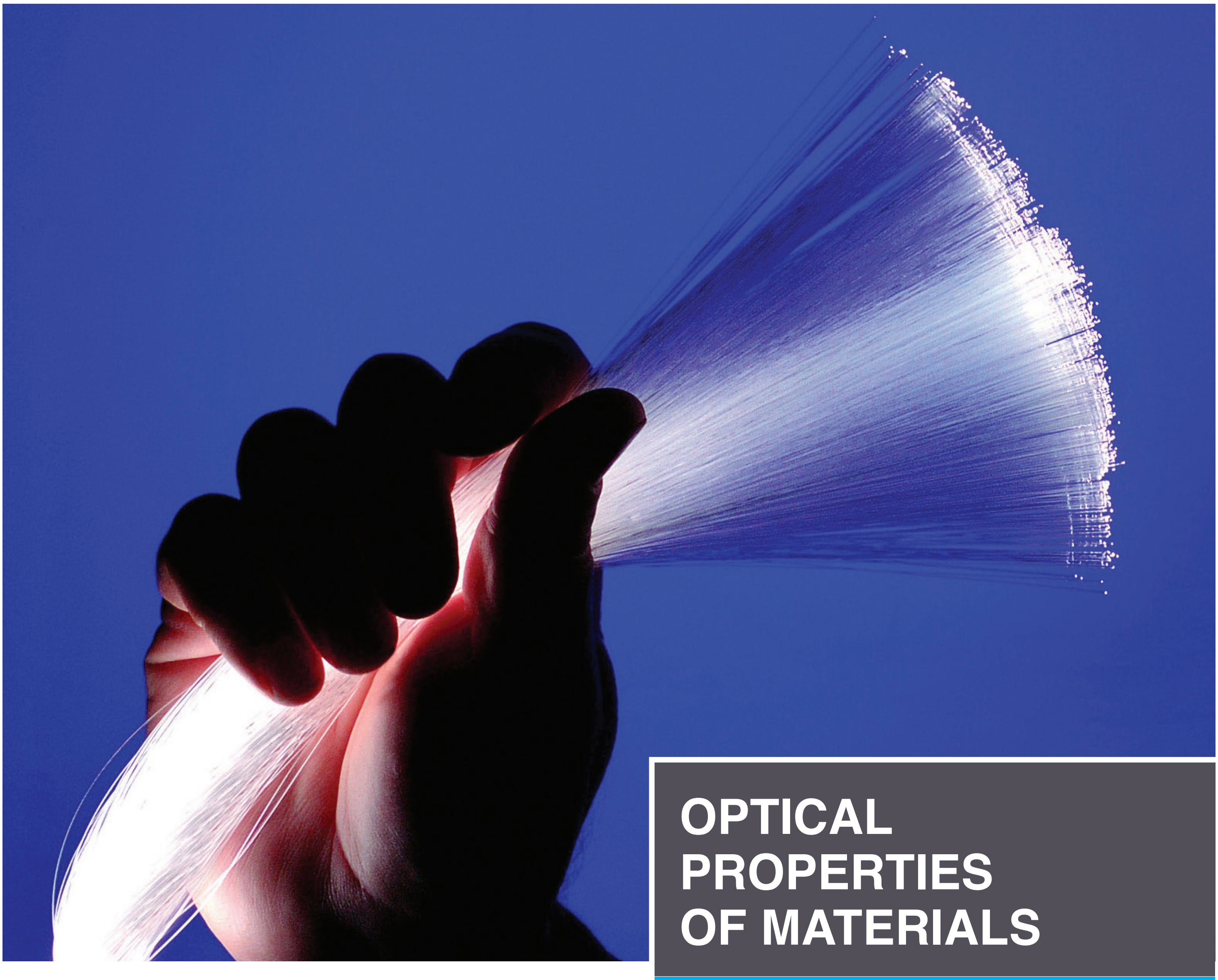

OPTICAL PROPERTIES OF MATERIALS

TEACHING AND LEARNING ACTIVITIES

ADAPTED VERSION

MATERIALS SCIENCE PROJECT

UNIVERSITY-SCHOOL PARTNERSHIPS FOR THE DESIGN AND IMPLEMENTATION OF RESEARCH-BASED ICT-ENHANCED MODULES ON MATERIAL PROPERTIES

SPECIFIC SUPPORT ACTIONS

FP6: SCIENCE AND SOCIETY: SCIENCE AND EDUCATION

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OPTICAL PROPERTIES OF MATERIALS

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CONTENTS

UNIT 0:
HOW DO WE SEE?

0 HOW DO WE SEE?

0.1.

0.1.1. In the box we have put a coin. Look through the small hole on top of the box.

Can you see the coin? Yes or no? Why?

0.1.2. Light up the torch and try to shed light into the box from the hole on its side.

Can you now see the coin? Yes or no? Why?

0.2.

0.2.1. Aim the wall with your torch.

Where do you believe there is light?

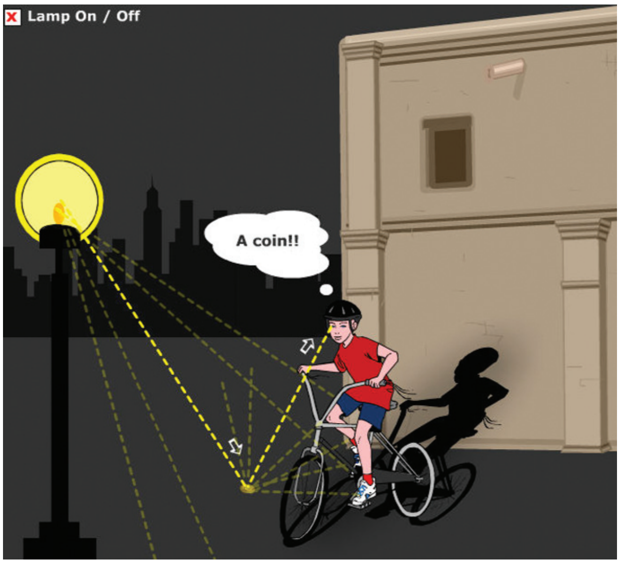
0.2.2. You can make the air "dirty" using dust, flour, chalk powder or smoke.

What do you observe?

0.3.

0.3.1. Watch on the projection screen for the moment when the biker is able to see the coin.

What precisely happens that enables him to see the coin?

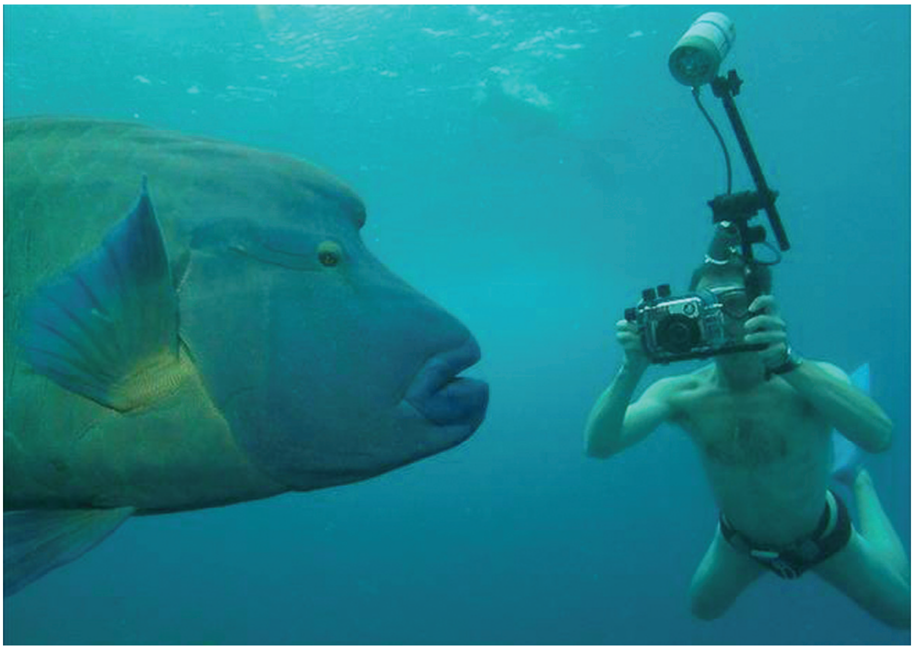


0.3.2. What is your conclusion?

0.4.

0.4.1. The diver in figure 1 is submerged together with a photo camera on the bottom of the sea.

Why doesn't he light up his torch when taking pictures?



....

....

0.4.2. The diver in figure 2 has his torch on when taking pictures. Why?

....

....

0.4.3. **The diver in figure 3 has his torch on when taking pictures. However, the picture taken is foggy. Why does this happen?**

....

....

0.4.4. **In which way is light useful for the fish living in the deep sea?**

....

....

UNIT 1: WHAT ARE OPTICAL FIBERS?

Let's observe some common objects made of optical fibers. Probably you might have seen those nice lamps that look as if they are made of plastic strings; or the decorative items where you can see a lighted spot at the end of a plastic string. These objects are called "optical fiber" lamps.

1.1 OBSERVE

1.1.1. Let's see how such a lamp is made. Light a torch near one extreme of the optical fiber lamp, where the fibers are bundled.

What do you observe at the other end of the fibers?

1.1.2. Make a drawing of how you think light travels in each of the following cases:

1.1.3. What are the most important similarities and differences between the optical fiber lamp and a "normal' one?

1.1.4. Place an optical fiber straight on the table, a piece of black cardboard (as screen) at the one end of the fiber and a small torch bulb at the other end and light up the torch.

What do you observe on the screen?

1.1.5. Without moving the small screen or the torch, bend the fiber.

What happens to the brightness of the light spot on the screen as you bend the fiber?

1.1.6. Repeat the experiment using the other plastic tubes on your bench.

What do you observe?

This experiment has to be performed by a couple of students: your peer holds one end of the fiber and the laser and you stay behind an obstacle and observes the other end of the fiber.

1.1.7. Tell your friend what signals (short, long, how many) your peer sent you at the other end of the fiber.

1.2 EXPLAIN

1.2.1. How would you describe an optical fiber? What are its main features?

	CORRECT	WRONG
• An optical fiber can “guide” light.		
• The brightness of the light at the end of the optical fiber remains about the same, independent of how much we bend it.		
• An optical fiber has a visible interior.		
• An optical fiber is transparent.		
• When an optical fiber is bent, the light at its end fades out.		

1.2.2. An optical fiber can be used:

	CORRECT	WRONG
• To absorb and store light.		
• To transmit information.		
• To increase the speed of light.		
• To increase the brightness of an optical signal.		
• To guide light.		

UNIT 2: IS IT POSSIBLE TO GUIDE LIGHT?

Light can travel along an optical fiber, but we cannot see its path. Let's try to make a light guide where it is possible to see the light path.

Materials:

- A transparent vessel
- A laser pointer
- A cork stop for the hole in the vessel
- A basin to collect the water poured out of the vessel

2.1 PREDICT

2.1.1. Laser beam hits a plastic transparent vessel full of water, in a way parallel to its base. The plastic vessel has a hole through which water can pour out of it.

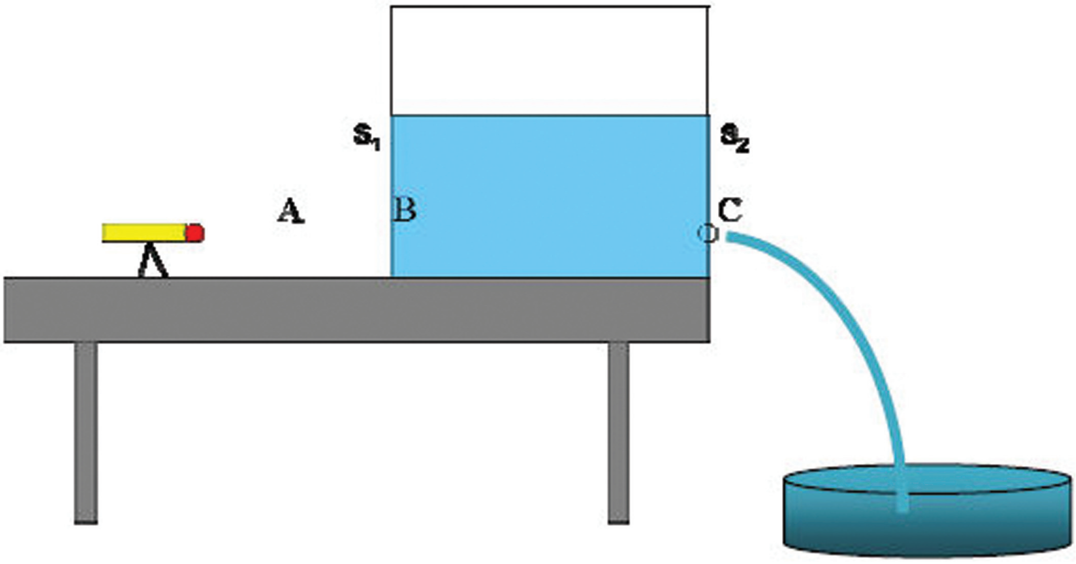
What happens if we aim that hole with the laser beam?

....

....

....

2.1.2 The figure shows the experimental setup. Draw the path followed by the laser beam from its source (the pointer) to the basin that collects the water.



2.2 OBSERVE

2.2.1. Carry out the experiment. Focus your attention on the path followed by the laser beam in air (AB) and in the water (BC).

(To be able to see the laser beam in the air, "dirty up" the air by adding some particles of e.g. dust or smoke. In this way you can see the laser beam.).

The path of the laser beam in air (AB in the previous figure) is:

straight ☐ curved ☐

jagged ☐ random ☐

The path of the laser beam in the water (BC in the previous figure) is:

straight ☐ curved ☐

jagged ☐ random ☐

2.2.2. Aim now the laser beam directly on the hole from which water is ejected.

Describe in detail what you observe in the water jet.

....

....

....

UNIT 3: OBSERVING THE LIGHT PATH

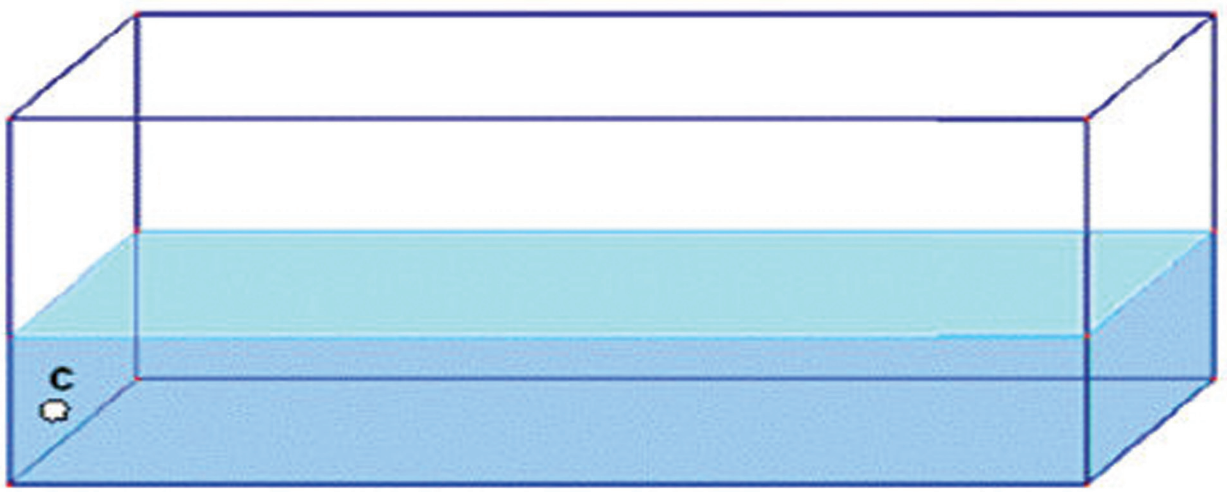
Materials:

- A transparent vessel
- A laser pointer
- A cork stop for the hole in the vessel
- Materials to create floating particles (dust, smoke etc.)

3.1 OBSERVE

- Half-fill the vessel with water and fill the air above the surface with smoke. Cover up the vessel using its transparent cover.
- Investigate in how many ways it is possible to hit point C (located at the hole in the vessel of the previous experiment) with the laser beam.
- Try to aim the laser beam using a direction that is not parallel to the base of the vessel.

3.1.1. In the following figure draw at least two different pathways of the laser beam in the air and in the water, using different colors. Also draw the position of the laser pointer for each case.



3.1.2. Did you notice any variations in the brightness of the laser beam along its path in the air and in the water?

Describe cases where such a variation occurred.

....

....

....

3.2 EXPLAIN

3.2.1. When a laser beam travelling in a less dense material (air) reaches at an angle a more dense material (water) then:

	CORRECT	WRONG
• It continues travelling in a straight path and does not change direction.		
• It continues travelling in a straight path but changes direction.		
• The light beam is reflected on the surface of the water and light does not enter water at all.		
• A part of the light beam is reflected and a part enters the water.		

3.2.2. When a laser beam travelling in a more dense material (water) reaches at an angle a less dense material (air) then:

	CORRECT	WRONG
• It continues travelling in a straight path and does not change direction.		
• It continues travelling in a straight path but changes direction.		
• The light beam is reflected on the surface of the water and light does not enter water at all.		
• A part of the light beam is reflected and a part enters the water.		
• When the angle of incidence takes a certain value, the light beam is reflected on the surface of the water and is “guided” into the water.		
• The light beam is always “guided” in the water		

UNIT 4: WHEN AND HOW DOES LIGHT DEVIATE? REFLECTION

4.1 AN INTRODUCTION TO MEASUREMENT ERRORS

Measurements always have **uncertainties**.

We often state the **precision** of a number by writing the number, the symbol ± and a second number denoting the **probable uncertainty**. If, for example, the diameter of a metal rod is given as 56.47 ± 0.02 mm, then what is meant is that the **true value** of the diameter is quite improbable to be **lower** than 54.65 or **higher** than 56.49 mm.

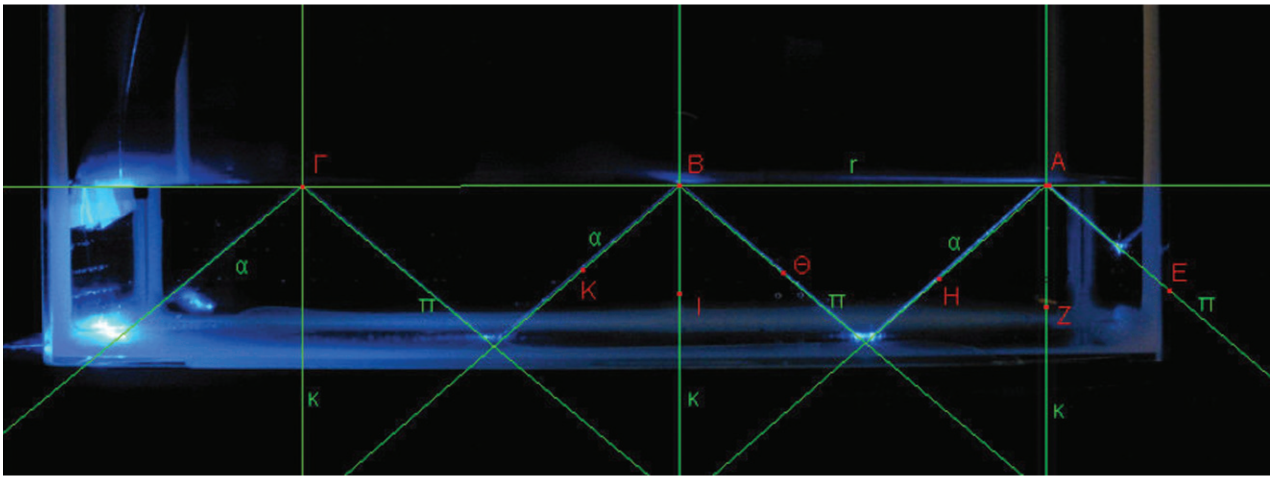
Uncertainty is also often expressed as a **percentage**. The thickness of a vessel wall having a nominal value of 20 ± 10% mm is improbable to differ from 20 mm more than 10% (of 20 mm), i.e. more than 2 mm. Thus, the true value of the thickness is most probably between 18 and 22 mm.

4.2

Open the file “multiple_reflection.fig” using Cabri.

4.2.1. Use the Cabri software and:

- Superimpose a light ray r on the water surface.
- From the right part of the screen, a light ray π enters which reaches the boundary between air and water and then undergoes multiple reflections **in** the water.
- Define the points of consecutive reflections on the line r (the boundary between air and water) and name them A, B and Γ.
- Then draw the half-lines defined by the incident light rays and name them respectively Aπ, Bπ and Γπ. Then draw the half-lines defined by the reflected light rays and name them respectively Aα, Bα and Γα.
- Finally, draw the vertical segments κ to the line r at points A, B and Γ. Your figure should now look like the following:



- Define points E, Z, H, Θ, I and K on the half-lines Aπ, Aκ, Aα, Bπ, Bκ and Bα respectively.
- Measure the angles EAZ, ZAH, ΘBI and IBK and complete the following table.

Compare the angles in the first two pairs of adjacent angles.

	EXAMPLE	1ST PAIR OF ANGLES (AT A)		2ND PAIR OF ANGLES (AT B)	
Measured angle value	45º				
Are the angles equal?	-				
10% uncertainty in the above measurement	± 4,5º				
Interval of probable true value	41,5º - 49,5º				
Is there an overlap in the two values of the pair?	-				

4.2.2. Can we say that the angles in each pair are equal?

4.2.3. Observe again the photograph.

The light beam has been sent from the water into the air or inversely?

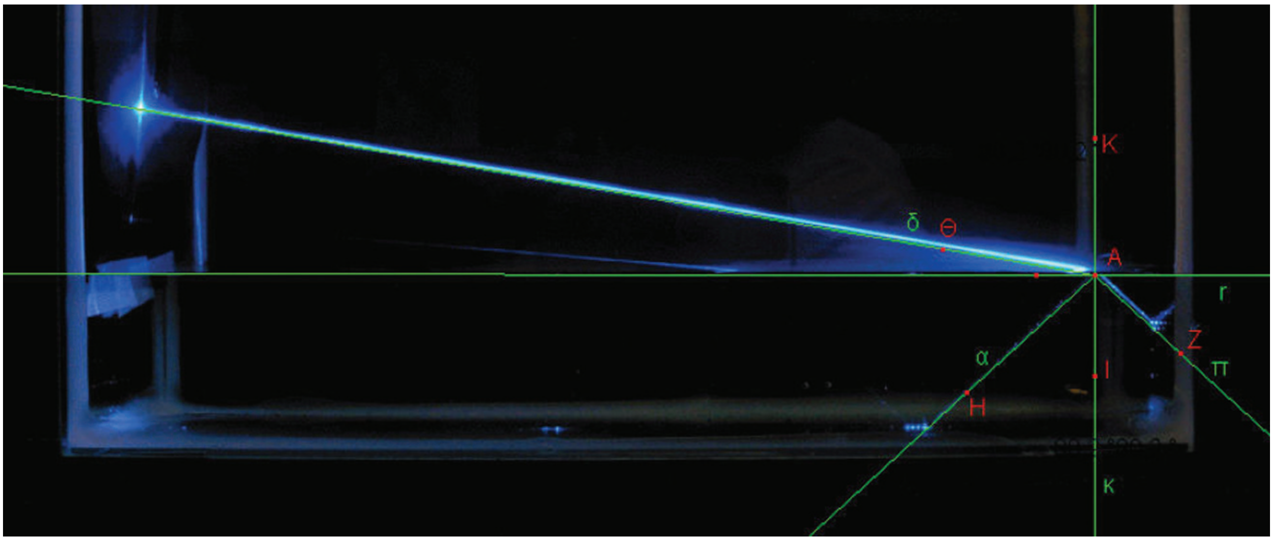
4.3

Open the file “reflection_refraction.fig” using Cabri.

4.3.1. Use the Cabri software and:

- Superimpose on the surface of the water a light ray r.
- Draw the half-line Aπ, which defines the incident incoming ray π, on the right side of the image, the half-line Aα, which defines the reflected beam α, and the half-line Aδ, defining the course of the light beam in the air (refracted beam) δ.
- Finally, draw the vertical like κ to the line r at point A.

Your figure should now look like the following one:



- Define points Z, H, I and Θ on the half-lines Aπ, Aα, Aκ in the water and Aδ in the air, respectively.
- Measure angles ZAI, IAH and ΘAK and complete the following table:

	ANGLES IN THE WATER		ANGLE IN THE AIR
Measured angle value			
Are the angles equal?			
10% uncertainty in the above measurement			
Interval of probable true value			

4.3.2. Is there an overlap in the values of the two angles in the water? ……………

Is there an overlap in the values of the angles in the water and the angle in the air? ……………

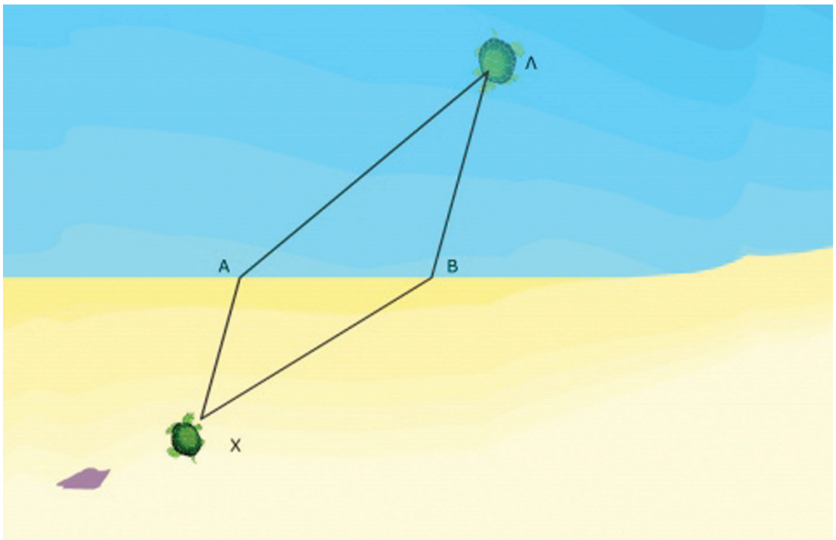
4.4 CONCLUSIONS

When a light beam in a more dense material (water) reaches at an angle a less dense material (air), then:

	CORRECT	WRONG
• The light beam continues exclusively in the same medium (only in the water).		
• The light beam continues exclusively in the other medium (only in the air).		
• A part of the light beam continues in the same medium (water) and another enters the other medium (the air).		
• **Reflection** happens exclusively in the same medium.		
• **Refraction** happens exclusively in the same medium.		
• The angle formed by the incident beam and the vertical is equal to the angle formed by the **reflected** beam and the vertical.		
• The angle formed by the incident beam and the vertical is equal to the angle formed by the **refracted** beam and the vertical.		

UNIT 5a: PRINCIPLE OF THE LEAST TIME OR FERMAT PRINCIPLE

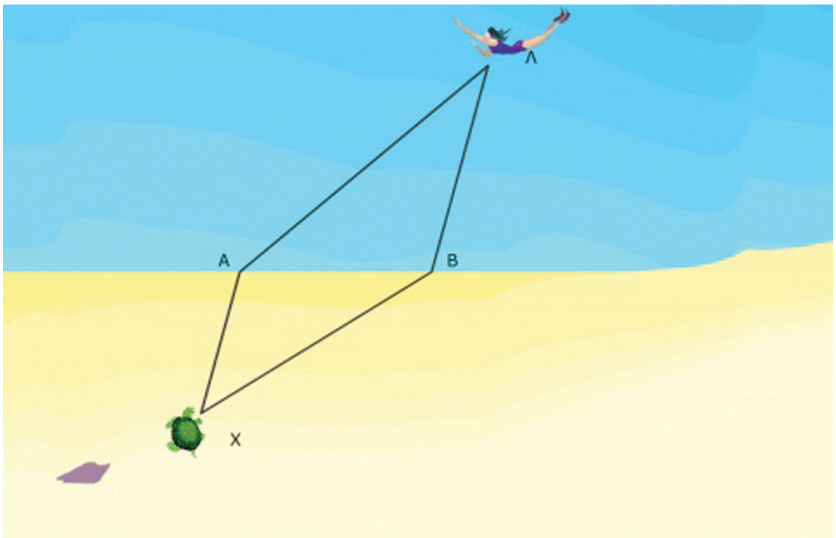
5a.0



5.0.1. **The turtle will follow the path:**

ΛAX ☐ ΛX ☐ ΛBX ☐

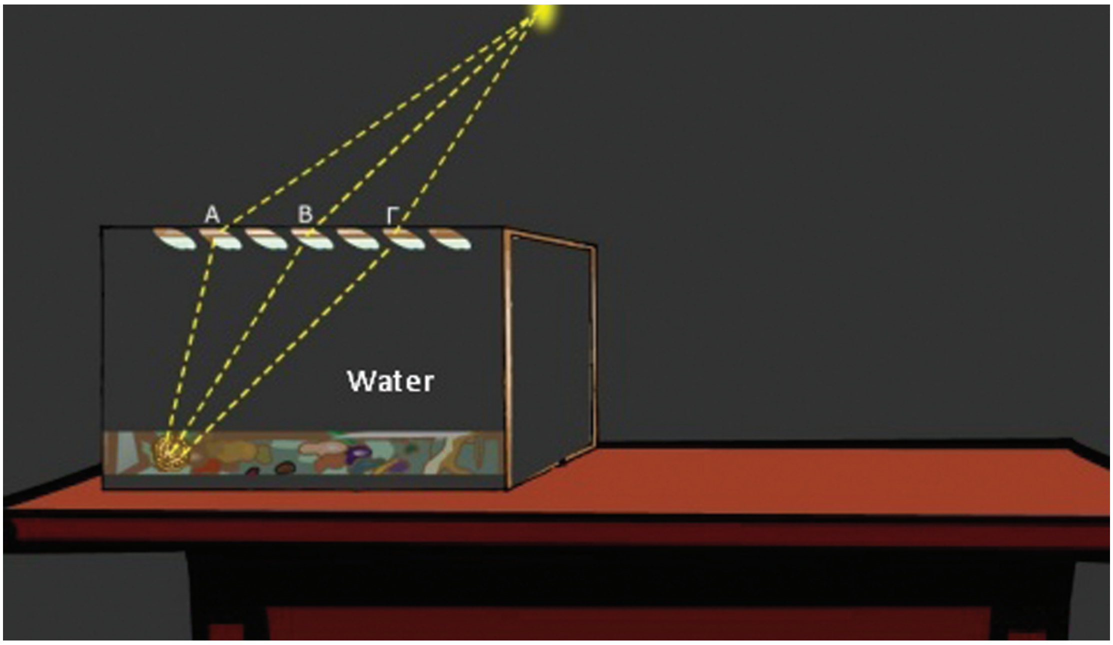
Use a tick √ for the correct path and justify your choice



5.0.2. **I would follow the path:**

ΛAX ☐ ΛX ☐ ΛBX ☐

Use a tick √ for the correct path and justify in case you chose differently from the turtle.



5.0.3. The light will follow the path through hole:

A ☐ B ☐ Γ ☐

Use a tick √ for the correct path followed by the light in order to reach the coin and justify your choice.

....

....

5.0.4. Then trace the vertical lines to points A, B and Γ.
If you did not choose the path through hole B, answer the following question:

When the light followed the path of your choice (through A or Γ), did the light beam approach or retreat from the vertical, compared to the case of rectilinear transmission (through hole B)?

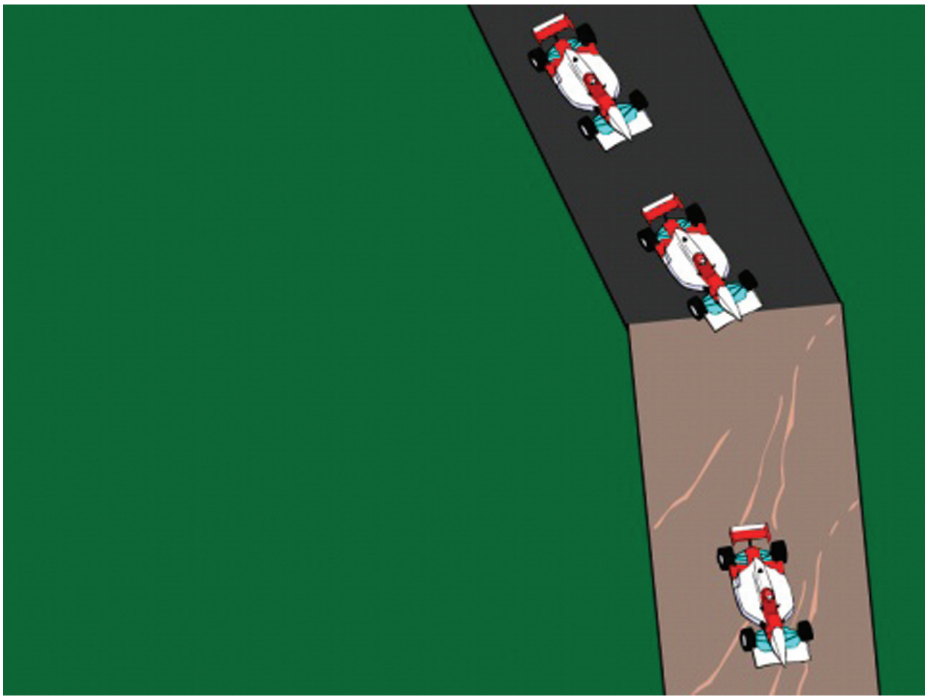
....

....

....

Conclusion: *When a light beam travels from an optical medium having a higher speed of light (optically less dense material) into an optical medium having a lower speed of light (optically more dense material), then the light beam changes direction and .... the vertical.*

Complete with the appropriate expression: "approaches to" or "retreats from"



5.0.5. **In the picture you can see a car on the highway entering sideways into a muddy area.**

The wheel that will enter first the muddy area will cover ________________ distance than the other wheel that is still on the highway.

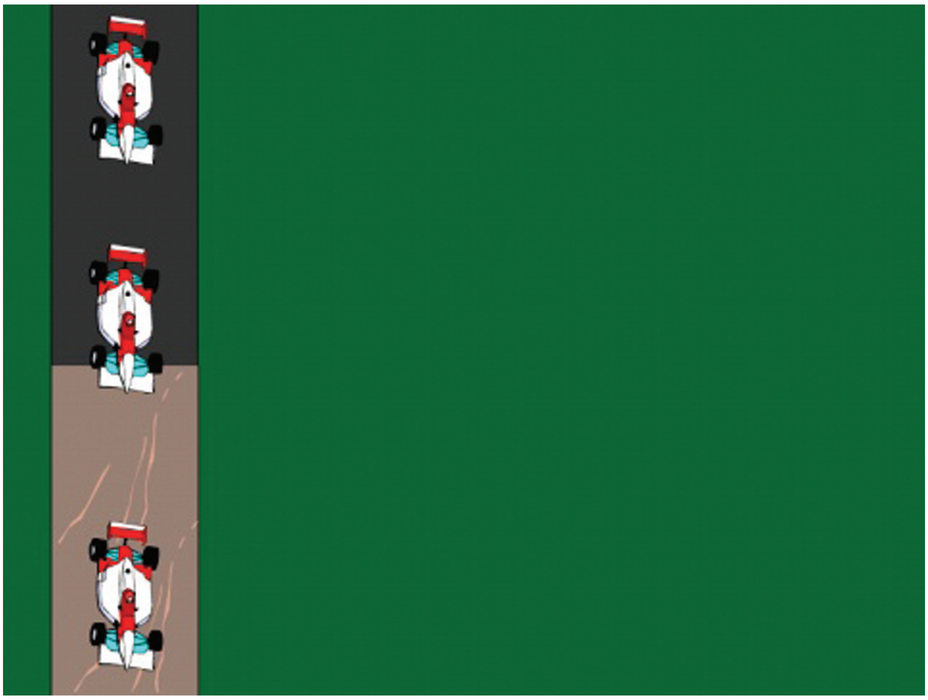
Complete using the appropriate world: higher – equal – lower

5.0.6. **Since the wheels are joined together with an axe, the car when entering the muddy area will move as follows:**

5.0.7. **Considering that light moves faster in the air than in the water, I think that an analogy can be drawn between the car and the light, as follows:**

5.0.8. **Therefore, light entering from the optically less dense material (higher velocity) into an optically more dense material (lower velocity) will:**

5.0.9. **If the car enters the muddy area vertically, it will:**



....

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....

5.0.10. **If light traveling in one optical medium enters vertically into another one, it will:**

....

....

....

UNIT 5b: WHEN AND HOW DOES LIGHT DEVIATE? REFRACTION

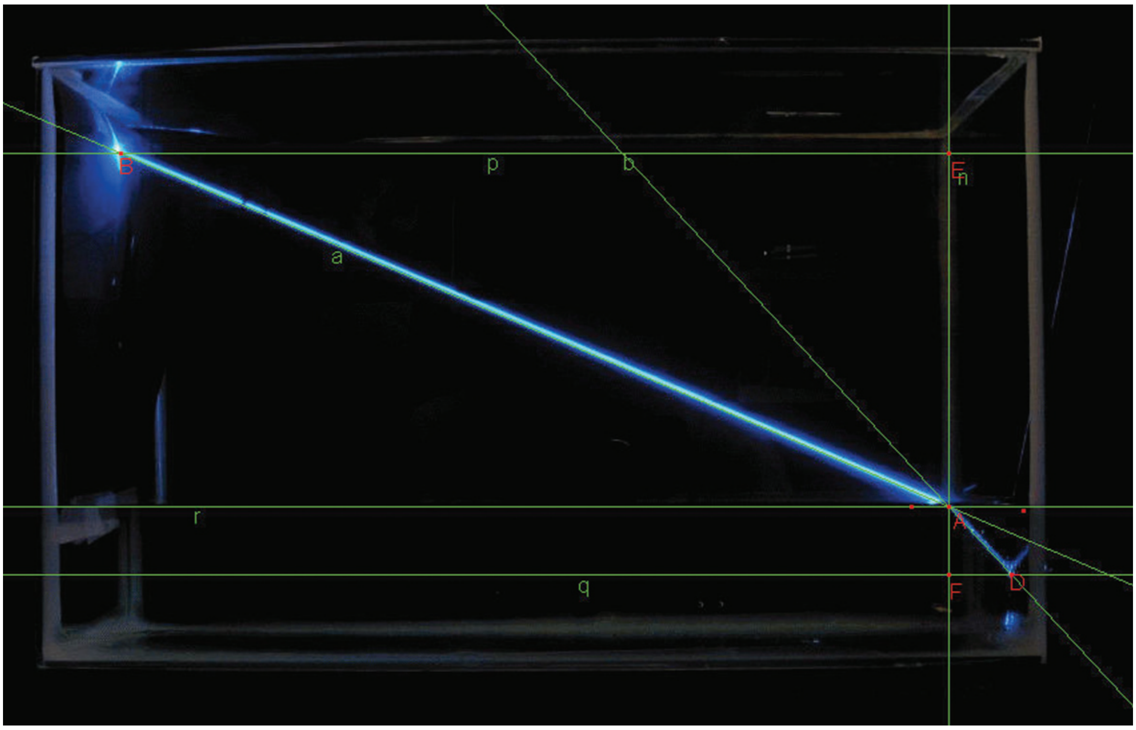
5b.1

Open the file “refraction_image.fig” with the software Cabrì

Use the software options to:

- Superimpose a ray r on the water surface
- Superimpose a ray a to the light beam that travels in air; call A the intersection point between a and r.
- Superimpose a segment AB to a, in order to identify completely the light beam travelling in air.
- Superimpose a ray b to the light beam travelling in water; Ray b pass through point A. Define a second point D on ray b and superimpose a segment AD, in order to individuate completely the light beam travelling in the water.
- Trace the perpendicular n to the water surface through points A.
- Trace two parallel rays p and q to the water surface and through points B and D respectively.
- Identify the intersection points between p and q and the perpendicular n to the water surface. Call these intersection points E and F respectively.
- Trace the segments BE and DF;

Your figure should now look like the following:



- Identify the triangles ABE and ADF and measure their sides AB, BE, AD, and DF.

AB = __________; BE = ____________; CD = ______________; DF =________________

Determine the ratios $\frac{BE}{AB}$ and $\frac{DF}{AD}$

$\frac{BE}{AB}$ = ____________________; $\frac{DF}{AD}$ = ____________________

Determine the ratio $\frac{\frac{BE}{AB}}{\frac{DF}{AD}}$ = ____________________

The ratio could be also determined as sin ratio of the angles $\frac{\frac{BE}{AB}}{\frac{DF}{AD}} = \frac{\sin(\_\_\_\_\_\_)}{\sin(\_\_\_\_\_\_)}$

We shall call this ratio **“refraction index of water relative to air”.**
Save your file with the name “refractionindex_group…”

5b.2

By using Cabrì open the file “refraction_index.fig”

5.2.1. Fix the value 1 for the number called “refraction index of material 1” (n_1= 1) and 1,33 for refraction index of material 2 (n_2= 1,33). Fix a value for the angle α = 44° and write the data in the Table below

angle α = 44°

QUANTITY	MEASUREMENT
sen β	
sen α	
$\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n_2}{n_1}$	

5.2.2. Modify the value of the inclination angle of the laser beam (α) and write down the values in the Table below.

INCLINATION ANGLE α	$\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n_2}{n_1}$
α1=	
α2=	
α3=	
α4=	

5.2.3. Fix the value of the inclination angle (α) and then modify the water height (h), selecting point H and write down the values in the Table below

WATER HEIGHT h	$\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n_2}{n_1}$

5.2.4. Modify the material in the tank, by modifying the refraction index of material 2 according to the values of column one of Table below and write down the value of the refraction angle β

MATERIAL 2	Refraction angle α	Refraction index $\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n_2}{n_1}$
Olive oil (n=1,46)		
Gasoline (n =1,49)		
Sunflower oil (n=1,65)		

5.2.5. What conclusions can you draw?

Does ratio $\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n_2}{n_1}$ depends on inclination angle for specific materials 1 and 2?

Does ratio $\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n_2}{n_1}$ depends on water's height for specific materials 1 and 2?

Finally what factors do you think that affect the ratio $\frac{\sin(\alpha)}{\sin(\beta)} = \frac{n_2}{n_1}$?

5b.3

Open the file “critical_angle.fig” with Cabrì.

- Let the refraction index of medium 1 be n1 = 1 and n2 = 1,33 that of medium 2 (relative to air).
- Place on the normal n the semi-ray a that represents the incident beam. Turn a until you cannot see any more the refracted rays in air.
- Use the software options to measure the incidence angles θi and reflection θr of the light beam at the interface water-air.

θ_i = _______________

θ_r = _______________

- Call $\theta_i = \theta_L$ the smallest angle for which you don’t see any more the refracted beams.

θ_L = __________________

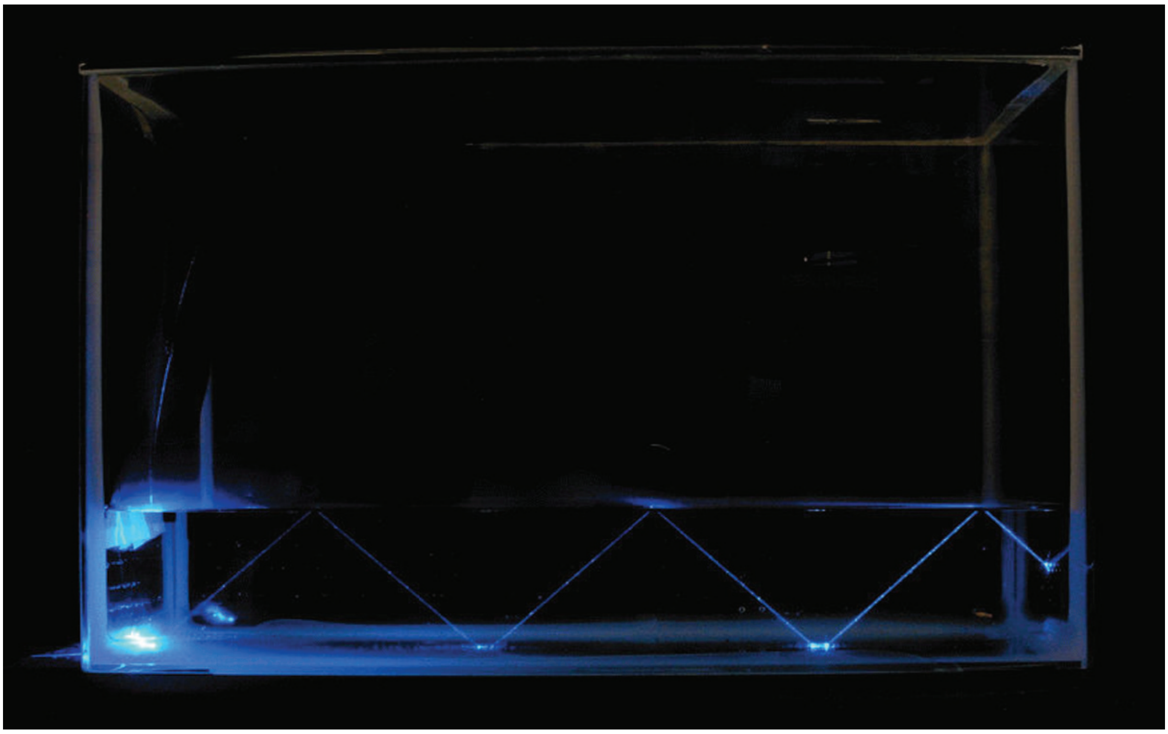
θ_L is called **“limit angle”**, or **“critical angle”**

UNIT 6: HOW IS AN OPTICAL FIBER MADE? FIRST CLUES

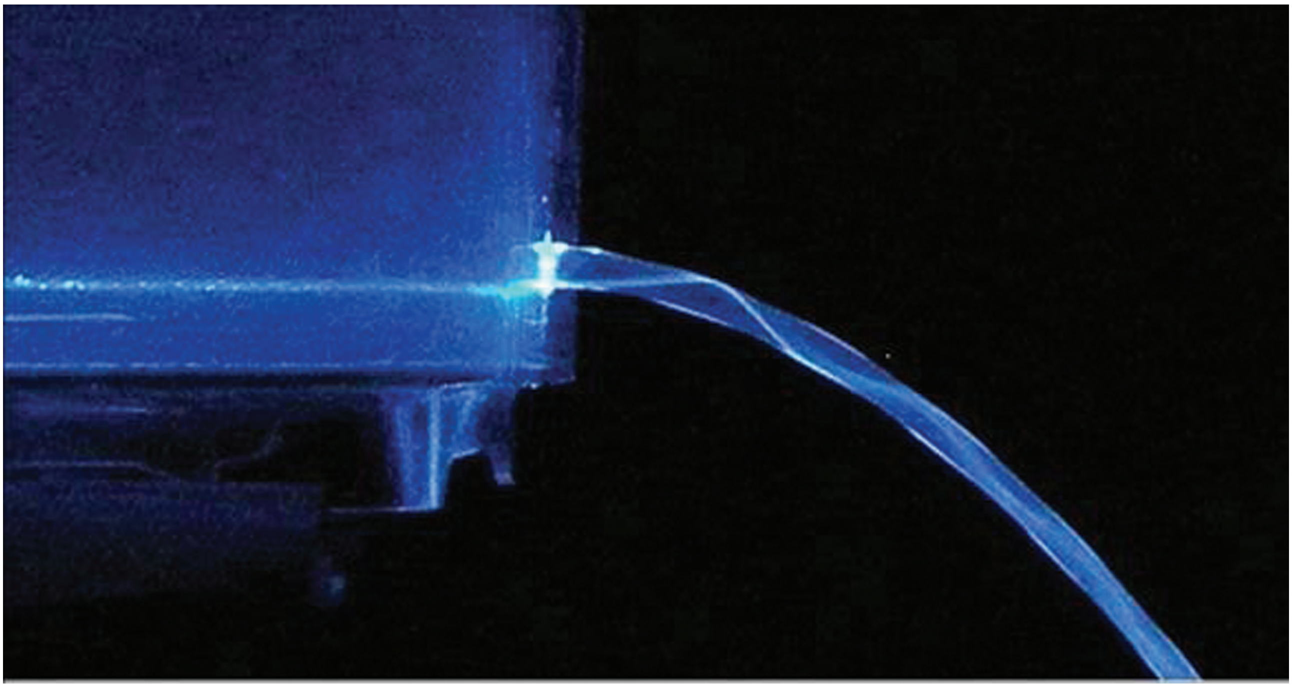
6.1

Observe carefully the pictures of the two experiments you have performed.

Experiment 1



Experiment 2



6.1.1. **What are the materials that form the upper and lower parts of the tank?**

6.1.2. **Can you see any differences in the behavior of light on the two surfaces?**

6.1.3. **In the above experiment, which are the surfaces where light undergoes total internal reflection?**

In the photos of the initial activities you carried out, observe once more the trajectory of the water jet.

6.1.4. **Which are the features of the water jet that allow it to guide the light?**

6.1.5. **Which is the light guide core for the water jet? Which is the outer cladding?**

UNIT 7: DO WE WANT TO SEE THE LIGHT PATH IN THE FIBER?

7.1

7.1.1. For which applications could the water-jet experiment be useful?

Which are the main problems for signal transmission?

7.1.2. Is it really important to see the light path in a light guide?

7.2

Your teacher performs the following experiment: scratches part of the fiber and sends laser light in the fiber.

7.2.1. Does the end of the optical fiber remain lightened?

Describe what you observe and make hypotheses for the observed behavior.

7.2.2. How do you think that an optical fiber is constructing?

Which are the main attributes and properties of optical fibers?

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