❑ Four times smaller.
- ❑ Two times smaller.
- ❑ The same.
- ❑ Two times greater.
- ❑ Four times greater.

**8.** How does the angle θ change if we replace the piece of glass with a piece of identical size having a higher refractive index?

How does the angle θ change if the piece of glass is replaced by a piece of identical size having a higher refractive index?

- ❑ It increases
- ❑ It stays the same
- ❑ It decreases
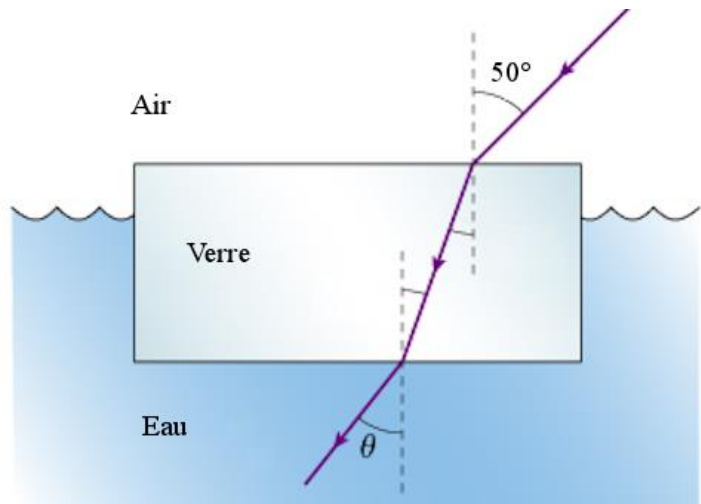
9. Draw the principal rays to find the position of the image of the candle made by this mirror.
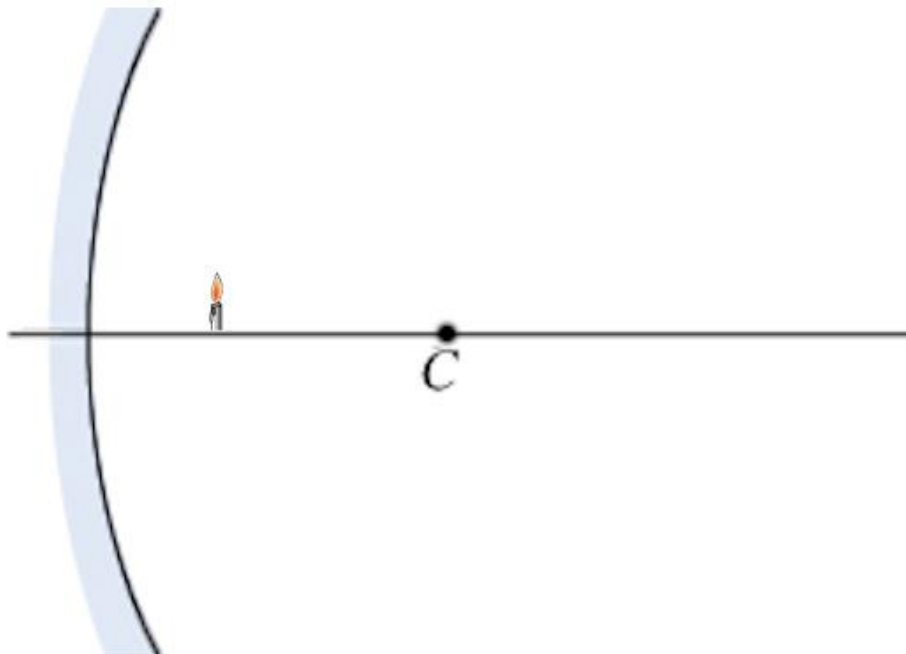
10. There are about 3×10^9 heartbeats in an average human lifetime. If, from Earth, we observe humans living all their lives on a spaceship moving away from Earth at 0.6 *c*, how many heartbeats will we count, on average, during the lifetime of these humans?

- ❑ $0.6 \times 3 \times 10^9$
- ❑ $0.8 \times 3 \times 10^9$
- ❑ 3×10^9
- ❑ $1.25 \times 3 \times 10^9$
- ❑ $1.67 \times 3 \times 10^9$
- ❑   None of the above

11. A light wave goes out of a transparent substance and enters vacuum: a fraction of the light gets reflected back into the substance while the other is transmitted in the vacuum. Which of the following quantities necessarily increase(s) when the light leaves the substance? *In short, we are comparing the transmitted wave in the vacuum to the incident wave in the transparent substance.*

1. The wavelength
2. The speed of the wave
3. The frequency
4. The intensity of the wave
5. The amplitude of the wave

Answer(s): _____

12. When light is sent on a very thin film of transparent plastic (n = 1.5) in air, green light is more intensely reflected than the other visible colours. What happens to the light reflected by the plastic thin film if we do the same experiment under water (n = 1.33)?

- ❑   The reflected light contains more red.
- ❑   The reflected light contains more blue.
- ❑   The reflected light has the same colours, but it is less intense.
- ❑   The reflected light has the same colours, but it is more intense.
- ❑   The reflected light has the same colours and is as intense (nothing changed).

13. Two guitar strings are made of the same material. When the first string is plucked, its fundamental frequency is 1000 Hz. Compared to the first string, the second string has twice the length, twice the width (diameter) and its tension is twice as strong. What is the fundamental frequency of the second string?
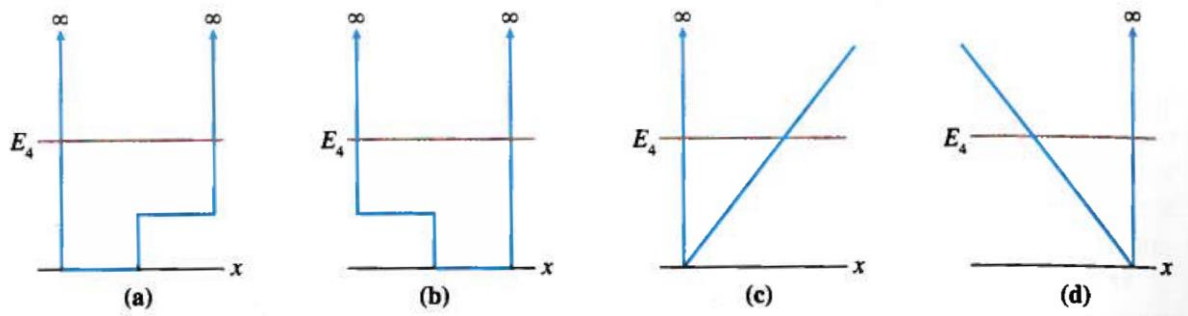
Answer: _____

14. Here is the wave function of an electron on the level $n = 4$.
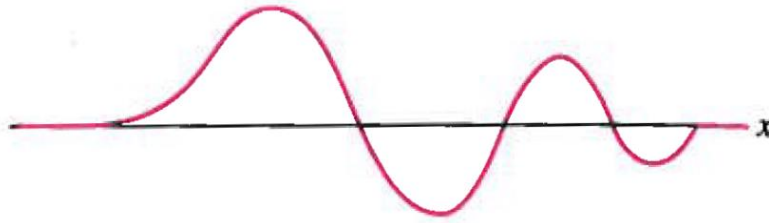
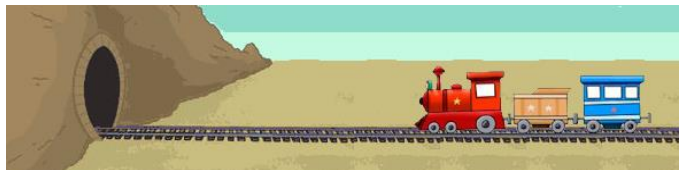Which of the following graphs correctly show the potential energy of this electron?

| (a) | (b) | (c) | (d) |

☐   a   ☐   b   ☐   c   ☐   d

15. A train blows its whistle when approaching the entrance of a tunnel going through a mountain. Following the reflection of the sound wave on the mountain, the sound wave on the mountain, the train driver hears beats. Among the following options, which would increase the frequency of the beats? *Select all the possible answers.*

1. Increasing the speed of the train.
2. Decreasing the speed of the train.
3. Using a whistle that produces a higher note.
4. Using a whistle that produces a lower note.
5. Living under the sea (replacing air by water).

Answer(s): _____

16. (14 points)

Christophe is sent in a spaceship toward the star Betelgeuse with a speed of 0.996 *c*. Joséfina, who stays on Earth, measures that the distance between Earth and Betelgeuse is 500 light-years.

    a) What is the duration of the trip according to Joséfina?
    b) What is the duration of the trip according to Christophe?

To pass the time during the trip, Christophe decides to hone his skills with his powerful gun. From the back of his spaceship, Christophe shoots toward a target placed at the front of the spaceship. According to Christophe, the distance between him and the target is 300 m. Also according the Christophe, the gun fires bullets at 0.5 *c*.

    c) How long does it take for a bullet to reach the target, according to Christophe?
    d) How long does it take for a bullet to reach the target, according to Joséfina?
    e) What is the speed of a bullet, according to Joséfina?

You have two pages to answer.

17. (12 points)

Young Luc receives sound waves coming from two sources.
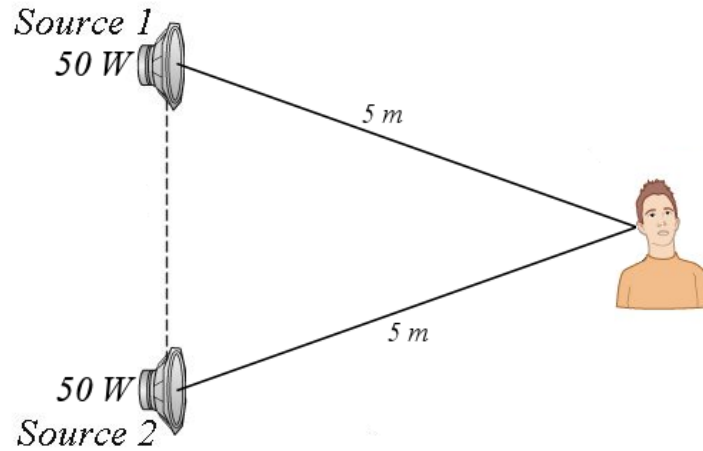
Source 2 lags behind source 1 by 1/3 of a cycle. Considering the interference of the two waves, how many decibels does Young Luc hear?

18. (10 points)

A beam of light is sent on a metal surface and the frequency is increased continuously. When the wavelength of the light reaches 400 nm, electrons begin to be ejected from the metal.

a) What is the maximum speed of the ejected electrons when the wavelength of the light is 310 nm?
b) What is the wavelength of the electrons being ejected at that speed?

Mass of an electron = 9.11 X 10^{-31} kg

19. (12 points)

Polonium 210 disintegrates by alpha decay with a half-life of 138 days.

a) What is the nucleus obtained after this decay?
b) What is the energy released by this reaction?
c) What is speed of the helium nucleus after the decay? *Use the relativistic kinetic energy formula.*
d) What is the activity (in Ci) of 1 gram of polonium 210?
e) How much time has elapsed when 5 % of the initial polonium is left?

20. (10 points)

In the following setup, there are two images. One is made directly by the lens while the other is made by the mirror and the lens. The figure is not necessarily to scale.
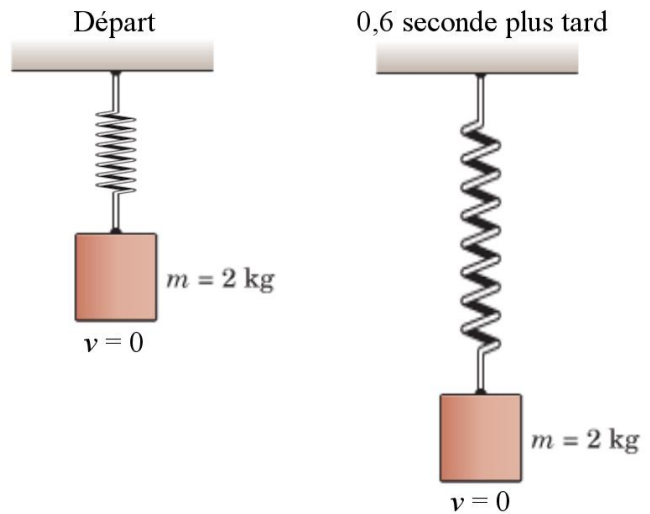
$f = 12$ cm

Objet

Image 1

20 cm

35 cm

30 cm
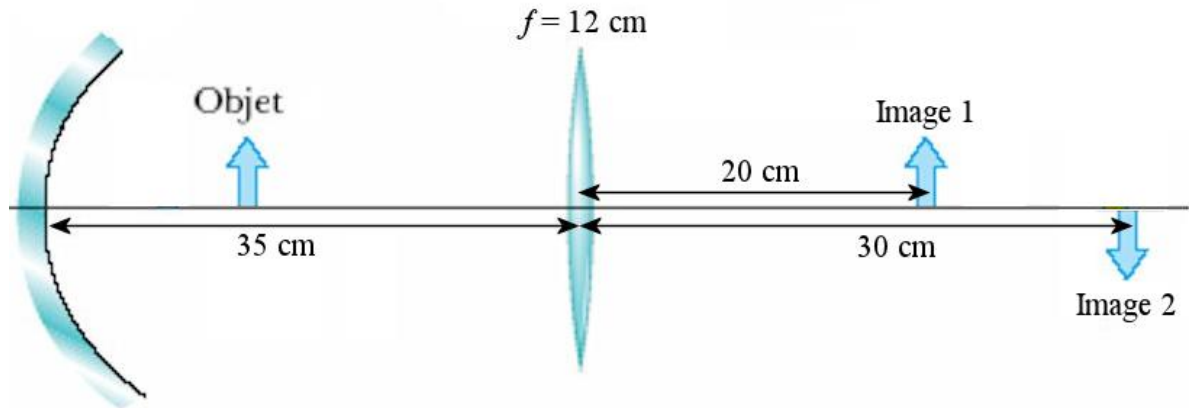
Image 2

a) What is the radius of curvature of the mirror?
b) Which image is taller (in absolute values)?

21. (12 points)

Départ   0,6 seconde plus tard

A mass of 2 kg is suspended at the end of a spring. Initially, the mass is at rest above its equilibrium position, and we let it go from there. The mass then falls 20 cm during 0.6 s before changing direction and going up.

$m = 2$ kg

a) What is the maximum speed of the mass?

$v = 0$

b) What is the spring constant?

c) When will the mass have a speed of 0.2 m/s directed upward for the first time?

$m = 2$ kg

$v = 0$

Answers

1. x = 1   2. C   3. C   4. $I_D > I_A = I_C > I_B$ 5. None of them

6. top to bottom: A-C-B   7. The same   8. It stays the same

9. The image is erect, taller and to the left of the mirror (virtual image)

10. 3×10^9 11. 1-2-5

12. The reflected light has the same colours, but it is less intense

13. 354 Hz   14. d   15. 1-3

16. a) 502.008 y   b) 44.856 y   c) 2,0014 µs   d) 33.553 µs   e) 0.998 665 c

17. 112.02 dB

18. a) 562.6 km/s   b) 1.293 nm

19. a) Lead 206   b) 5.4075 MeV   c) 15.97×10^6 m/s   d) 4506 Ci   e) 596.4 d

20. a) 7.5 cm   b) image 2 is taller

21. a) 52.36 cm/s   b) 54.83 N/m   c) 0.675 s