# Sample virtual program: Year 11 Physics

## The inverse square law

### Outcomes

* PH11-10 - explains and analyses waves and the transfer of energy by sound, light and thermodynamic principles
* PH11/12-3 - conducts investigations to collect valid and reliable primary and secondary data and information
* PH11/12-4 - selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media
* PH11/12-5 - analyses and evaluates primary and secondary data and information
* PH11/12-7 - communicates scientific understanding using suitable language and terminology for a specific audience or purpose

Outcomes referred to in this document are from [Physics Stage 6 Syllabus](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/stage-6-learning-areas/stage-6-science/physics-2017) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2017

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| Guiding questions |  |
| What are your students going to learn? (Objectives) | Students will develop working scientifically skills and their understanding of sound energy and energy transformations. |
| How are they going to learn it? (Resources and Strategies) | Students will conduct an investigation to demonstrate the relationship between inverse square law, the intensity of light and the transfer of energy. They will collect and process data collecting using the light sensor on a mobile phone and compare it to data collected using a data logger and light probe. |
| Target date for completion | Activities take approximately 2 hours and 45 minutes to complete. |
| How are you going to know that they learned it? (Success criteria) | Students can:   * select appropriate equipment * can describe a suitable method for collecting light intensity data * Organise collected data into tables and graphs * Use appropriate technology to assist in data processing * Identify and account for trends in collected data * Recognise errors and limitations in their data * Construct an evidence-based argument in response to a key question * Apply appropriate scientific terms |
| Differentiation including HPGE | Adapting process: Students can explore a wider range of situations in their experiments such as using different filters to investigate impact that different light frequencies have on the sensor’s performance.  Adapting product: A guide has been included on how to normalise results so that students seeking opportunities for extended skill development can further process their data to facilitate comparisons.  Adapting product: Students can demonstrate their understanding using their choice of format for the presentation of their investigation's findings. |
| Collecting evidence of student learning (Verification) | Students will produce a concise report outlining their response to the inquiry questions. This report will refer to evidence supporting their conclusions. It should be submitted via e-mail, Google Classroom or Microsoft Teams to the teacher for feedback. |
| Feedback (Evaluation) | Teachers can provide feedback via the submission pathway (e-mail, Google Classroom or Microsoft Team) to students on their progression towards the learning outcomes.  Peer feedback could be facilitated through Microsoft Teams after students submit their reports. |
| Communication | **Orientation** Teacher will post the activity description on the class’ Teams notice board. Students will be expected to independently complete a short activity before the orientation online lesson. Teams video or audio conference will be used to guide students through learning activities  **Sharing information:**  All relevant information is included as links on the activity description. Initial orientation conference will be posted to Teams for students to access asynchronously. Sample data and graph paper is included with the student learning materials to support students unable to access the internet.  **Promoting student-teacher interactions:**  Students may require clarification and assistance at various times in their investigation. Using an [asynchronous discussion](https://app.education.nsw.gov.au/digital-learning-selector/LearningActivity/Card/580#.XmbrZ3MkfVI.link) or chat will make questions and answers visible to all students. The teacher could communicate when they are available for student questions and answers. This may be aligned to normal class times or by negotiation with the class.  **Promoting student-student interactions:**  Students can use the post function to communicate between the class members and teacher to facilitate collaboration, discussion of questions and feedback obtained.  **Monitoring and supporting progress in student learning:**  Provide a clear channel for communication with students during the data collection and processing activities. This is the time most likely to challenge students. Consider running a short video session and share your screen with students so that they can see how the data is processed in Excel or desmos. |

### Resources

[Phyphox: physical phone experiments app](https://phyphox.org/) – A free app available for apple and android phones that provides access to the phone’s sensors. It displays sensor readings in simple formats and allows data to be exported for further analysis on a computer.

[Google Science Journal](https://sciencejournal.withgoogle.com/) - A free app available on student mobile devices. This app provides access to record data using the phone sensors and record this data for students to analyse and present through their school google accounts.

[Peter Hurley – How to understand the inverse square law – photo lighting explained](https://www.youtube.com/watch?v=xO-J42VM448) (video duration 15:05).

A video tutorial on the inverse square law intended for viewing by amateur and professional photographers. Peter describes how to apply the inverse square law to lighting in portrait photography. Whilst this is beyond the course requirements for Year 11 Physics, it is a clear example of how physical principles can be applied to solve real-world problems.

[The inverse square law of light – NASA](https://www.nasa.gov/pdf/583137main_Inverse_Square_Law_of_Light.pdf)

An alternate investigation into the inverse square law that could be completed by students at home with mostly household items. The lesson package contains teacher notes along with sample data and graphs.

[Padlet](https://padlet.com/) - An online brainstorming tool where teachers can pose questions and students can collaborate and freely contribute responses that appear in the format of a sticky note.

[Asynchronous discussion](https://app.education.nsw.gov.au/digital-learning-selector/LearningActivity/Card/580#.XmbrZ3MkfVI.link) - A template from the digital learning selector gives a format to which students can respond to the lesson provided by the teacher at times where synchronous lessons are not possible.

[Evaluating data – NSW Department of Education](https://education.nsw.gov.au/content/dam/main-education/teaching-and-learning/curriculum/key-learning-areas/science/Evaluating_scientific_data_S_4_to_6.docx)

This document provides an in-depth discussion of the criteria used to evaluate scientific investigations, such as accuracy, precision, reliability and validity. The document also addresses measurement uncertainties and errors of measurement.

### Lesson sequence

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| --- | --- | --- |
| Session | Learning Sequence | Evidence of learning |
| 1. Time: 15 minutes Asynchronous | * distribute student learning materials via Teams or email * students read background information and watch videos introducing the inverse square law |  |
| 2. Time: 30 minutes  Synchronous is preferred | * invite students to attend a video conference on Teams (or Hangouts or another platform) * demonstrate the experiment procedure and run a brief question and answer session * advise students where they can post questions and negotiate where/how they should submit their finished work. | Students:   * will be able to select appropriate equipment * can describe a suitable method for collecting light intensity data. |
| 3. Time: 1.5 hours Asynchronous | * collect light intensity data and complete data processing and analysing activities * produce report with responses to key questions | Students:   * organise collected data into tables and graphs * use appropriate technology to assist in data processing * identify and account for trends in collected data * recognise errors and limitations in their data * construct an evidence-based argument in response to a key question |
| 4 (30 mins) (synchronous is preferred) | * students share their results with the class by posting to Microsoft Teams * students encouraged to view and provide constructive feedback on at least one other student’s work | Students:   * communicate issues relating to the investigation with clarity and accuracy. * use appropriate formats for communication. * apply appropriate scientific terms. |

### Student learning materials for distribution

#### Introduction

**Inquiry questions:**

* will smartphones eventually replace our expensive laboratory equipment?
* which phones have the most effective light sensors?

**Scenario:** Smartphones have continued to improve, both in terms of their processing capabilities, and in the range and quality of sensors they include. Many phones now have accelerometers, gyroscopes, light and sound sensors, along with magnetic field sensors and access to GPS location data.

Free phone apps such as [Phyphox](https://phyphox.org/) and [Google science journal](https://sciencejournal.withgoogle.com/) provide direct access to the rich data collected by phone sensors and offer a range of display options including real time meters and graphs over time.

The quality of these sensors varies significantly between phone models and even between production batches. For phones to replace purpose built scientific instruments, they must be able to reliably and accurately measure physical quantities. So, how well do the sensors on your phone perform?

**Task description:** You will be conducting an investigation to compare the effectiveness of your phone’s light sensor with that of a typical light probe used in high school science labs. After completing your investigation, you will produce and submit a report outlining your results and conclusion.

##### Orientation – do this before our lesson **<date/time>**

1. Read the Background information below
2. Download Phyphox, Google science journal or other app and check that you are able to locate the light sensor on your phone and view the light intensity in the phone app.
3. Join the class Team using this link **<insert link to Microsoft Team site>**.

##### Background information

The relationship;

is an example of the inverse square law. This relationship will be encountered several times throughout the physics course. , is the intensity of the light and roughly describes the amount of light energy passing through a unit area per second. As the distance from the light source increases, the light energy being produced is spread over an increasingly large area and as a result the intensity of the light is decreased.

The light sensors in your phone are typically located above the phone’s screen or next to its camera. It records the intensity of the light received (in units of lux or, possibly, exposure value EV). The lux (symbol: lx) is the SI unit of illuminance and luminous emittance, measuring luminous flux per unit area. It is used in photometry as a measure of the intensity, as perceived by the human eye, of light that hits or passes through a surface.

Typical lux readings are approximately:

* 10−4 lux = Total starlight, overcast sky
* 50 lux = Family living room lights
* 320–500 lux = Office lighting
* 32,000–130,000 lux = direct sunlight

For further introduction to the inverse square law, watch “[The inverse square law](https://www.youtube.com/watch?v=F-xNMdIXJIs)” (duration 4:24) or read the [butter gun analogy as described by the Khan academy](https://www.khanacademy.org/science/electrical-engineering/ee-electrostatics/ee-electric-force-and-electric-field/a/ee-inverse-square-law).

#### Getting Started

On **<date/time>**, join the class in Microsoft Teams for a discussion and introduction to your task. We will be:

* answering any of your questions, either about getting started with your investigation or about the processing of data that will be required.

**Note:** A video of this session will be posted on Teams in case you are unable to attend.

##### Conducting your investigation

1. Select a suitable light source and location to conduct the investigation. The light source should emit a constant brightness and should be bright enough illuminate your phone from at least 1-2 meters. Try to find a dark room to conduct the investigation as background light will adversely affect the results.
2. Use a tape measure or ruler to mark out a range of distances from the light source. Marking out 5 cm or 10 cm intervals from 0.10 to 0.90 meters would be suitable.
3. Position the phone’s light sensor at the first marked distance and record the light intensity without the light source on. This will represent the background lighting in the room.
4. Turn the light source on, measure and record the light intensity at each of the marked distances. **Note:** take care to ensure that the phones sensor is positioned at the correct mark and is aligned with (pointing directly at) the light source.
5. Compare your results to those provided in the table that were collected using a data logger, light probe and a lamp connected to a 12 V power supply.

Diagram 1: A sample experimental setup for this investigation. The distance, r, from the light source is measured from the source to the phone’s light sensor.

A sample experimental setup for this investigation. The distance, r, from the light source is measured from the source to the phone’s light sensor. 
It shows a light source, which could be a lamp, torch or computer monitor, separated by a distance, r, from the light sensor of a phone. 

When collecting data seek assistance early if you are finding difficulty by posting a message to your teacher by **<posting on Teams/emailing teacher>.**

Keep detailed records of all data, any observations and adjustments made during the experiment.

A sample data set has been provided for any students unable for any reason to collect first-hand data using a phone or other device.

##### Results

Record your results in the **third** column of table provided below. Include the units of measurement used by your phone in the top row.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Distance, r (m) | Light intensity: Probe (lux) | Light intensity: Phone  ( ) | Inverse square of distance (m-2) | Normalised probe intensity | Normalised phone intensity |
| 0.10 | 400 |  |  |  |  |
| 0.15 | 220 |  |  |  |  |
| 0.20 | 150 |  |  | 0.38 |  |
| 0.25 | 100 |  |  | 0.25 |  |
| 0.30 | 80 |  |  | 0.20 |  |
| 0.35 | 55 |  |  | 0.14 |  |
| 0.40 | 43 |  |  | 0.11 |  |
| 0.45 | 36 |  |  | 0.09 |  |
| 0.50 | 32 |  |  | 0.08 |  |
| 0.60 | 24 |  |  | 0.06 |  |
| 0.70 | 17 |  |  | 0.04 |  |
| 0.80 | 13 |  |  | 0.03 |  |
| 0.90 | 8 |  |  | 0.02 |  |

#### Processing and analysing data

##### Plotting a graph of the data

To compare your results to those from the light probe, try plotting intensity versus distance for both data sets on the same set of axes. Use excel, [desmos](https://www.desmos.com/calculator/hdjebxwkmz) or the graph paper provided.  
Attach your graph and consider the similarities and differences between the results.

|  |  |
| --- | --- |
| Similarities | Differences |
|  |  |

##### Processing distance measurements

1. Calculate the inverse square of each distance and record these values in the fourth column of the results table. The first has been done for you. Using your calculator is ok, but Excel and desmos each have functions for quickly processing these values.
2. Plot the intensity recorded on your phone versus and add a line-of-best-fit.
3. Do your results support the relationship ? Justify your answer with reference to your graph.

##### Processing intensity measurements: normalisation (extension)

Normalising the intensity measurements will support a more direct comparison of the data sets. The results you have collected and those supplied from the light probe were collected under difference conditions.

To directly compare them, you will need to **normalise** the results, that is, you will need to adjust the range of values for intensity to a common scale.

In this case, we will set the maximum intensity (recorded at 0.10 m) to 1 by dividing it by itself. The same process is applied to other intensity values to produce values between 0 and 1. This has been done for the probe data already.

Plot the normalised intensities for each set of results using Excel, desmos, or using the graph paper provided. Discuss any similarities and differences.

#### Communicating: sharing your findings

Share the conclusions of your investigation with your class.

* The two key questions you will be answering are:
  + How well does your phone’s light sensor perform compared to a school light probe?
  + Will smartphones eventually replace our expensive laboratory equipment?
* Support your responses with the evidence you have collected.
* Your report may be in any form, for example:
  + A short word document with graphs and data included
  + An Excel spreadsheet with comments added
  + A short video

Submit your task by **<posting on Teams/emailing teacher>** before **<date/time>**.

### Sample data and graphing materials

#### Sample data

An [Excel spreadsheet](https://drive.google.com/file/d/1V2o2KOV06HIYOUzkNtj70X11DaH-p9CU/view?usp=sharing) with data for eight light probes and 15 mobile phones is available for download from Google drive.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Distance, r (m) | Light intensity: Probe1 (lux) | Light intensity: Probe2 (lux) | Light intensity: Samsung S9  (lux) | Light intensity: iPhone 8+ (lux) | Light intensity: Phone  (lux) |
| 0.10 | 400 | 420 | 290 | 158 | 1200 |
| 0.15 | 220 | 217 | 166 | 77 | 620 |
| 0.20 | 150 | 108 | 124 | 58 | 350 |
| 0.25 | 100 | 80 | 87 | 44 | 220 |
| 0.30 | 80 | 56 | 73 | 23 | 170 |
| 0.35 | 55 | 40 | 60 | 23 | 120 |
| 0.40 | 43 | 32 | 48 | 23 | 98 |
| 0.45 | 36 | 28 | 38 | 23 | 80 |
| 0.50 | 32 | 25 | 32 | 16 | 75 |
| 0.60 | 24 | 18 | 25 | 16 | 46 |
| 0.70 | 17 | 15 | 20 | 11 | 35 |
| 0.80 | 13 | 12 | 15 | 16 | 32 |
| 0.90 | 8 | 11 | 13 | 11 | 26 |

#### Graph paper A graph of intensity (lux) versus distance (m). The graph shows 13 data points arranged in an inverse square relationship

