2025 Geometric Optics

Welcome to the **British Physics Olympiad Computational Challenge 2025.** The goal is to build *computer models* based upon the instructions in the **Challenge Presentation document**. These can mostly be achieved using a *spreadsheet* such as Microsoft Excel, although you are very much encouraged to use a *programming language* of your choice*.

The challenge runs from **Easter 2025 till August 2025.** To submit an entry you will need to fill in a web form at **https://www.bpho.org.uk/.**

Additional resources can be found at: **http://www.eclecticon.info/physics_bpho_compphys.htm**

The deliverable of the challenge is to produce a **screencast** of ***maximum length three minutes*** which describes your response to the challenge, i.e. the graphs and the code & spreadsheets and your explanation of these. Your video should make it really clear *how you* have arrived at your solutions to the tasks set. This is what we need evidence for in your video. All credit is for 'show your working' !
No videos over three minutes can get a Gold. Deliberately speeded up videos will be disqualified.

The videos must be uploaded to **YouTube**, and we recommend you set these as *Unlisted* with *Comments disabled*. **Your entry will comprise a YouTube link.** To produce the screencast, we recommend the Google Chrome add-on **Screencastify.**

You can enter the challenge **individually** or in **pairs**. If you opt for the latter, *both* of you must make equal contributions to the screencast.

Gold, Silver or **Bronze** e-certificates will be emailed to each complete entry, and the **top five** Golds will be invited to present their work at a special ceremony. Note no additional feedback will be provided, and the decision of the judges is final.

Bronze: All spreadsheet-based challenge elements completed. Some basic coding attempted.

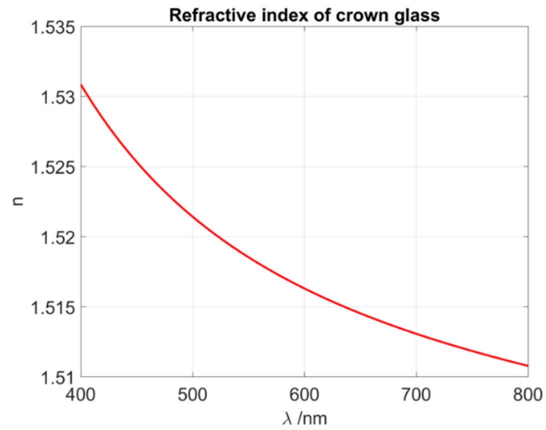
Silver: All tasks completed in code.

Gold: All tasks completed to a high standard, with possible extension work such as the construction of apps (i.e. programs with graphical user interfaces) and significant development of the models. The highest quality entries will typically contain research papers based upon the models and computational methods. For this challenge we also provide a *Geometric Optics* problem sheet, which could be attempted and written up. Many of the problems link directly to the challenges (Task11 *Rainbows,* Task 12 *Prism dispersion*).

*MATLAB or Python is recommended, although any system that can easily execute code in loops and plot graphs will do. e.g. Octave, Java, Javascript, C#, C++, Mathematica... Use what you can access and feel comfortable with. These Programming resources might be a helpful start.

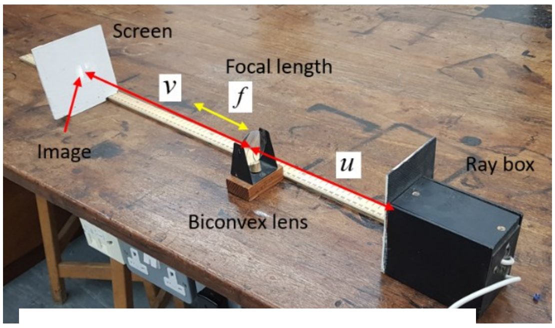
INSTRUCTIONS *** First download the Challenge Presentation from the BPhO website ***

Summary of tasks (each will have Bronze, Silver and Gold aspects - although each task is more involved than the previous). All mathematical details for tasks are provided in the Challenge Presentation pack.

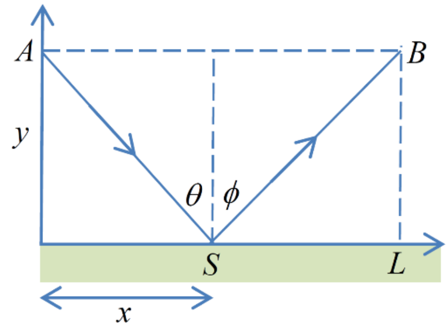


TASK 1a: Use the *Sellmeier formula* to plot the refractive index of crown glass vs wavelength over the range of visible light (approximately 400nm to 800nm).

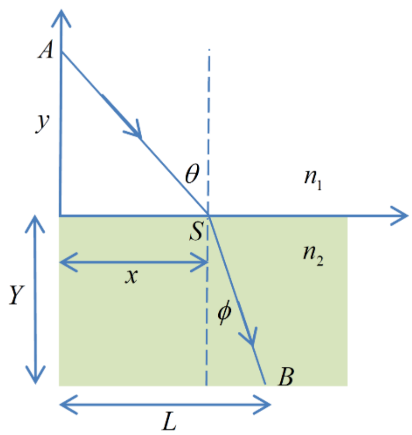
TASK1b: Use the (provided) empirical formula to plot the refractive index of water vs frequency of visible light.



TASK2: Assess the veracity of the *thin lens equation* $1/u + 1/v = 1/f$ by plotting a line of best fit of $1/v$ vs $1/u$ using the data provided. Hence determine the focal length f of the lens.

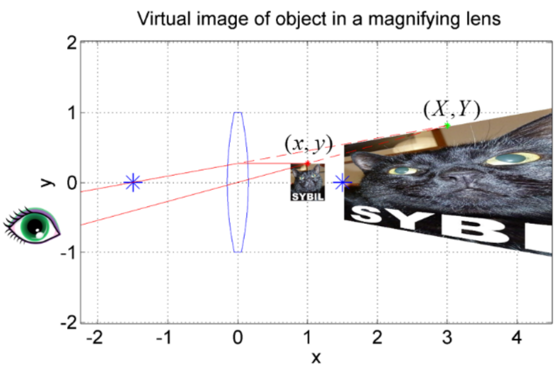


TASK3: For a ray from A to B reflected off a surface S, plot the travel time vs AS horizontal distance x and hence demonstrate that *Fermat's principle* of *minimizing travel time* implies the *law of reflection.*



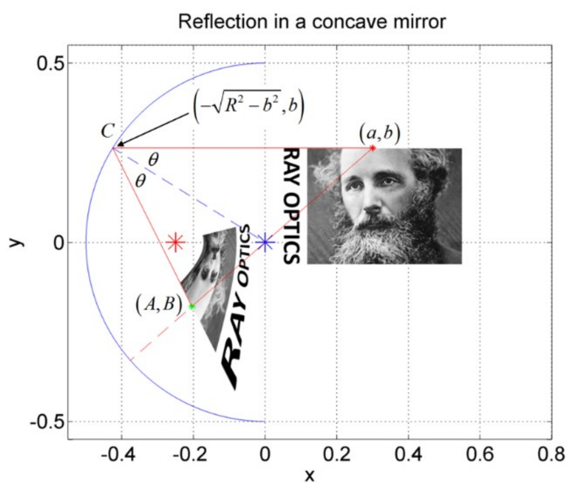
TASK4: Repeat TASK3, but now for the scenario of the ray being *refracted* on a path between two media with differing wave speeds c_1 and c_2. Demonstrate that Fermat's principle of minimizing travel time implies *Snell's law of refraction.*

TASK5: Write a computer program that imports an image file (the 'object') and then computes the locations of the pixel coordinates that constitute a virtual image in a plane mirror. Use this information to plot the virtual image. Use this image import and plot functionality in tasks 5-10.



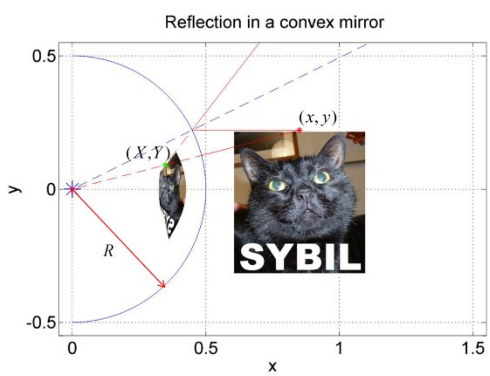
TASK6: Create an interactive model of the real, inverted image of an object placed *outside the focal range* of an ideal thin lens.

TASK7: Create an interactive model of the virtual, enlarged image of an object placed *inside the focal range* of an ideal thin lens.

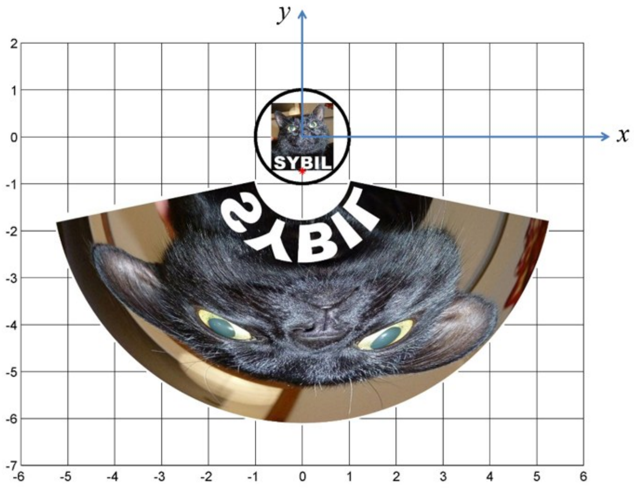


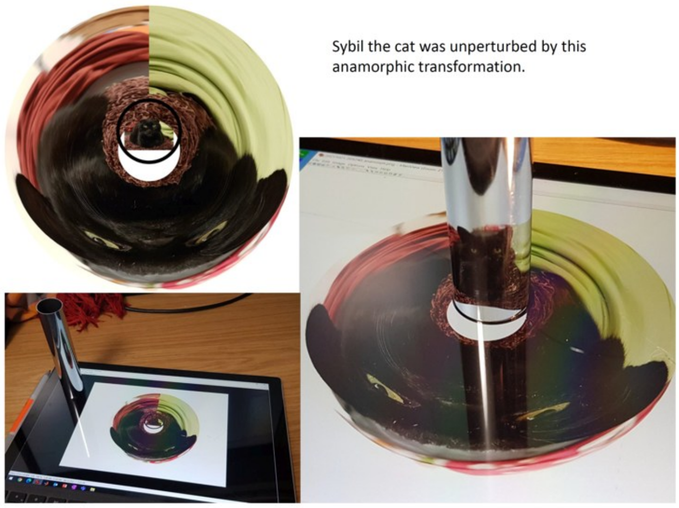
TASK8: Create an interactive model of the (surprising!) *real image* of an object in a *concave* spherical mirror.

TASK9: Create an interactive model of the virtual image of an object in a *convex* spherical mirror.

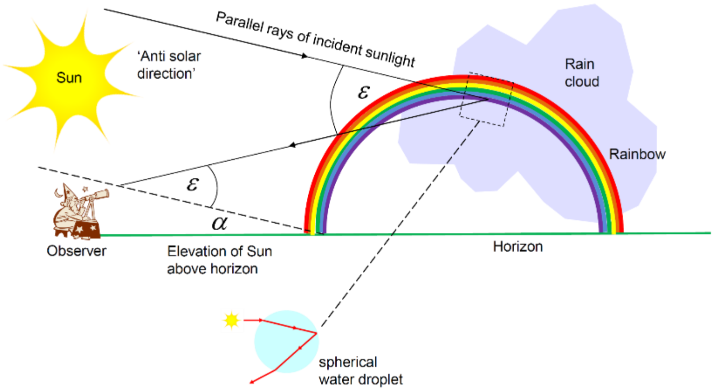


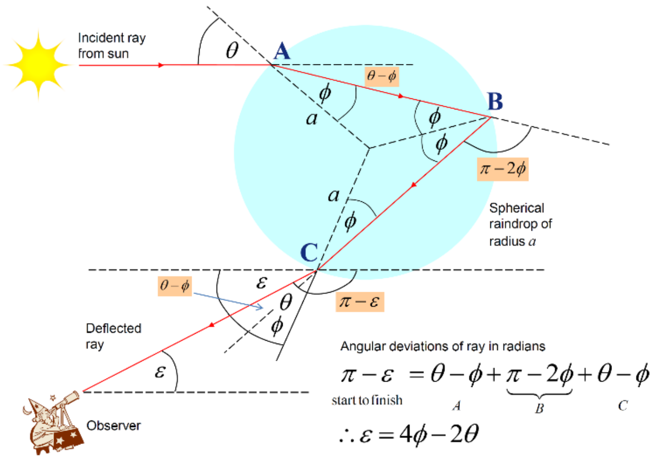
TASK10: Create a mapping of pixel coordinates (that are fitted into a unit circle) to a sector of a circle with radius Rf, centered at the base of the object (the red star). If you place a polished cylinder over the unit circle, you will create an *anamorphic* image. It will appear to look somewhat three dimensional.





TASK11: RAINBOW PHYSICS! Use Descartes' model to plot the elevation angles of primary and secondary rainbows.

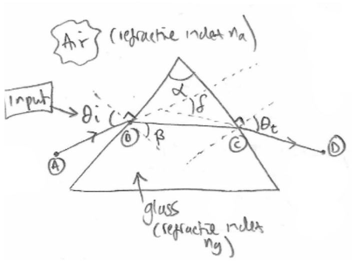


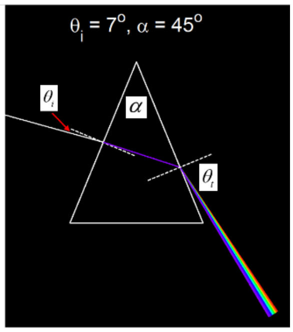


TASK12: Create a dynamic model of the path of a beam of white light through a triangular prism.

POSSIBLE EXTENSION OPPORTUNITIES:

- Answer the questions in the **Ray Optics problem sheet** (provided with this document) and write these up in an illustrated paper. Many link to the challenge tasks, so you can re-use your models. A good opportunity to learn LaTeX – which is the typesetting language used to write most technical papers and books in the physical sciences. Including [Science by Simulation.]





- Write a graphical user interface (GUI) for some of the ray optics models (e.g. the thin biconvex lens, the concave spherical mirror, prism dispersion, rainbows) and encode these as an 'app'. Coding up an iOS/Android smartphone app will particularly impress the judges.

$$\boxed{\sin\theta_t = \sqrt{n^2 - \sin^2\theta_i}\,\sin\alpha - \sin\theta_i\cos\alpha}$$

$$\boxed{\delta = \theta_i + \theta_t - \alpha}$$ Deflection of (white) light ray

- Create a dynamic model in an app to demonstrate short and long sight (and how to correct for it).