Welcome to Physics 4L!

Catherine H. Crouch

Please pick up flashcards and handouts in the back

Welcome to Physics 4L!

Catherine H. Crouch

Mary Ann Klassen (labs and demos)

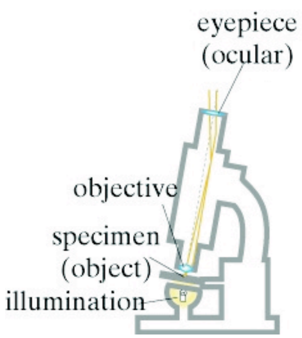
Emily Hager, Elizabeth Mills, Erik Smith, Ari Strandburg-Peshkin

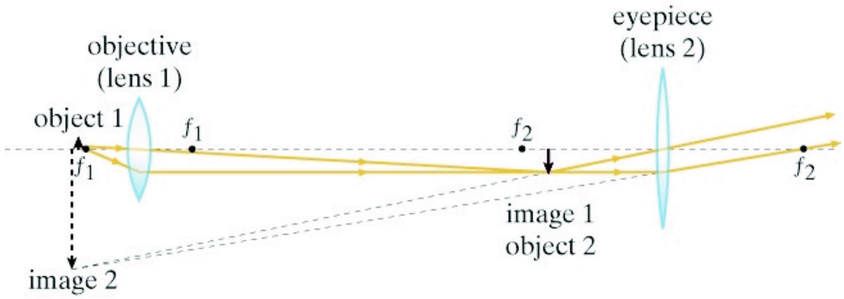
Course goals

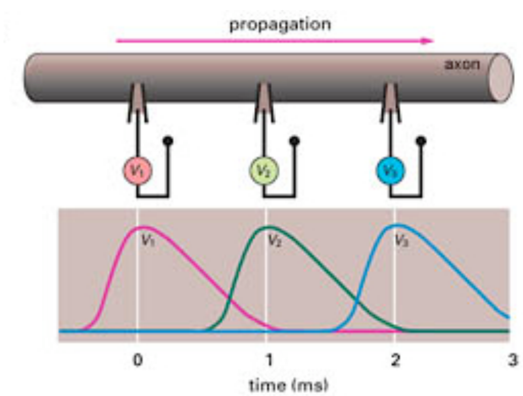
- Master basic physics both qualitatively and quantitatively
- Build problem-solving skills
- Explore relevance to biology, biochemistry, and medicine

Course content

- Physics of light, electricity, magnetism
- Start with simple examples
- Apply to more complicated biomedical examples







Course content

- Physics of electricity, magnetism, and light
- Amazingly: they are all fundamentally the same phenomenon!

Learning physics

- Gaining not just information, but expertise
- Develop new ways of thinking!

How *not* to learn physics

Instructor pours knowledge into students.

Little knowledge is retained.

Student's Fault

Impedance mismatch between student and instructor.

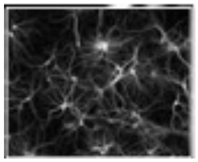
Instructor's Fault

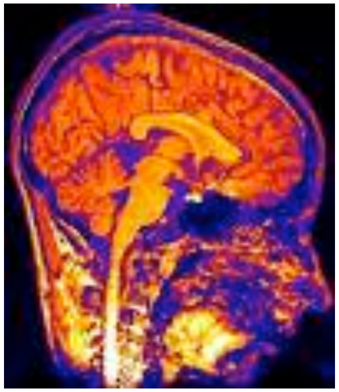
Learning is much more complicated

Leonard et. al. (1999). Concept-Based Problem Solving.

Learning physics

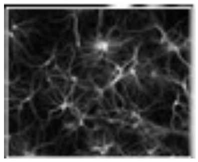
- My job:
  (1) demonstrate these ways of thinking
  (2) provide opportunities to try them out
  (3) provide feedback
- Your job:
  (1) practice!
  (2) help each other

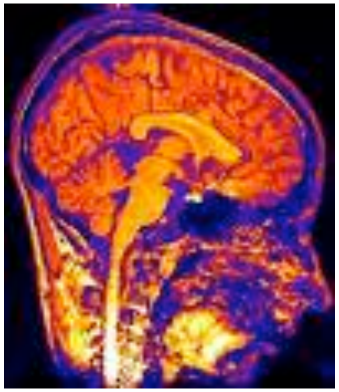




Opportunities to practice

- Questions in class
- Lab
- Homework (problem session)
- Mistakes are part of learning!





Course logistics: highlights

- Read syllabus carefully; note evening exams
- Web site will have questions/probs by 9 a.m.
- Explore course web site: discussion forums for posting questions, handouts, Phys 4L S08 exams with solutions, day-by-day reading
- “Self-test” homework problems
- One “free late” problem set: MUST arrange in advance
- Labs begin next week (bring/buy binder in lab)
- Lab sectioning —email Mary Ann Klassen

Today's announcements

- Reading for today and Thursday: Wolfson chapter 30 and 31.1 (also listed on web site)
- Mechanics review session Thursday night, 7:30 - 9, SC 128
- SA sessions Thursday, Sunday, Monday, problem set due Tuesday

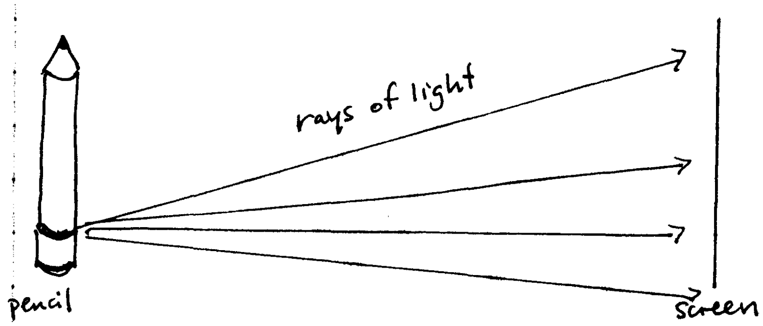
J. J.

1/19/2010

Powerpoint overview

Geometric Optics: How light travels and interacts with objects
Goal: build up to understand human vision and microscopy
A few principles determines how light travels and how images are formed:

(1) Light comes from every point on a bright object.
Bright: either glows or reflects light
(2) Light is emitted in every direction from each point
(3) Light travels in straight lines until it reaches a surface

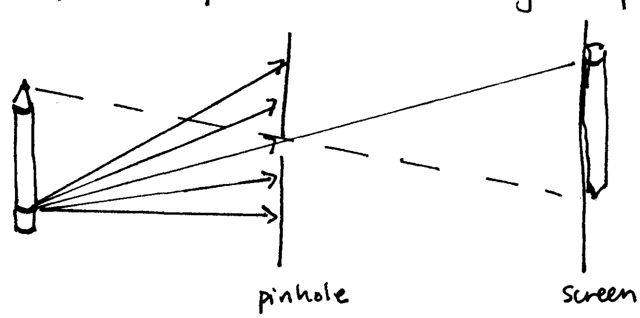


Light from every point on the pencil spreads over entire screen

Demo: show light bulb? other bright source? use pink martini glass light

Screen just has blur of light from pencil
How do we see the pencil clearly? Why not a blur of light from every point?

Our eyes form images: pattern of light that matches bright object
Simplest way to form an image: pinhole



pinhole blocks all but a narrow bundle of rays from each point
→ image of each point forms on screen
→ image of pencil

(This is how vision works in some invertebrates!) (pinhole camera)

1/19/2010

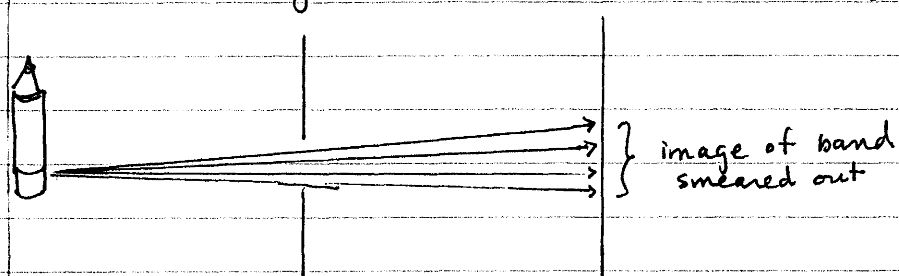
$\boxed{CT}$: To increase size of image, what should you do?
More pinhole closer to object (sketch)

What else happens?

Brightness = $\dfrac{\text{total amount of light}}{\text{area}}$ ("intensity")

Same amount of light gets through pinhole
Spreads over larger area of screen → dimmer image

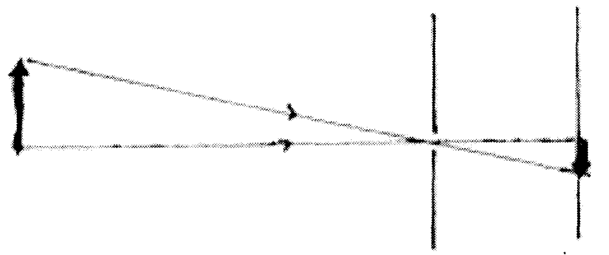
What if you made the pinhole bigger?
More light through (bigger bundle of rays) BUT spreads over larger area of screen → blurs image "out of focus"



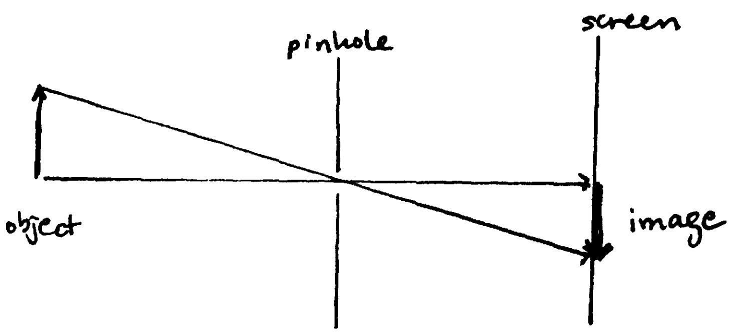
How big is the image? $\boxed{\text{Problem}}$: Chambered nautilus (see problem sheet for solution)

1. Interpret problem: draw a picture
Goal: find distance s_i from pinhole to image
Relevant physics: light travels in straight lines
2. Devise plan: use trigonometry to find s_i
3. Execute plan: substitute values
4. Assess answer: units, reasonable value ($s_i \ll s_o$)

To make the image larger, move the pinhole closer (keeping the screen in the same place):

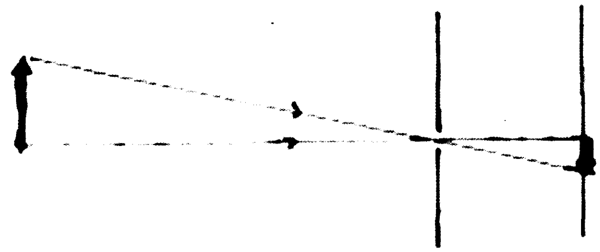


becomes



Physics 4L questions and problems, January 19, 2010

An image of a bright arrow is formed on a screen by a pinhole.

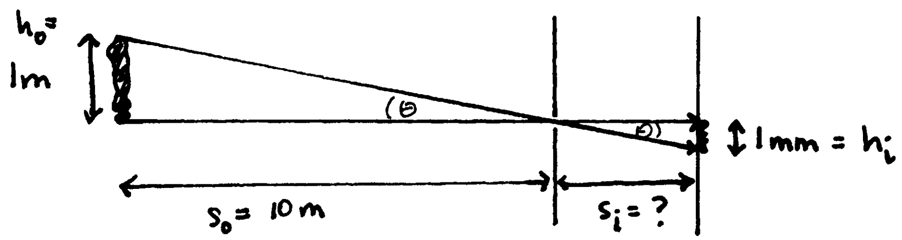


To increase the size of the image, you should:

1. move the pinhole closer to the object (arrow).
2. move the pinhole closer to the image.
3. move the pinhole up.
4. move the pinhole down.
5. make the pinhole bigger.
6. make the pinhole smaller.

A chambered nautilus has eyes consisting of 1-mm holes in front of a small region of light-sensitive tissue. Suppose the light-sensitive tissue is a circular region 1 cm in diameter. If a complete image of a 1-m tall seaweed 10 m in front of the nautilus will be 1 mm tall on the light-sensitive tissue, where is the pinhole relative to the light-sensitive tissue?

Interpret: draw figure, label



Relevant physics: light travels in straight lines

Plan: use trigonometry to find s_i

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{h_o}{s_o} = \frac{h_i}{s_i}$$

(Or use similar triangles $\rightarrow \dfrac{h_o}{s_o} = \dfrac{h_i}{s_i}$)

Solve for s_i $\Rightarrow$ $s_i = s_o \dfrac{h_i}{h_o}$

Substitute $\Rightarrow$ $s_i = (10\,m)\dfrac{(1\,mm)}{1\,m} = \dfrac{(10\,m)(1\times10^{-3}\,m)}{1\,(m)} = 10^{-2}\,m = 1\,cm$

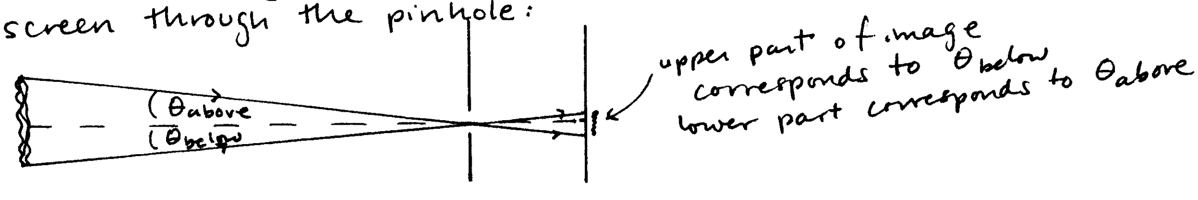
Pinhole is 1 cm in front of tissue

Reasonable?

right units (length)

smaller than s_o

Drew seaweed so its lower end is level with pinhole. If not, apply same reasoning to parts above and below the line normal to the screen through the pinhole:



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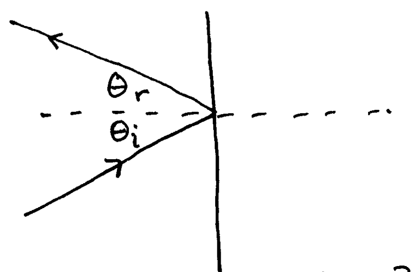
<u>Light at interfaces</u> (surface between two ~~materials~~ media).

can be absorbed (~~am~~ light goes into material)
reflected (light bounces back)
transmitted (light passes through)

For now consider just reflection and transmission:
shiny or transparent media

<u>Reflection</u> from smooth surface: $\theta_i = \theta_r$

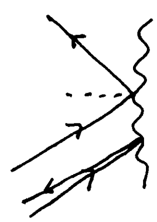


(mirrors or any smooth ~~mirrors, glass~~ surfaces)

Note: measure angles from <u>normal</u> to surface

Metals → 99% reflecting (mirror)
Transparent (glass, plastic) → 10% reflecting

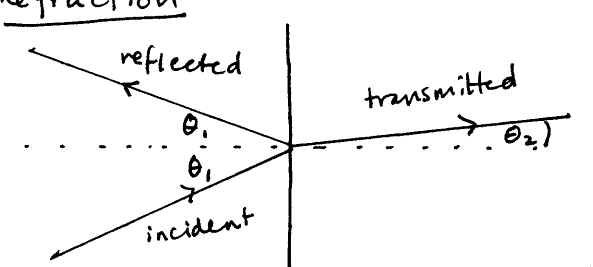
Rough surface: still have $\theta_i = \theta_r$ but roughness → reflected light in all directions ("diffuse")



how we see most objects: diffuse reflection of sunlight, room lights

If medium 2 is transparent get both reflection and transmission - and ~~refraction~~ <u>transmitted</u> ray is bent "refraction"

<u>Refraction</u>



transmitted ray is <u>bent</u>

[Blackboard optics demo w/ slab
start ⊥, rotate]

NOTE: transmitted ray is on the <u>other</u> side of the normal

What determines bending angle?
index of refraction n of each medium

$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

$n = 1.000$ for vacuum
$n = 1.003$ for air
greater for liquids and solids

Refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's Law)

Looking at my figure: which ~~is~~ is bigger, n_1 or n_2?
$n_2 > n_1$

$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$ so smaller angle → smaller $\sin\theta$

larger n → smaller angle ~~[illegible]~~
ray is closer to normal for larger n

[Could illustrate more here] Effect of refraction: changes where light appears to come from

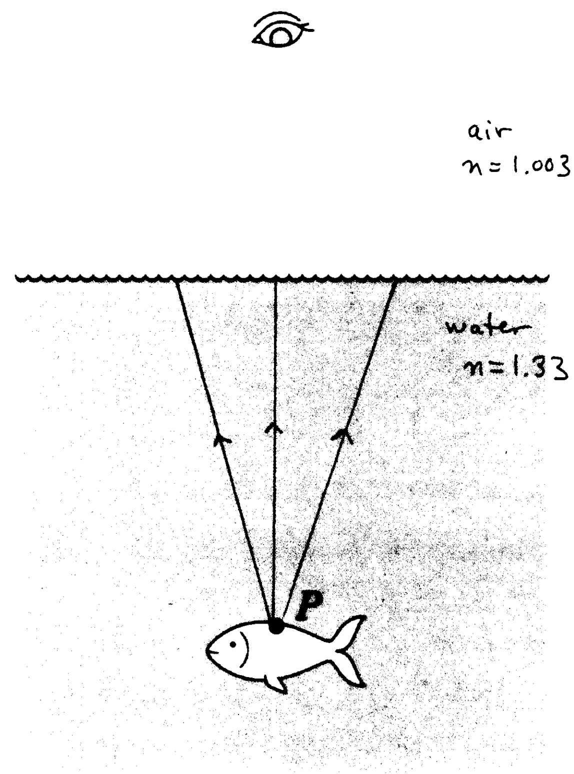
$\boxed{\text{CT}}$ fish (add underwater rays as read question)

Rays appear to come from above P — trace refracted rays back underwater

Note: ~~[illegible]~~ change in index of refraction ~~[illegible]~~ is required for reflection
if $n_1 = n_2$, no reflection!

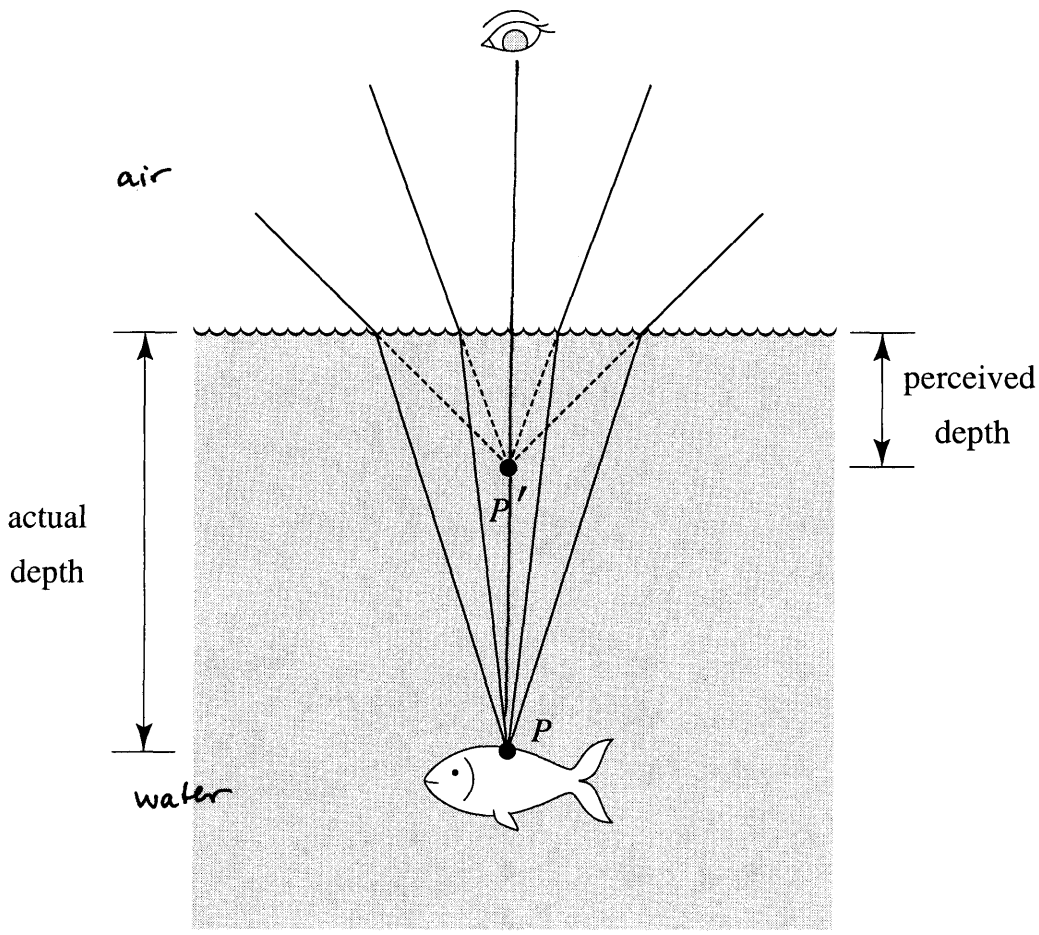
Demo: index matching fluid
(ask who has used microscope w/ immersion oil
oil eliminates reflection + refr. of light going from sample to microscope objective lens)

A fish swims below the surface of the water. Suppose an observer looks at the fish from directly above. Light rays leave point *P* and travel from the water into the air and to the observer's eye. Those light rays appear to come from



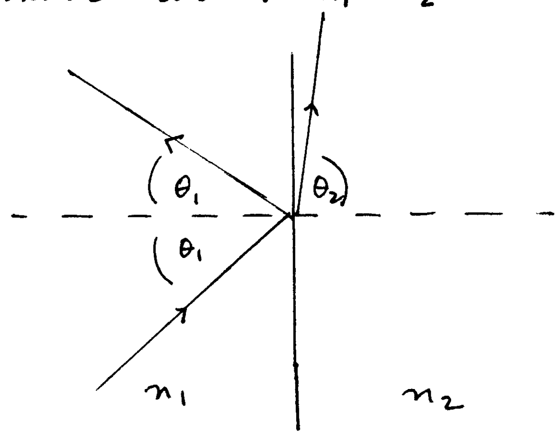
1. Point P.
2. Somewhere above point P.
3. Somewhere below point P.
4. Need more information to answer.

2. Somewhere above point P.



<u>Total internal reflection</u> (TIR)

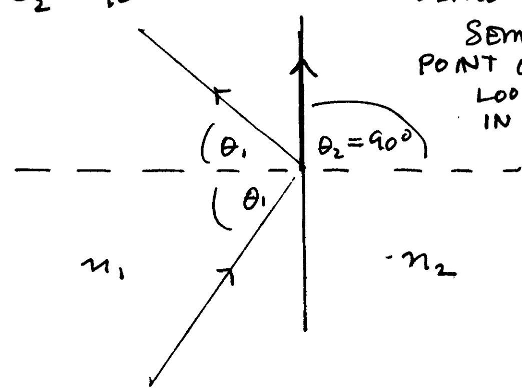
Consider case of $n_1 > n_2$ so $\theta_1 < \theta_2$



(Let's choose n_1 to always be the medium with the incident beam)

If you keep increasing θ_1, get to $\theta_2 = 90°$

$\Rightarrow$



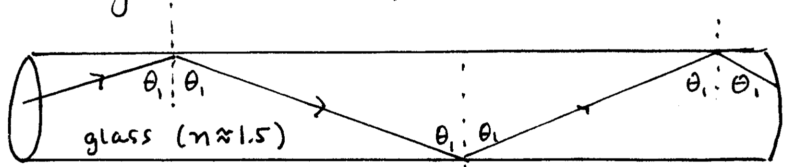
DEMO w/ SEMICIRCLE
POINT OUT: LOOK AT RAY IN PLASTIC

Transmitted ray goes along interface (Hard to see!)

Nothing stops us from increasing θ_1 further — but now θ_2 can't increase further

$\rightarrow$ NO TRANSMITTED RAY — all light is reflected from the surface — <u>perfect</u> reflection

Light can thus be guided along inside a medium with higher index of refraction than what surrounds it



air $n = 1.003$

cylindrical optical fiber — if light comes in at large enough angle, get total internal reflection guiding light down fiber

Basis of medical endoscopes

Fiber does not even need to stay straight

Demo: TIR in water

laser pointer follows stream of water