EXAM 1

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

Fall 2016
Prof: Jean-Raphaël Carrier

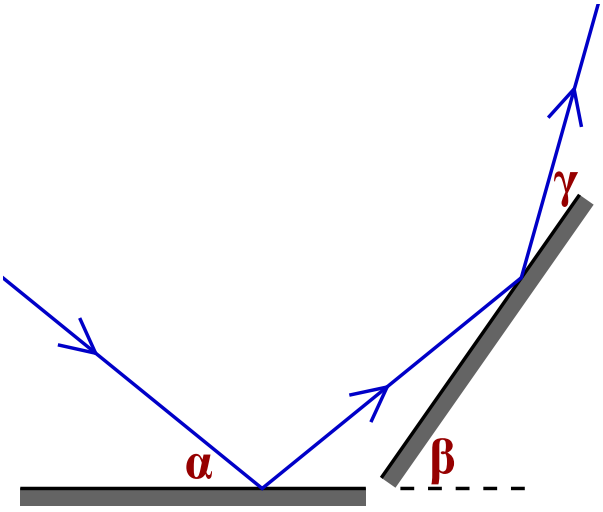
First name:
Last name:

Instructions

- For questions 1 to 10, only the correct answer is 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 three first 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 ray is reflected by two plane mirrors. If $\alpha = 39°$ and $\beta = 55°$, what is the angle γ?



Answer: $\gamma =$

Question 2 [3 points]

An instrument produces a sound where the first three harmonics are 340 Hz, 1020 Hz and 1700 Hz. What instrument could this be? *Circle every correct answer.*

a) A guitar string.
b) A tube with both extremities open.
c) A tube with one extremity open and the other closed.

Question 3 [3 points]

Here are the parameters of three different simple pendula.

Pendulum 1: $L = 80\,\text{cm}$, $m = 1.25\,\text{kg}$, $\theta_{\text{max}} = 12°$

Pendulum 2: $L = 60\,\text{cm}$, $m = 0.75\,\text{kg}$, $\theta_{\text{max}} = 15°$

Pendulum 3: $L = 80\,\text{cm}$, $m = 0.75\,\text{kg}$, $\theta_{\text{max}} = 8°$

Which pendulum has the highest frequency of oscillation? *Circle the correct answer.*

a) Pendulum 1.

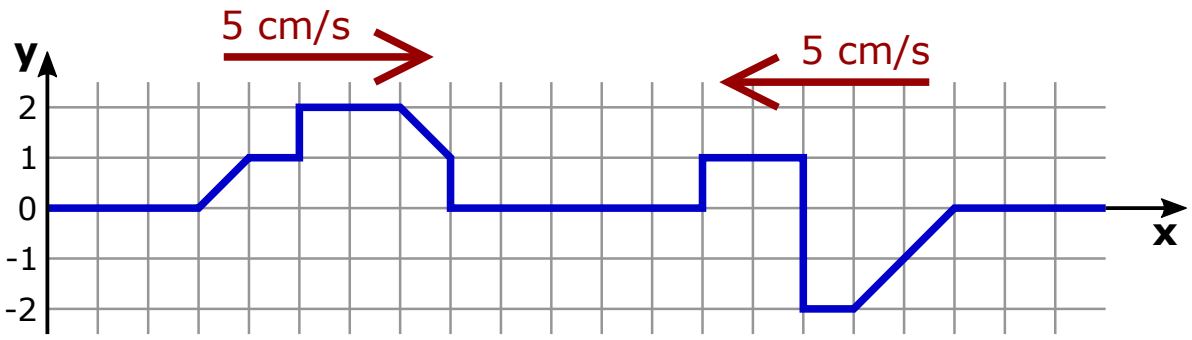
b) Pendulum 2.

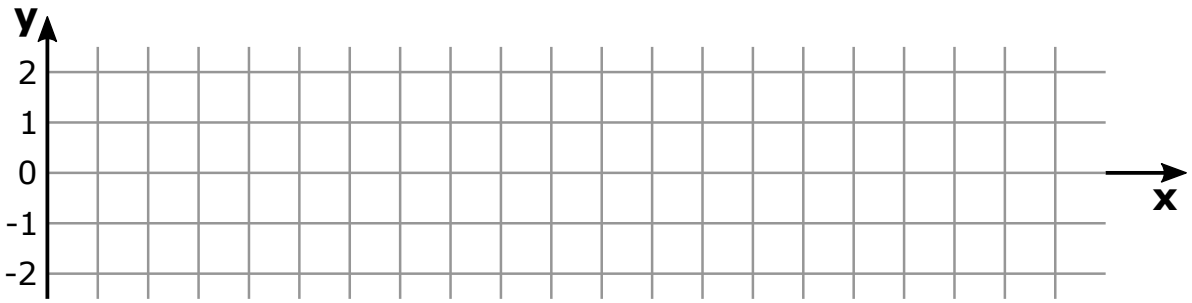
c) Pendulum 3.

d) Pendula 2 and 3, which have the same frequency.

Question 4 [3 points]

Two transverse mechanical waves are propagating on the same rope, in opposite directions, with a speed of 5 cm/s. In the empty grid below, draw the resulting wave 1 s later. Each square in the grid is 1 cm by 1 cm.





Question 5 [3 points]

Feeling particularly energetic one morning, Maxime throws a bright yellow ball at a very, very high speed (90 000 km/h) away from her, in a vacuum (absolutely no friction due to air resistance). From her point of view, what colour is the ball? *Circle the correct answer.*

a) Maxime's eyes cannot see the ball as it appears to be in the infrared.

b) The ball seems to be yellow, but a tiny bit more orange than before.

c) The ball seems to be yellow, but a tiny bit greener than before.

d) Maxime's eyes cannot see the ball as it appears to be in the ultraviolet.

Question 6 [3 points]

A ray of light propagating in water ($n_1 = 1.33$) hits the surface of an object made of glass ($n_2 = 1.49$). Knowing that the indices i, r, and t stand respectively for *incident ray*, *reflected ray* and *transmitted ray*, which of the following statements is true? *Circle the correct answer.*

a) $f_t < f_i$

b) $f_t > f_i$

c) $\lambda_r > \lambda_t$

d) $v_r = v_t$

Question 7 [3 points]

When using a concave spherical mirror, where should we place a real object in order to have an erect image three times as tall as the object ($m = 3$)? *Circle the correct answer.*

a) The object should be between the focus and the mirror.

b) The object should be between the centre of curvature and the focus.

c) The object should be farther away from the mirror than its centre of curvature.

d) It is impossible, we would need an object behind the mirror (virtual object).

Question 8 [3 points]

We want to use a guitar string ($\mu = 8\,\text{g/m}$, $L = 64\,\text{cm}$) to produce the same fundamental frequency as a tube open on both ends ($L = 45\,\text{cm}$, $v_{\text{air}} = 340\,\text{m/s}$). What must the tension in the guitar string be? *Circle the correct answer.*

a) 1871 N

b) 5024 N

c) 7352 N

d) 18 706 N

Question 9 [3 points]

Here are the equations of three transverse mechanical waves propagating on separate ropes.

$$y_1 = 2\,\text{cm} \cdot \sin(2\,\text{rad/cm} \cdot x - 2\,\text{rad/s} \cdot t + 2\,\text{rad})$$

$$y_2 = 1\,\text{cm} \cdot \sin(3\,\text{rad/cm} \cdot x - 3\,\text{rad/s} \cdot t)$$

$$y_3 = 1\,\text{cm} \cdot \sin(4\,\text{rad/cm} \cdot x - 2\,\text{rad/s} \cdot t - 1.5708\,\text{rad})$$

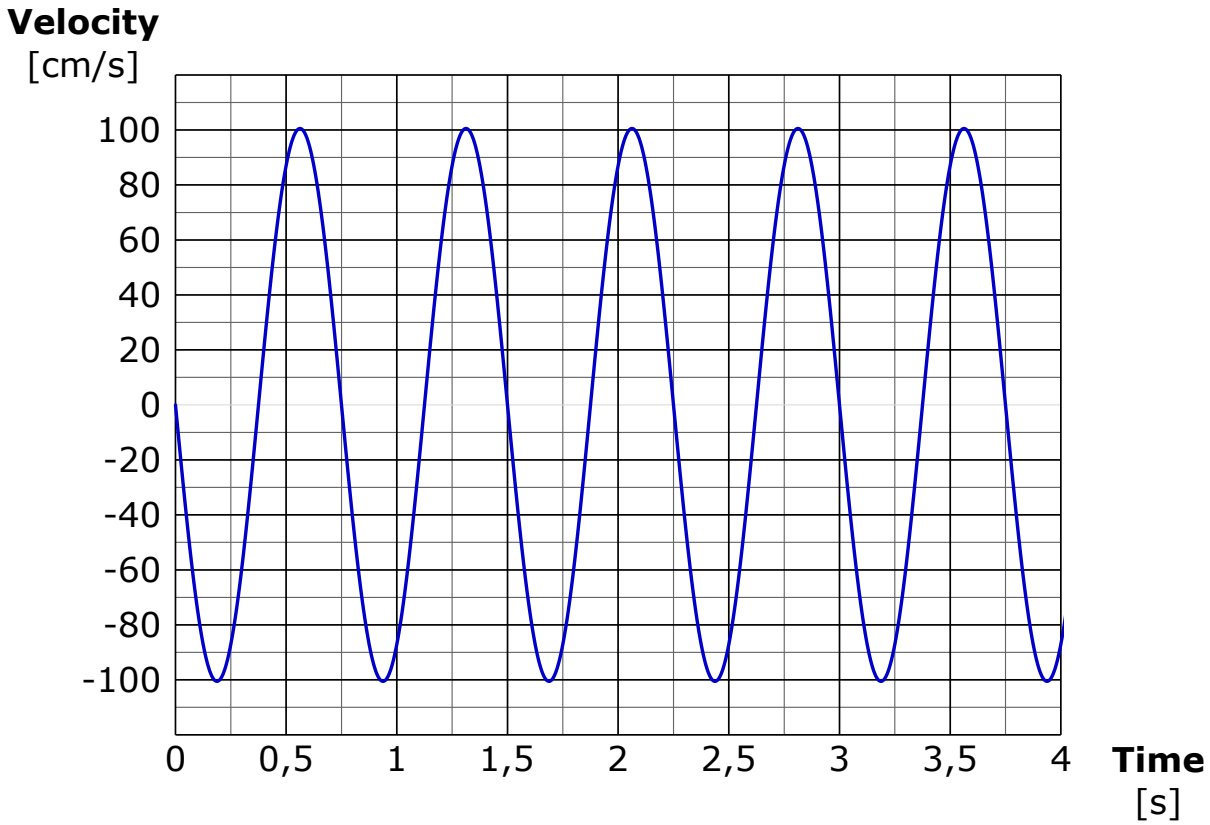
If v represents the speed of the wave and $v_{y\text{max}}$ the maximum vertical speed of a point on the rope, add the correct symbols ($<$ or $=$ or $>$) in the boxes below.

$v_1 \square v_2 \square v_3$ $\qquad$ $v_{y\text{max}1} \square v_{y\text{max}2} \square v_{y\text{max}3}$

Question 10 [3 points]

The figure below shows the graph of the velocity of a mass-spring system with respect to time. What is the value of the phase constant (in radians)?

Answer: $\phi =$



Question 11 [20 points]

A box ($m = 12\,\text{kg}$) attached with a massless spring to the ceiling of a room oscillates between the heights $h_{\text{min}} = 1.60\,\text{m}$ and $h_{\text{max}} = 2.14\,\text{m}$ relative to the floor. When no mass is attached to the spring, its length is 35 cm. The ceiling is 3 m above the floor. At a given moment ($t = 0\,\text{s}$), the box is located 10 cm below its equilibrium position and is going down.

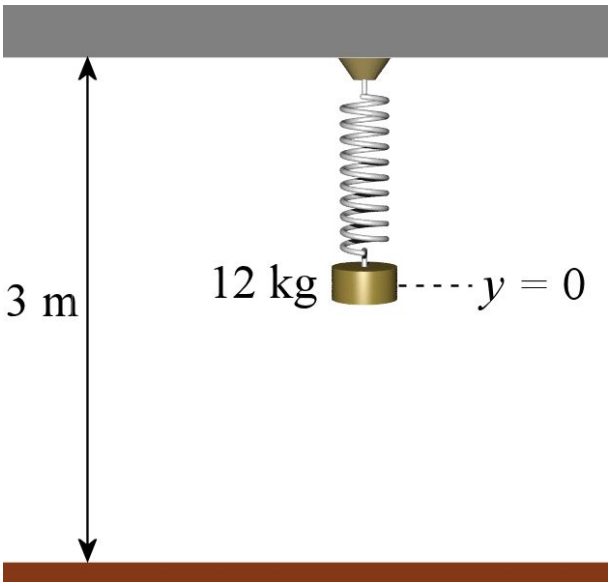
The figure below shows the system when it is at its equilibrium position.

a) [5 pts] Calculate the period of the mass-spring system.

b) [5 pts] Using the format $y = A\sin(\omega t + \phi)$, give the complete equation for the position of the box with respect to time.

c) [5 pts] At $t = 0\,\text{s}$, what percentage of the total mechanical energy is present in the form of kinetic energy?

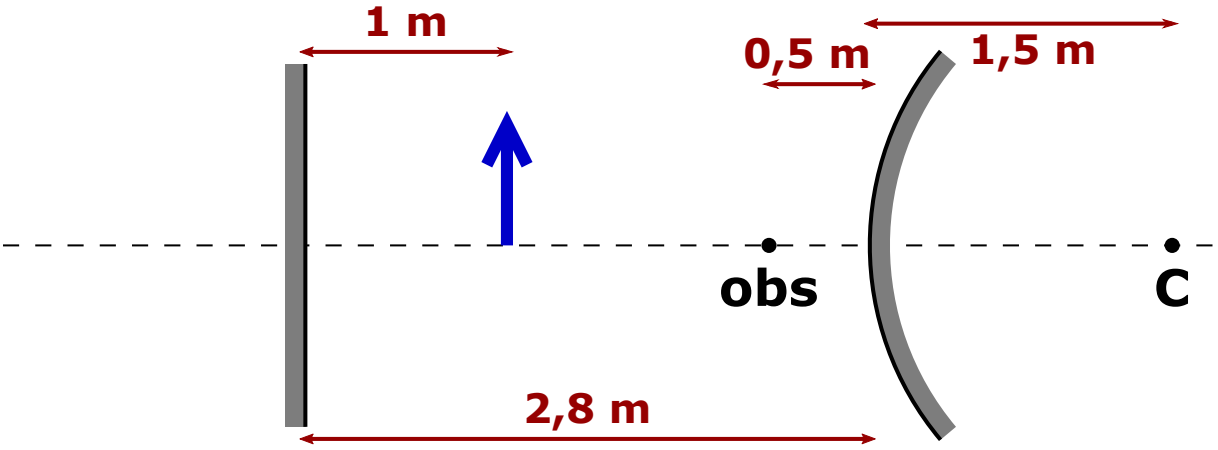
d) [5 pts] When will the box reach its lowest position? *Give the first positive time this happens.*



Question 12 [20 points]

An object (arrow) is placed somewhere between a plane mirror and a convex spherical mirror, as shown below. An observer, also placed between the two mirrors, looks *into the convex mirror* at the first reflection of the object made by the plane mirror.

Technically, there is an infinite number of reflections (and images), but here we only consider the image obtained after one reflection by each mirror, which is the second image.



Using the graphical method (principal rays) on the figure above, determine...

a) [4 pts] ... whether the second image is erect or inverted.

b) [4 pts] ... whether the second image is smaller or bigger than the initial object.

Using the algebraic method (equations), calculate...

c) [6 pts] ... the distance between the observer and the second image.

d) [6 pts] ... the total transverse magnification (m_{tot}).

Question 13 [15 points]

Two long ropes ($\mu_1 = 625\,\mathrm{g/m}$ and $\mu_2 = 250\,\mathrm{g/m}$) are attached together, while the second rope is also fixed to a wall. A transverse sine pulse having an amplitude of 6 cm and a length of 8 cm is sent in the first rope, where it travels at a speed of $9\,\mathrm{m/s}$.

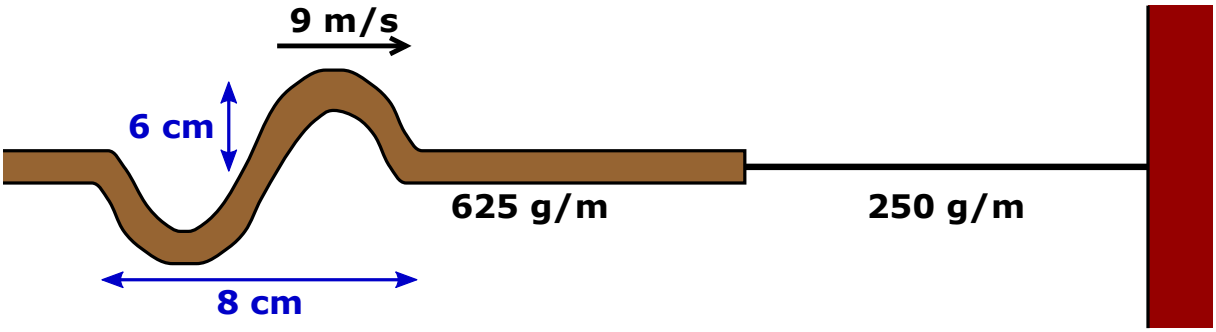
a) [5 pts] What percentage of the energy is reflected when the pulse meets the second rope?

b) [4 pts] At what speed does the transmitted pulse travel in the second rope?

One fraction of the initial pulse gets transmitted in the second rope, then reflected by the wall, then directly transmitted back into the first rope.

c) [4 pts] What is the amplitude of this pulse when it has come back in the first rope?

d) [2 pts] At this point, is this pulse inverted relative to the initial pulse?



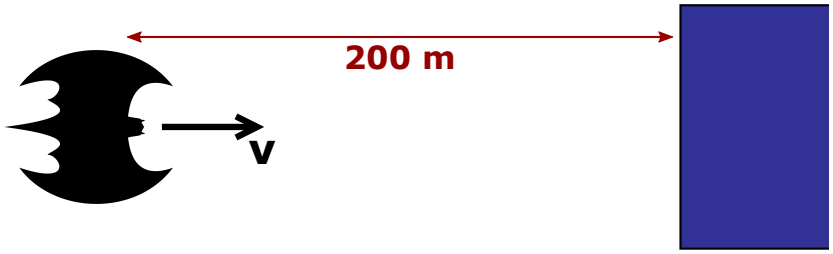
Question 14 [15 points]

One cool night ($T = 10\,°\text{C}$), Batman soars horizontally over Gotham. His new *Batsonar* emits a constant sound at 300 Hz with a power of 8 W. When Batman is 200 m from a skyscraper, the waves from his device and from the reflection on the building produce beats at 16 Hz.

a) [3 pts] At what speed does the sound travel?

b) [6 pts] What is Batman's speed?

c) [6 pts] What is the intensity, in decibels, of the sound heard at that moment (when Batman is 200 m away) by a person standing at an open window in this skyscraper?



Answers

1. 16° 2. c 3. b 5. b 6. c 7. a 8. a

9. $v_1 = v_2 > v_3$ and $v_{y\max 1} > v_{y\max 2} > v_{y\max 3}$ 10. $\frac{\pi}{2}$ rad or $-\frac{3\pi}{2}$ rad

11. a) 1.773 s b) $y = 0.27\,\text{m} \cdot \sin(3.545\,\text{rad/s} \cdot t + 3.521\,\text{rad})$ c) 86.28 % d) 0.3361 s

12. a) erect b) smaller c) 1.126 m d) 0.1648

13. a) 5.069 % b) 14.23 m/s c) −5.696 cm d) yes

14. a) 337.3 m/s b) 8.761 m/s c) 72.02 dB