EXAM 1
203-NYC-05 — Waves, optics and modern physics

Fall 2017   **Name:**

Prof: Jean-Raphaël Carrier

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 digits in the final value must be correct for an answer to be considered valid. Units are also mandatory.

Question 1 [3 points]

A light bulb is placed $40\,\text{cm}$ in front of a convex mirror which has a radius of curvature of $20\,\text{cm}$ (absolute value). Compared to the light bulb, its image is. . .

a) . . . smaller and inverted.

b) . . . taller and inverted.

c) . . . smaller but not inverted.

d) . . . taller but not inverted.

Question 2 [3 points]

The four stationary waves described in the following equations are made on four ropes having the same linear density (μ). Which one of these is subject to the strongest tension force?

a) $y = 5\,\text{cm} \cdot \sin(5\pi\,\text{rad/m} \cdot x)\cos(10\pi\,\text{rad/s} \cdot t)$

b) $y = 3\,\text{cm} \cdot \sin(12\pi\,\text{rad/m} \cdot x)\cos(4\pi\,\text{rad/s} \cdot t)$

c) $y = 1\,\text{cm} \cdot \sin(8\pi\,\text{rad/m} \cdot x)\cos(12\pi\,\text{rad/s} \cdot t)$

d) $y = 2\,\text{cm} \cdot \sin(2\pi\,\text{rad/m} \cdot x)\cos(9\pi\,\text{rad/s} \cdot t)$

Question 3 [3 points]

Two frictionless mass-spring systems are made of identical springs and masses. However, the mechanical energy of system B is smaller than the mechanical energy of system A. Which mass-spring system has the longest period?

a) System A.

b) System B.

c) The period is the same for both.

d) It depends on their phase constant.

Question 4 [3 points]

A cylindrical tube, open at one extremity and closed at the other, produces a fondamental frequency f. If we open the extremity that is currently closed, the fondamental frequency of the tube will...

a) ...increase.

b) ...stay the same.

c) ...decrease.

d) ...increase, stay the same or decrease, it depends on the length of the tube.

Question 5 [3 points]

Ève and Laurence both have identical helium-neon lasers, which emit light with a wavelength equal to 632.8 nm. Ève decides to point her laser toward an aquarium filled with water ($n = 1.33$) while Laurence points hers toward a huge block of pure diamond ($n = 2.42$). Don't ask why she has that billion-dollar piece of diamond...

Assuming that in both cases, the emitted light hits the surface at a right angle, in which substance (water or diamond) does the transmitted light have...

...the longest wavelength? **answer:**

...the greatest speed? **answer:**

...the highest intensity? **answer:**
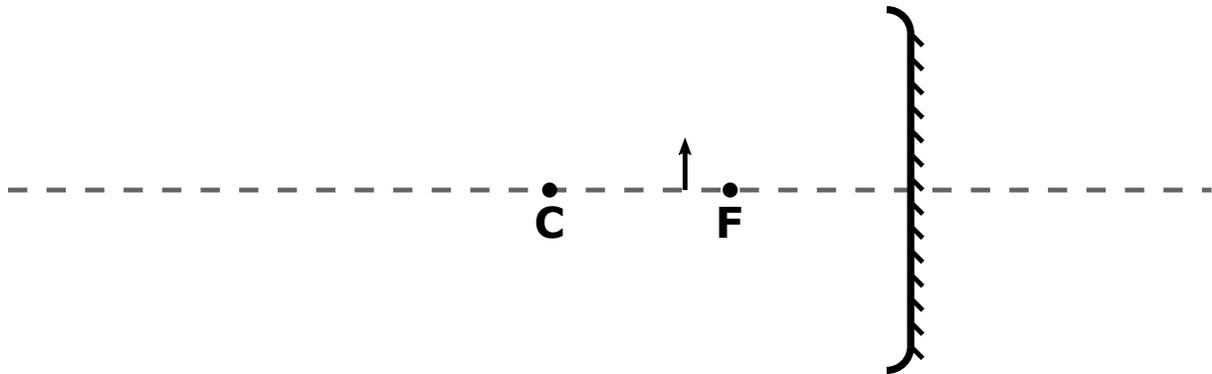
Question 6 [3 points]

The following graph represents the velocity of a particle in a harmonic oscillation, with respect to time. Considering that the fonction describing the position of the particle is $x = A \sin(\omega t + \phi)$, the value of the phase constant ϕ lies between...

a) ...0 and $\pi/2$ radians.

b) ...$\pi/2$ and π radians.

c) ...π and $3\pi/2$ radians.

d) ...$3\pi/2$ and 2π radians.
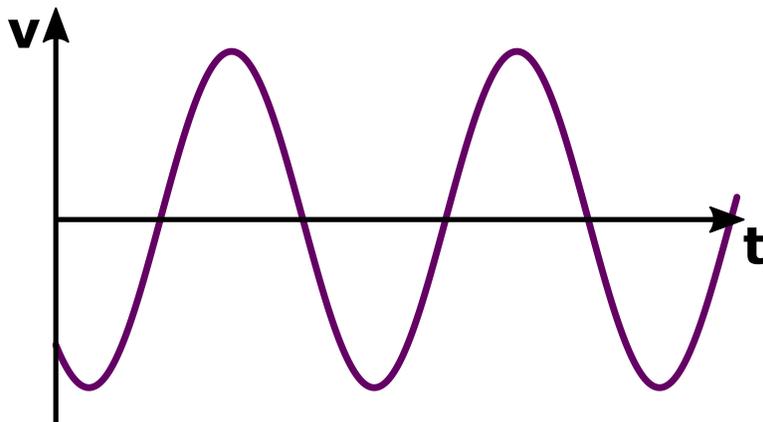
Question 7 [3 points]

Using (at least two) principal rays, find the position, height and orientation of the arrow-shaped object that creates the image shown below. Use a ruler and be precise.
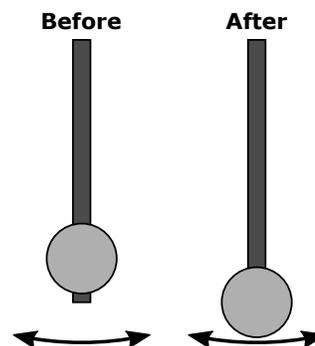

Question 8 [3 points]

When Mathieu was a mischievous kid, he once modified the position of the weight at the end of the pendulum on his family grandfather clock, as shown below. After his reprehensible act, was the clock getting late, in advance, or did it continue to give the correct time?
Assume that the mass of the rod is negligible relative to the mass of the weight itself.

a) The clock was getting late.

b) The clock became in advance.

c) The clock still gave the correct time.

d) It depends; we need more information.
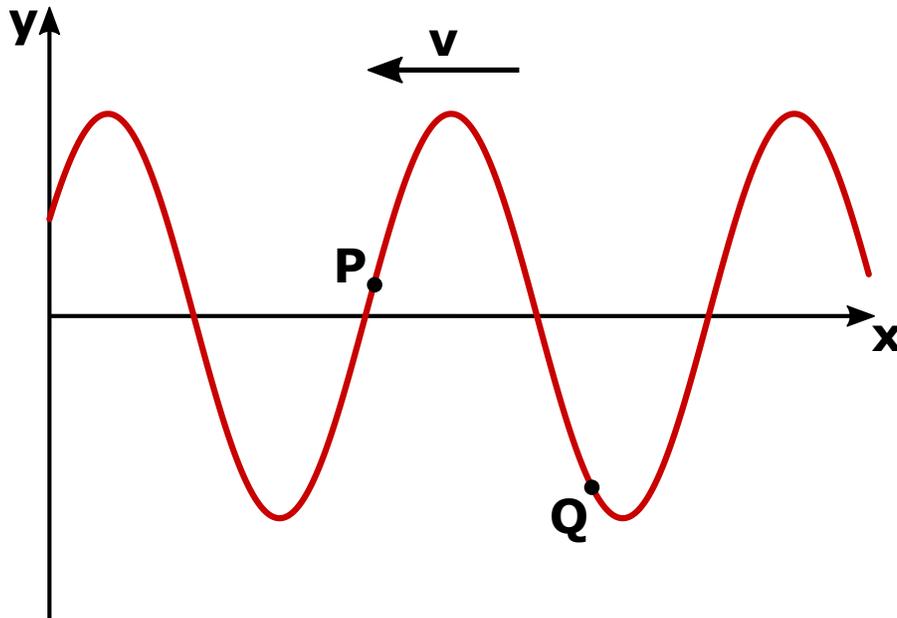

Question 9 [3 points]

While learning to play the guitar, Anne-Sophie plucks a string and hears a sound at $261.63\,\text{Hz}$ (she has a very precise sense of hearing). Tired of playing music — but not tired of doing science! — she decides to fill the room with helium and pluck the same string on her guitar. What note will she hear? *Assume that the speed of sound in helium is three times faster than the speed of sound in normal air... and that Anne-Sophie is still alive to hear the sound.*

a) The pitch will be higher (higher frequency).

b) The pitch will be lower (lower frequency).

c) She will hear the same note (same frequency).

Question 10 [3 points]

The following figure shows a wave on a rope at a given time. This wave is moving toward the left (negative x axis). Directly on the graph below...

...draw a vector showing the direction of the velocity of the rope at point P.

...draw a vector showing the direction of the acceleration of the rope at point Q.

...circle every point on the rope where the kinetic energy is equal to zero.

Question 11 [15 points]

We have to design a spherical mirror to concentrate 4 m in front of the mirror the light rays coming from a small light bulb. In other words, we want the image of the light bulb to be located 4 m in front of the mirror. The light bulb has a height of 5 mm and we want the image to have a height of 40 cm (inverted or not).

a) At what distance from the mirror must we place the light bulb?

b) What radius of curvature must the mirror have?

c) What type of mirror must we use, concave or convex?

Question 12 [15 points]

In the situation illustrated below, Jean-Raphaël is standing 20 m in front of the police car moving at 5 m/s, while being 10 m behind the one moving at 10 m/s. The siren of each car produces a sound at 400 Hz with a power of 100 W. The air temperature is 18 °C.

5 m/s   400 Hz   Police   10 m/s   400 Hz   Police

a) At that instant, what is the frequency of the beats heard by Jean-Raphaël?

b) What is the intensity (in decibels) of the sound heard by Jean-Raphaël?

Question 13 [20 points]

A given spring is streched by a distance of $8\,\text{cm}$ when a $6\,\text{N}$ force is applied on it.

a) What mass must we fix to that spring if we want to create a horizontal mass-spring system (without friction) with a period of $0.8\,\text{s}$?

b) If we make the mass-spring system described in a) oscillate with an amplitude of $4\,\text{cm}$, what is the speed of the mass when it is located $2\,\text{cm}$ away from its equilibrium position?

c) Still with the same system and an amplitude of $4\,\text{cm}$, at which distance from the equilibrium is the mass when its kinetic energy is equal to twice the potential energy within the spring?

d) If we attach the same mass found in a) at the end of a massless rope to create a simple pendulum, what must the length of this rope be to keep a period of $0.8\,\text{s}$?

Question 14 [20 points]

A metallic string has a mass of $0.5\,g$ and a length of $50\,cm$.

a) What must the tension force inside the string be for the fifth harmonic to have a frequency of $800\,Hz$?

b) What is the speed of the waves on this string?

c) For the fifth harmonic, if the string's motion $3\,cm$ away from one of its extremity has an amplitude of $2\,cm$, what is the amplitude exactly at an anti-node?

d) At an anti-node of the fifth harmonic, what is the maximum speed of the string?

Answers

1. c   2. d   3. c   4. a   5. water, water, water   6. b

7. The object is far on the left, bigger and inverted relative to the image.

8. a   9. c

10. The velocity of point P is vertical and upward, the acceleration of Q is vertical and upward, the maxima and minima of the sine have no kinetic energy.

11. a) $5\,cm$ (in front of the mirror)   b) $9.8765\,cm$ c) concave

12. a) $17.30\,Hz$ b) $109.98\,dB$

13. a) $1.216\,kg$ b) $\pm27.207\,cm/s$ c) $\pm2.3094\,cm$ d) $15.887\,cm$

14. a) $25.6\,N$ b) $160\,m/s$ c) $2.4721\,cm$ d) $124.26\,m/s$