Optics - Cooperative problem solving

23^{rd}, 27^{th} February, 2018

1 Background story

Six research groups, three from the East coast and three from the West coast of the US, have bought some equipment for experiments about optics from the company "CrappyOptics Inc.". As the name of the company suggests, this was not a good choice: the material was *delivered* to the labs with no documentation, the *technical support service* does not answer to the questions asked by the scientists. As a result now the researchers must find a way to calculate the *technical specifications* of the lab equipment themselves.

2 Goal

The problem is solved only when all the teams know the technical specifications of their equipment.

3 Rules

3.1 Groups

The students form 6 groups, with each group representing a research team from the following institutes:

- M.I.T. (Massachusetts Institute of Technology)
- Harvard University
- Princeton University
- California Institute of Technology
- Stanford University
- University of California - Berkeley

The first three institutes are based on the East coast, the other three on the West coast.

3.2 Communication

Every group works independently. Communications between groups are allowed only during "conferences" or by "e-mail" .

The conferences are organised by the teacher. There are two kinds of conferences: "local", and "national".
When a local conference is organised, the research teams from the same coast can communicate their results to each other and/or ask for advice.
On the other hand in a national conference all the groups are invited and can talk to each other.
Local conferences are more frequent than national conferences (*e.g.* a local conference may be organized once every 15 minutes and a national conference once every 30 minutes).
Every time a group attends a conference, its members select a person as the "responsible for communication" and he/she is the only member allowed to talk during the conference. The "responsible for communication" must change at every conference.

If a group wants to communicate with another group (from the same or from the other coast) in the time interval between two conferences, this can be done by "email". One of the members of the group writes down a small note on a piece of paper and gives it to the teacher, that will *pass it on* to the desired group.

3.3 Problem solving

The members of the same group can work together on their problem. During the first hour of the game each group can use one textbook, after the first hour the use of the book is not allowed anymore.

Sometimes the data available to a group may not enough to solve their problem. The missing data must be obtained by communicating with the other groups. Each group needs to go as far as possible in the solution of their problem even without the missing data: this will make it easier to communicate to the other groups what are the data *at your disposal*, what are the data you need, and what you could calculate once you have all the data you need.

3.4 Invitation to the first conference

From: the@boss.it
To: boss@optics.UCberkeley.edu; boss@optics.caltech.edu; boss@optics.harvard.edu; boss@optics.MIT.edu; boss@optics.princeton.edu; boss@optics.stanford.edu

Dear colleagues,

From the recent communications that I had with you on separate occasions, it seems that we have all bought material from CrappyOptics Inc. and have the problem of finding out what are the precise techincal specifications of the equipment. Therefore I invite you to the conference that I am organising in Trento (IT) on 23rd February 2018, in the prestigious “Liceo da Vinci”.
It would be very helpful if each group could send a member to say a few words telling everyone what equipment his/her team has bought from CrappyOptics Inc.. Then we can start to think of a strategy to find out all the techincal specifications we need.
I anticipate that, since I am currently very busy with my research, I will not be able to help you directly. However I can still offer some support and advice: you can contact me via email or we can talk during the conferences.

Best regards,
the Boss

M.I.T.

Research team

Name and surname of the research team members:

- . . . .
- . . . .
- . . . .
- . . . .

Equipment

- one CrappyOptics laser module (model LM0001) of **unknown** wavelength
- basic equipment to precisely measure lengths and angles
- screens (with different numbers of *slits*)

Notes for the first conference

Before the first conference begins you need to have a clear picture of

- what equipment is at your disposal
- what kind of experiments you can do with that equipment
- what is your goal (*i.e.* what is the quantity that you want to find)

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Communication history

On this page you must note down every participation to a local/national conference together with the name of the ”responsible for communication” of your group for that conference, for example:
”National conference 1 $\longrightarrow$” Albert Einstein.
Also write a note every time you send/receive an email, for example:
”email sent to/received from boss@optics.berkeley.edu”.

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M.I.T.

Problem

When you come back to the lab after the national conference you find an *unpleasant* surprise. The screens with single and double slits are damaged and you cannot *carry out* interference or diffraction experiments.
On the bright side while searching information online about the CrappyOptics laser LM0001 you find an article from a scientist that says that she used that laser to make a double slit interference experiment with the following setup:

- distance between the slits $d = 25.8\mu$m
- distance between the screen with the slits and the target screen $L =$ 1.83m

Moreover the article *states* that a dark band can be seen on the screen at a distance $y = 16$cm above the central light band. Unfortunately the author does not mention either the value of the wavelength of the laser or the number of the dark band.

With the data at your disposal you cannot calculate the exact value of the wavelength of the laser, but you can still get important information about it. What is this information? Try to find out!

Harvard university

Research team

Name and surname of the research team members:

- . . . .
- . . . .
- . . . .
- . . . .

Equipment

- one CrappyOptics laser module (model ??????) of **unknown** wavelength
- one CrappyOptics triangular prism (model P0001 with angles of 90°, 54°, 36°) of **unknown** refraction index
- basic equipment to precisely measure lengths and angles

Notes for the first conference

Before the first conference begins you need to have a clear picture of

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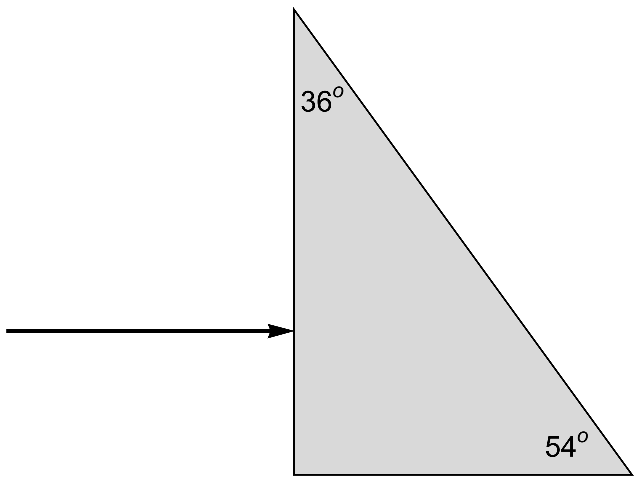
Harvard

Problem

You decide to do an experiment about the dispersion of light: you *shine the beam* from your laser on the surface of your triangular prism as in shown in figure. The light of the laser *exits the prism* at an angle of 32.2° with respect to the initial direction of the beam. This is enough information to calculate the refraction index of your prism for the specific wavelength of the laser. You think that the experiment is easy enough to let a student do it but, in order to be sure that the student does not *mess up the task*, you write down a few lines about the phenomenon of the dispersion of light that he must read before solving the problem. Also you complete the figure with the path followed by the light, the normal directions to the various surfaces that the light beam encounters, and the angles of refraction.



Princeton University

Research team

Name and surname of the research team members:

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Equipment

- one CrappyOptics laser module (model **??????**) of **unknown** wavelength
- one CrappyOptics rectangular prism (model P0002) of **unknown** refraction index
- basic equipment to precisely measure lengths and angles

Notes for the first conference

Before the first conference begins you need to have a clear picture of

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Princeton

Problem

You decide to do an experiment about the refraction of light: you *shine the beam* from your laser on the surface of your CrappyOptics rectangular prism P0002. You notice that when the orange-red light propagating inside the prims hits the surface with an incident angle larger than 42.5°, the light is completely reflected. This data is enough to calculate the index of refraction of your prism specific for the wavelength of your laser. Therefore you decide to write a short paragraph regarding total reflection and how you calculated the index of refraction of your prism.

California Institute of Technology

Research team

Name and surname of the research team members:

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Equipment

- one CrappyOptics laser module (model LM0002) of **unknown** wavelength
- basic equipment to precisely measure lengths and angles
- screens (with different numbers of *slits*)

Notes for the first conference

Before the first conference begins you need to have a clear picture of

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California Institute of technology

Problem

It looks like somebody has stolen your screens with single and double slits: you cannot carry out interference or diffraction experiments!
Luckily during a coffee break you talk to a colleague that says that he has done an experiment about diffraction from a single slit using the LM0002 laser of your lab while you were away on a conference. He gives you his notes about the experiment but they are a bit chaotic. You manage to collect the following data

- width of the slit $W = 9.16\mu$m
- distance between the screen with the slits and the target screen $L = 1.08$m

Moreover your colleague remembers that a dark band could be seen on the screen at a distance $y = 23$cm above the central light band. Unfortunately he does not remember either the value of the wavelength of the laser or the number of the dark band.

With the data at your disposal you cannot calculate the exact value of the wavelength of the laser, but you can still get important information about it. What is this information? Try to find out!

Stanford University

Research team

Name and surname of the research team members:

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- . . . .
- . . . .
- . . . .

Equipment

- one CrappyOptics laser module (model **??????**) of **unknown** wavelength
- one CrappyOptics triangular prism (model P0001 with angles of 90°, 54°, 36°) of **unknown** refraction index
- basic equipment to precisely measure lengths and angles

Notes for the first conference

Before the first conference begins you need to have a clear picture of

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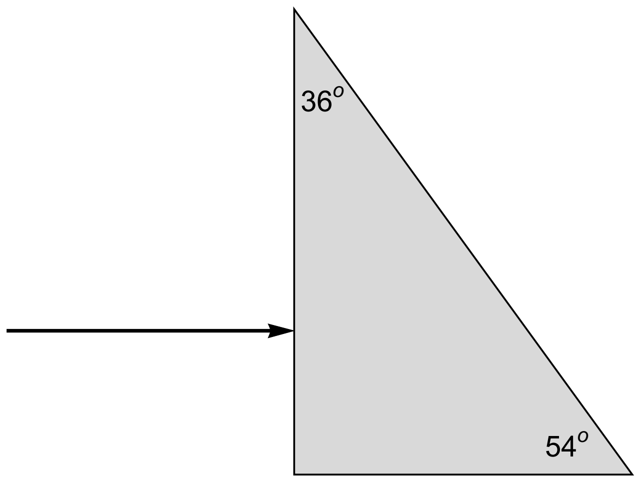
Stanford

Problem

Since you have a triangular prism, you decide to do an experiment about the dispersion of light: you *shine the beam* from your laser on the surface of your triangular prism P0001 as in shown in figure. The orange-red light of the laser *exits the prism* at an angle of 35.1° with respect to the initial direction of the beam. This is enough information to calculate the refraction index of your prism for the specific wavelength of the laser. You think that the experiment is easy enough to let a student do it but, in order to be sure that the student does not *mess up the task*, you write down a few lines about the phenomenon of the refraction of light that she must read before solving the problem. Also you complete the figure with the path followed by the light, the normal directions to the various surfaces that the light beam encounters, and the angles of refraction.



University of California - Berkeley

Research team

Name and surname of the research team members:

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Equipment

- one CrappyOptics laser module (model **??????**) of **unknown** wavelength
- one CrappyOptics rectangular prism (model P0002) of **unknown** refraction index
- basic equipment to precisely measure lengths and angles

Notes for the first conference

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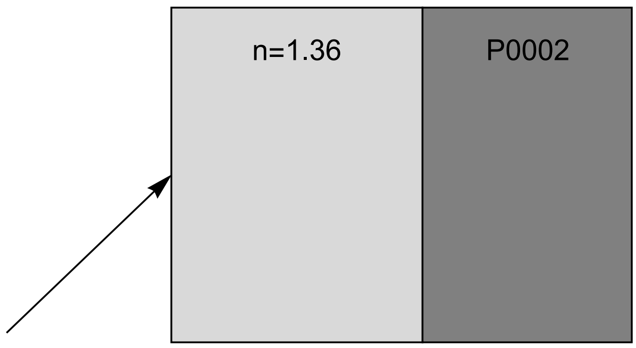
University of California - Berkeley

Problem

You want to calculate the index of refraction of your rectangular prism P0002 so you decide to do an experiment about the refraction of light: you shine the beam from your laser on the surface of a rectangular prism that you found in a closet that has a refraction index (specific for the wavelength of your laser) equal to 1.36. Next to this first prism you place your CrappyOptics rectangular prism P0002. You measure that, if you shine the light with a incident angle of 49.0° on the first prism, the angle of refraction of the light that comes out of it is equal to 31.37°. Therefore you decide to write a short paragraph regarding refraction and how you calculated the index of refraction of your prism. Also complete the figure with a realistic representation of the path followed by the light.



Glossary

While reading this document you will encounter some words or expressions that you may find difficult to understand: some of them are highlighted by writing them in *italic*, and their meaning is given here below.

- delivered = consegnato
- technical support service = servizio di supporto tecnico
- technical specifications = specifiche tecniche
- e.g. = per esempio (e.g. è infatti l'abbreviazione dell'espressione latina "exempli gratia")
- pass something on to someone = passare/inoltrare qualcosa a qualcuno
- to be at someone's disposal = essere a disposizione di qualcuno
- unknown = sconosciuto
- i.e. = cioè (i.e. è infatti l'abbreviazione dell'espressione latina "id est")
- unpleasant = spiacevole
- carry out = eseguire
- on the bright side = dal lato positivo
- to state = affermare
- to shine light/a light beam on something = colpire/illuminare qualcosa con un raggio di luce
- to exit something = uscire da qualcosa
- to mess up something = sbagliare/eseguire male qualcosa

Technical terms

- light ray/beam = raggio di luce
- wavelength = lunghezza d'onda
- frequency = frequenza
- path = percorso
- reflection = riflessione
- refraction = rifrazione
- refraction index = indice di rifrazione (N.B. il plurale di "index" è "indices")
- deflection = deviazione
- dispersion = dispersione
- rectangular/triangular prism = prisma a base rettangolare/triangolare
- incident/reflection/refraction angle = angolo di incidenza/riflessione/rifrazione
- slit = fenditura
- interference/diffraction pattern = figura di interferenza/diffrazione