**ACTIVITY: Angle of refraction calculator challenge**

**Activity idea**

By the end of this activity, students should be able to:

* use a spreadsheet calculator to calculate the angle of refraction
* define the terms ‘incident ray’, ‘refracted ray’ and ‘normal’
* recall the refractive index values for water and air
* describe how the amount of refraction (bending) depends on the refractive index of the two substances light is passing between
* describe the direction that light bends when it passes into a substance with a higher refractive index
* describe the direction that light bends when it passes into a substance with a lower refractive index
* find the maximum angle possible before all light is totally internally reflected when light travels from a more-dense substance (such as water) into a less-dense substance (such as air).

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Student record sheet: [Analysing angles of refraction](#analysing)

**Introduction/background**

In this activity, students investigate how much light refracts (changes direction or bends) as it passes from one substance into another.

The [Angle of refraction calculator](https://www.sciencelearn.org.nz/resources/62-angle-of-refraction-calculator-challenge) spreadsheet allows students to select each substance from dropdown menus. The refractive index for each substance is shown.

Students are then able to enter any value for the angle of incidence and to see the calculated value for the angle of refraction, as well as a graphic image showing the ray of light at the surface where the two substances meet.

It is important to note that all angles are measured from the ray to the normal line. This is an imaginary line drawn at 90° to the surface between the two substances at the point where the ray meets the surface.

**What you need**

* Access to the [Angle of refraction calculator](https://www.sciencelearn.org.nz/resources/62-angle-of-refraction-calculator-challenge)
* Copies of the student record sheet [Analysing angles of refraction](#analysing)

**What to do**

1. Introduce the challenge: to investigate how much light refracts (changes direction or bends) as it passes between two transparent substances, using the [Angle of refraction calculator](https://www.sciencelearn.org.nz/resources/62-angle-of-refraction-calculator-challenge).
2. Hand out copies of the student record sheet [Analysing angles of refraction](#analysing) and ask students to work through it.

**[Analysing angles of refraction](#analysing)**

You will investigate how much light refracts (changes direction or bends) as it passes between two different substances. Use the [Angle of refraction calculator](https://www.sciencelearn.org.nz/resources/62-angle-of-refraction-calculator-challenge) to complete this investigation.

1. Light travelling from air into water.

Select air as your substance 1 using the dropdown arrow. Select water as your substance 2.

Refractive index of air = \_\_\_\_\_

Refractive index of water = \_\_\_\_

Complete the table to find out the angle of refraction when light enters the water at each of the following angles.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Angle of incidence (degrees) | 0 | 20 | 40 | 60 | 80 |
| Angle of refraction (degrees) |  |  |  |  |  |

Does the refracted ray move **closer towards** or **further away** from the normal line?

|  |
| --- |
|  |

1. Light travelling from air into glass.

Select glass (acrylic) as substance 2 using the dropdown arrow.

Refractive index of glass = \_\_\_\_

Complete the table to find out the angle of refraction when light enters the glass at each of the following angles.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Angle of incidence (degrees) | 0 | 20 | 40 | 60 | 80 |
| Angle of refraction (degrees) |  |  |  |  |  |

1. Light travelling from air into diamond.

Select diamond as substance 2 using the dropdown arrow.

Refractive index of diamond = \_\_\_\_

Complete the table to find out the angle of refraction when light enters the diamond at each of the following angles.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Angle of incidence (degrees) | 0 | 20 | 40 | 60 | 80 |
| Angle of refraction (degrees) |  |  |  |  |  |

1. Which of the above substances (water, glass or diamond) makes light bend the most?

|  |
| --- |
|  |

1. What does the refractive index show about how much light bends?

|  |
| --- |
|  |

1. Complete the following statements:

A more-dense substance like water has a *lower / higher* refractive index than air.

Whenever light enters a substance with a higher refractive index (more dense), it will bend *closer towards / further away from* the normal line.

1. Use a protractor and ruler to show how much a ray of light bends as it enters a pool of water at the angle shown.

All angles are measured from the ray to the normal line (as shown by the dashed line – this is an imaginary line drawn at 90° to the surface at the point where the ray meets).



1. Light travelling from water into air.

Now select water as substance 1 using the dropdown arrow. Select air as substance 2.

Refractive index of water = \_\_\_\_\_

Refractive index of air = \_\_\_\_

Complete the table to find out the angle of refraction when light comes out of the water and travels into the air for each of the following angles of incidence.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Angle of incidence (degrees) | 0 | 20 | 40 | 60 | 80 |
| Angle of refraction (degrees) |  |  |  |  |  |

What is the maximum angle of incidence before no light is refracted and all of the light is totally internally reflected back into the water (none of it comes out into air)?

Maximum angle of incidence = \_\_\_\_\_ degrees

1. Light travelling from glass into air.

Select glass as substance 1 using the dropdown arrow.

Refractive index of glass = \_\_\_\_

Complete the table to find out the angle of refraction when light comes out of the glass and travels into the air for each of the following angles.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Angle of incidence (degrees) | 0 | 20 | 40 | 60 | 80 |
| Angle of refraction (degrees) |  |  |  |  |  |

What is the maximum angle of incidence before no light is refracted and all of the light is totally internally reflected back into the glass (none of it comes out into air)?

Maximum angle of incidence = \_\_\_\_\_ degrees

1. Light travelling from diamond into air.

Select diamond as substance 1 using the dropdown arrow.

Refractive index of diamond = \_\_\_\_

Complete the table to find out the angle of refraction when light comes out of the diamond and travels into the air for each of the following angles.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Angle of incidence (degrees) | 0 | 20 | 40 | 60 | 80 |
| Angle of refraction (degrees) |  |  |  |  |  |

What is the maximum angle of incidence before no light is refracted and all of the light is totally internally reflected back into the water (none of it comes out into air)?

Maximum angle of incidence = \_\_\_\_\_ degrees

1. Complete the following statements:

Whenever light travels from a more-dense substance like water into a less-dense substance like air, it will bend *closer towards / further away from* the normal line.

The maximum angle that the incident ray can be is called the critical angle.

Whenever the angle of incidence is greater than the critical angle, the light will
t\_\_\_\_\_\_\_\_\_\_\_\_\_\_ i\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ r\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.