EXAM 2
203-NYC-05 — Waves, optics and modern physics

Fall 2017   **Name:**
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Instructions

- For questions 1 to 10, only the correct answer(s) is(are) needed.

- For questions 11 to 14, clearly expose every step of your solution. Points will be awarded to sketches, explanations and calculations, not only to the final values.

- Be precise in all your calculations: the first three significant digits in the final value must be correct for an answer to be considered valid. Units are also mandatory.

Question 1 [3 points]

During his class, Luc took one of his long dark hair and placed it in front of a red laser beam. Instead of a single red dot on the screen, his students observe (in amazement) a pattern of many dots, as shown below. Not to be outdone, Jean-Raphaël enters Luc's class, pushes his rival out of the way, throws Luc's long dark hair on the floor and places one of his own hair in front of the laser beam instead.
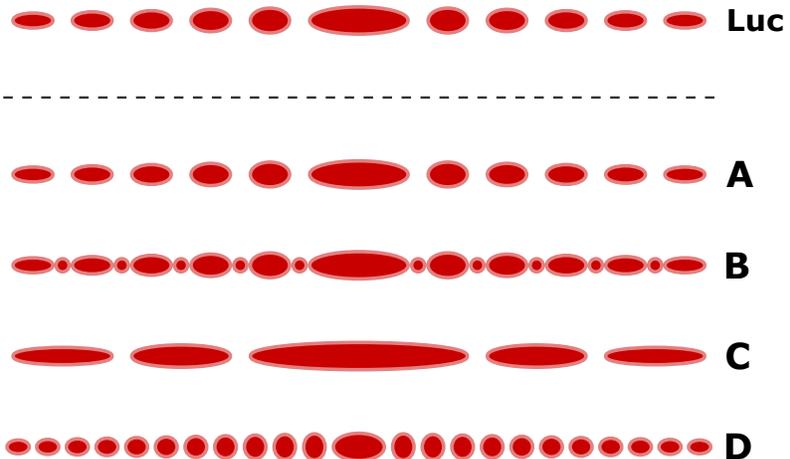
Considering that Jean-Raphaël's hair is thicker than Luc's, which of the following options will be visible on the screen?

a) A (nothing changed).

b) B.

c) C.

d) D.

Question 2 [3 points]

Dora the Explorer sends an unpolarized beam of light toward a puddle full of a strange liquid. She notices that when her beam of light hits the surface of the liquid at an angle of $38°$ relative to the surface, the reflected light is totally polarized. What might this liquid be?

a) Oil from Sniper's killing robot ($n = 1.28$).

**b)** Diego's blood ($n = 1.33$).

c) The poison that infected Boots ($n = 1.78$).

d) Reflected light can never be totally polarized.
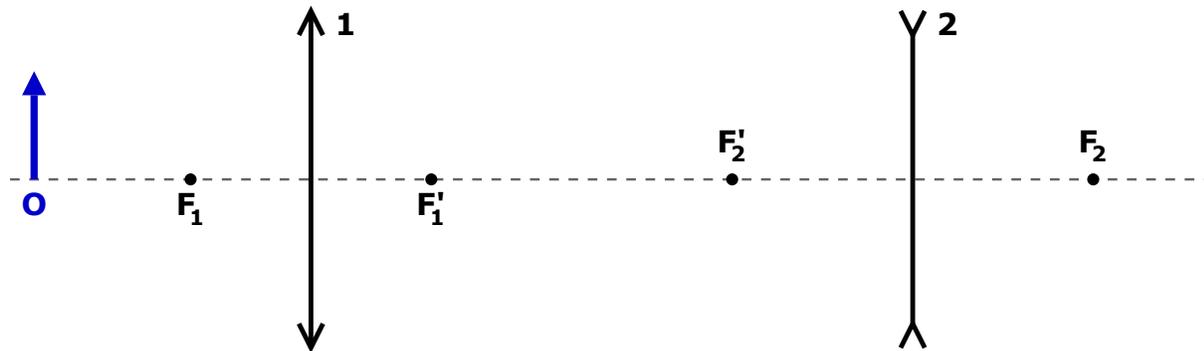
Question 3 [3 points]

During a Spartan Race, Mathieu has to run through sand, then swim across a river, and then run on a grass field. Assuming that he can run faster on grass than on sand, and assuming that he swims quite poorly (thus $v_{grass} > v_{sand} > v_{water}$), which trajectory among the following options would require the least amount of time?

a) A.

b) B.

c) C.

d) D.
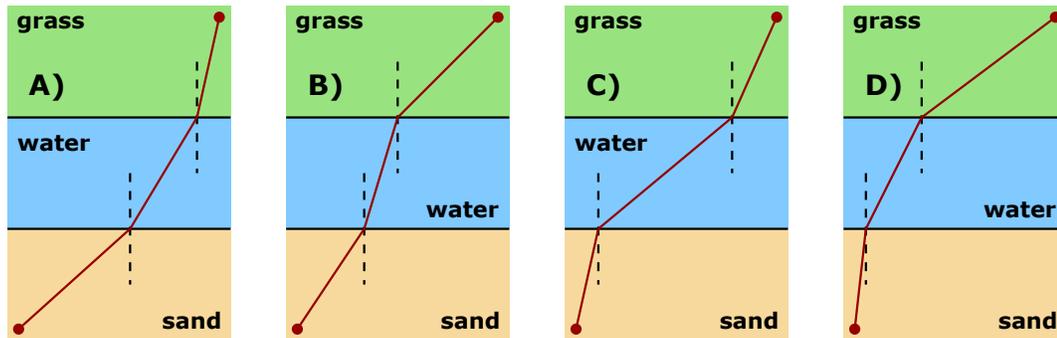
Question 4 [3 points]

Using principal rays, find the position, height and orientation of the final image, made by these two thin lenses, of the arrow-shaped object. Use a ruler and be precise.

Question 5 [3 points]

Can a sphere made of ice ($n = 1.31$) be used to start a fire during a sunny day?

a) Yes.

b) No, because it always acts like a converging lens.

c) No, because it always acts like a diverging lens.

d) No, because the image of the sun will always be virtual.

e) No, because the final image is inside the ice sphere.

f) No, because the surrounding medium (air) has a smaller refractive index than the ice.

g) No, because a sphere is not a thin lens.

Question 6 [3 points]

A laser beam ($\lambda = 650\,\text{nm}$) illuminates an opaque surface pierced with an unknown number of slits. The light intensity received on a far-away screen is represented on the graph below, where the distances are in centimetres.

How many slits are lit by the laser beam?

a) 1.

b) 2.

c) 3.

d) 4.

e) 5.

f) More than 5.

-30   -20   -10   0   10   20   30
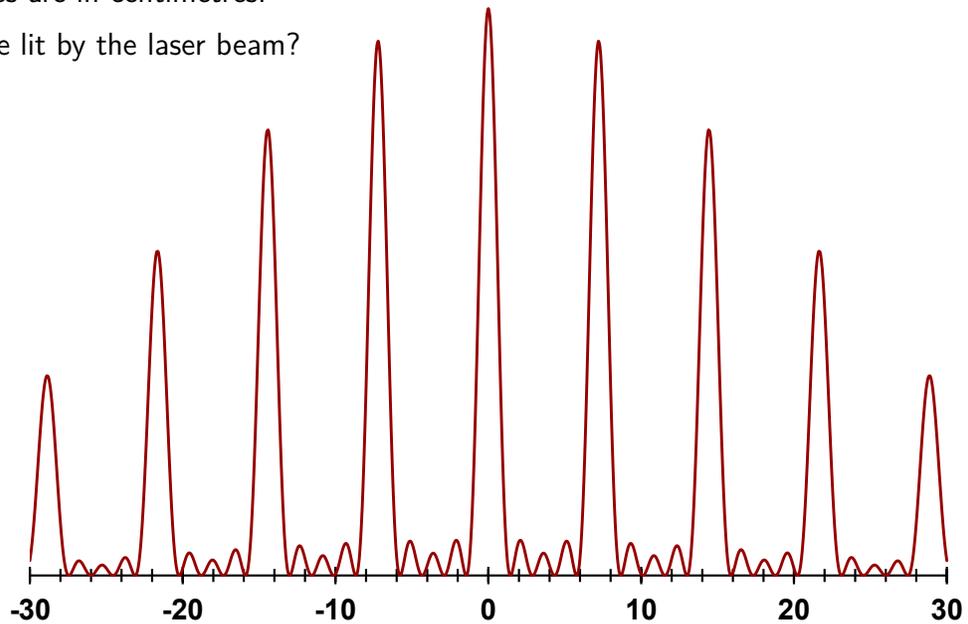
Question 7 [3 points]

Laurence is watching a campfire while Mireille, who is standing beside the fire, lights the smoke with her flashlight. If the beam of light seen through the smoke is horizontal (as shown below), what kind of polarized glasses should Laurence wear if she wants to reduce as much as possible the intensity of the light coming from the smoke? *The images below are glasses.*

a) A.

b) B.

c) C.

d) D.

e) They are all equally effective.

A)   B)   C)   D)
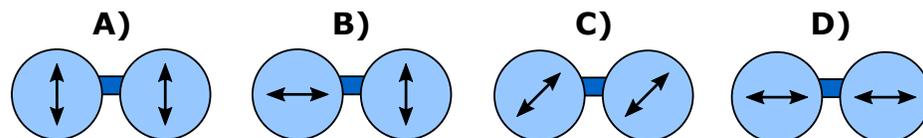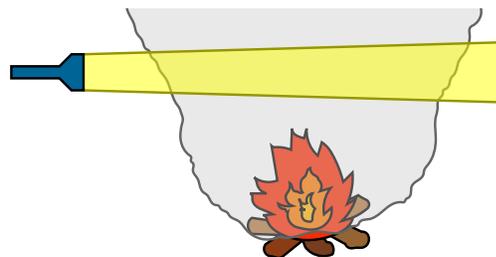
Question 8 [3 points]

Ann-Julie sends a $5\,\mathrm{W/m^2}$ beam of unpolarized light through two successive polarizing filters. If she wants the output light to be horizontally polarized while having an intensity of $2\,\mathrm{W/m^2}$, at what angle relative to the horizontal must she place the polarization axis of her first filter?

Answer:
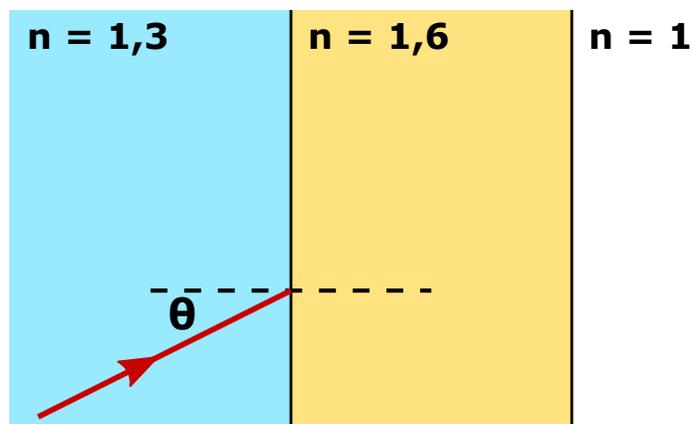
Question 9 [3 points]

Jean-Luc wants to design his own telescope, and his priority is to be able to distinguish individual stars within binary star systems. Except for placing his telescope in space, where there would be no air disturbances (he cannot afford that!), which of the following option(s) would help? *Circle each correct answer.*

a) Using a sensor sensitive to lower frequencies of light.

b) Adding a polarizing filter in front of his telescope.

c) Reducing the diameter of his telescope.

d) None of the above would help.

Question 10 [3 points]

Is it possible to have an incident angle θ so that no light is transmitted in the third medium (where $n = 1$)? If so, what is the critical value for θ?

Answer:

n = 1,3   n = 1,6   n = 1

θ

Question 11 [20 points]

A laser beam ($\lambda = 532\,\text{nm}$) hits a thin transparent plastic sheet ($n = 1.49$) at $90°$ relative to the surface. The thin plastic sheet is surrounded by air.

a) [10 pts] What must the thickness of this plastic sheet be if we want to reduce to a minimum the intensity of the light reflected? *Give the smallest non-zero possible value.*

b) [10 pts] If the plastic sheet has a thickness of $0.5\,\mu\text{m}$ and we replace the laser by a source of white light, what wavelengths are more strongly reflected? *Give all the possible values within the visible spectrum.*

Question 12 [15 points]

Ève uses an infrared laser (frequency of $1.75 \cdot 10^{12}\,\text{Hz}$) to illuminate two narrow slits. Those slits are $6.2\,\text{mm}$ apart (from centre to centre) and each has a width of $0.5\,\text{mm}$. A screen is placed far away, at $15\,\text{m}$ from the two slits.

a) [8 pts] On the screen, what is the width of the central diffraction maximum?

b) [7 pts] How many interference maxima are there within the central diffraction maximum?

Question 13 [15 points]

Two speakers produce a sound at a frequency of 440 Hz, with the same power, but speaker B is late by one fifth of a cycle relative to speaker A. A person (P) is standing between the two speakers, but closer to speaker A (as shown below). When only one speaker is working, the person perceives an intensity of $0.8\,\text{W/m}^2$. The speed of sound is 343 m/s.
For this question, assume that the intensity perceived when only one speaker is working is constant (neglect the fact that the intensity decreases when the distance increases.)

a) [8 pts] What is the intensity of the sound perceived by the person when both speakers are working at the same time?

b) [7 pts] If we move speaker B toward the right by a distance d (so that the distance between the person and speaker B becomes equal to $3\,\text{m} + d$), at what value of d does the person hear a sound of minimum intensity (destructive interference)? *Give the smallest possible value.*

Question 14 [20 points]

During a journey in Mexico, Marilyn decides to buy small spherical balls of Jell-O for her family. But because it is Mexico, Marilyn finds out that there is a small mosquito in one of them. That Jell-O ball has a radius of 7 cm, its refractive index is 1.35 and the mosquito is located 1.5 cm from the surface. Marilyn looks at the Jell-O ball from the side where the mosquito is closest to the surface.

a) [6 pts] When Marilyn looks at the Jell-O ball, at what distance from the surface does the mosquito seem to be?

b) [4 pts] If the mosquito has a height of 3 mm, what is the height of its image?

c) [1 pt] Is the image of the mosquito inverted?

d) [1 pt] Is the image of the mosquito real or virtual?

e) [6 pts] At what distance from the Jell-O ball must she place her magnifying lens ($f = 10$ cm) to be able to observe the image of the mosquito with the largest angular magnification possible? *Consider that her punctum proximum is located 25 cm in front of her eyes and that she places one eye very close to the magnifying lens.*

f) [2 pts] Relative to the mosquito itself, is the image that she sees through the magnifying lens inverted?

Answers

1. d   2. a   3. b

4. The final image lies between F_2' and the diverging lens, it is smaller and inverted.

5. a   6. e   7. d   8. 26.565°   9. d   10. Yes, $\theta_c = 50.285°$

11. a) 178.5 nm   b) 425.7 nm and 596.0 nm

12. a) 10.941 m   b) 25

13. a) 1.7566 W/m²   b) 57.25 cm

14. a) 11.765 mm   b) 3.1765 mm   c) No   d) Virtual   e) 59.664 mm   f) No