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Models & Inventions

Year 5-6

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Government of South Australia
Department for Education

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Building a simple hand-held telescope

Oliver Sainsbury - Brighton Primary School - Class 4.3

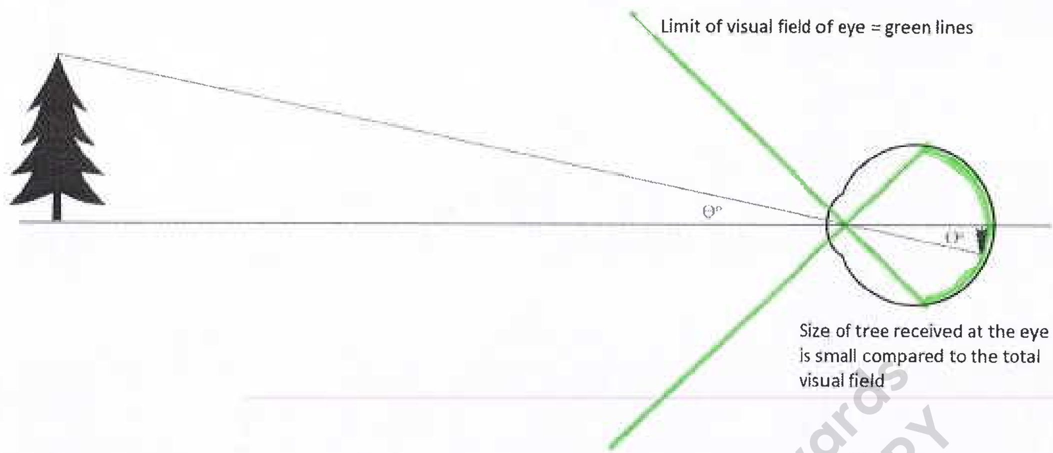
Aim

To construct a simple refracting hand - held telescope using inexpensive parts. We wanted to be able to magnify distant objects without spending too much on expensive custom lenses so we were restricted to using PVC pipe and "teaching lab" quality lenses 50mm in diameter easily sourced from sites such as www.madaboutscience.com.au.

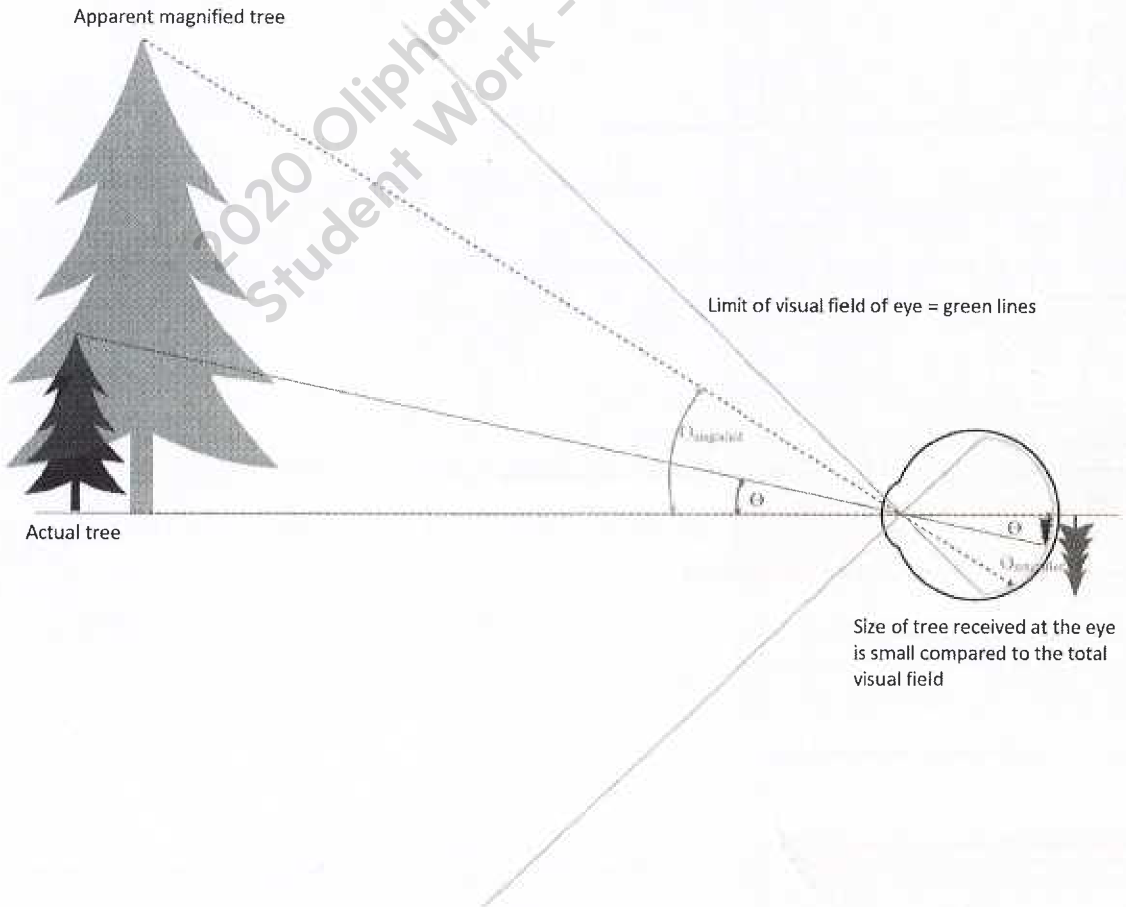
Theory

A refracting scope was the easiest to construct. Typically they use a long focal length at the front – the objective lens – and a smaller shorter focal length lens at the viewing end called the eyepiece.

The size of a a distant object tree when viewed from far away looks small because it is a tiny part of our eye's total angle of view which is more than 120 degrees.



To make the tree look larger – that is, to magnify it - we need to increase the angle that it makes across the back of the eye (or retina), Θ. To magnify by a factor of 2 we need to double the angle Θ that it makes on the retina.



Here follows a ray diagram which shows how this magnification is done:

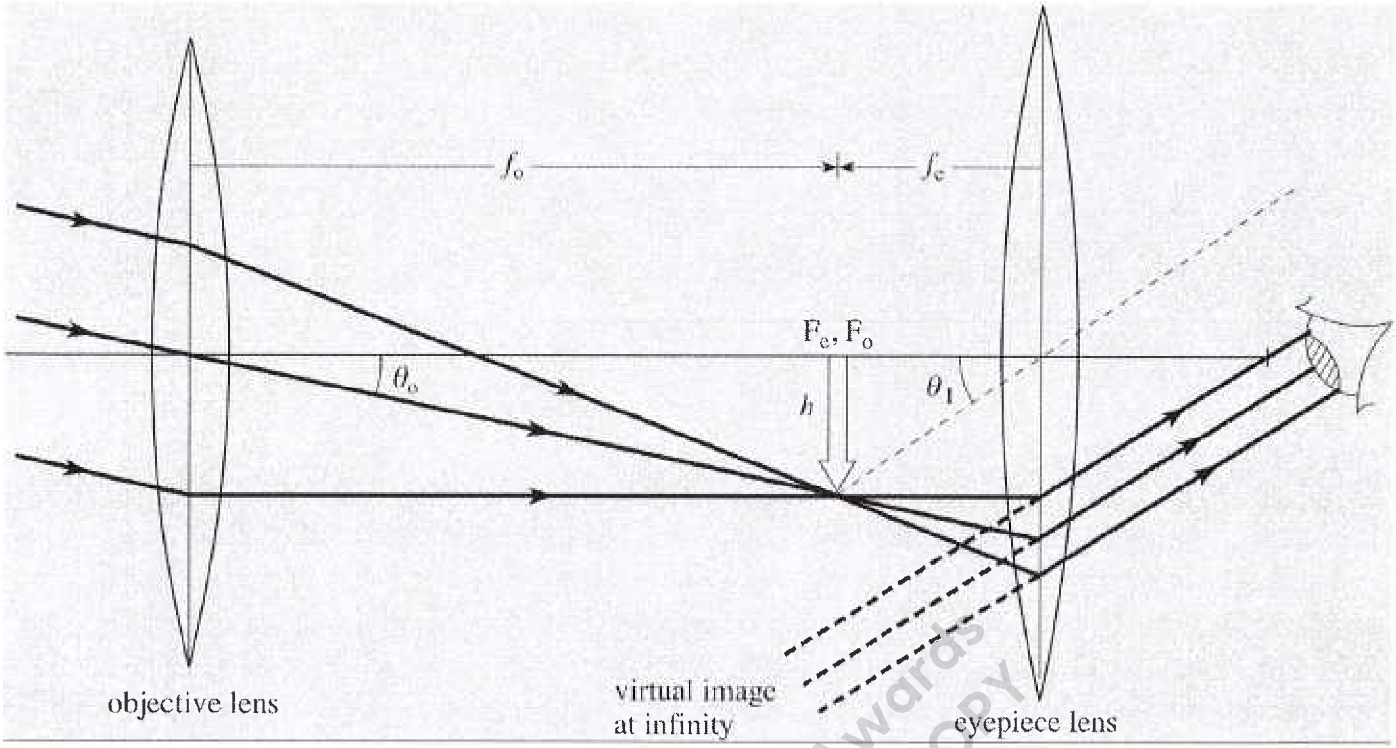


Image taken from https://schematron.org/refracting-telescope-ray-diagram.html

1. The convex objective lens: Light rays from a distant object are so far away that they are effectively parallel. These rays focus into a small image at the focal length of the objective lens f_0 which is 30cm in our scope.

2. If you place a white card at the objective lens focal point f_0 you will see an actual but inverted image of the tree shown here as an arrow of height *h*. Putting your eye at this position (at the focal length of the objective lens f_0) you wouldn't see any image, because the eye (when focussing is relaxed) needs parallel rays to converge to into it's own image on your retina.

3. The eyepiece lens is more powerful than the objective. That is, it is thicker with a shorter focal length. We have three different eyepiece lenses to try, with focal lengths of 5cm, 2.5cm and 1.7cm. The eyepiece lens acts as a simple magnifying glass for the image projected onto f_0,
30cm along from the front objective lens. This lens is placed so that it is exactly it's focal length from the projected inverted tree image. Rays from inverted tree image get refracted into parallel rays which enter the eye. Now the tree can be see, though upside down.

4. The angle of these rays Θ_1 is now more acute or sharper than when seen by the naked eye. This means it now covers a wider portion of your retina so that the tree is magnified.

5. Formulas for working out the amount of magnification:

   The angular magnification of a telescope M is the ratio of the angle of the telescope image of the object to the unaided eye's image of the object $M = \Theta_0 / \Theta_1$

   Also, magnification = Focal length of the objective / Focal length of eyepiece lens $M = f_0 / f_e$

Our objective lens has a focal length of 30cm, and we have three eyepiece lens focal lengths: 5cm, 2.5cm and 1.7cm.

Objective focal length f_O	Eyepiece focal length f_e	Magnification = f_O / f_e
30cm	5cm	6 x
30cm	2.5cm	12 x
30cm	1.7cm	18 x

To make stronger convex eyepiece lenses we placed 2 and then 3 of the 5cm focal length lenses just touching each other. The focal lengths are then reduced by each additional lens.