ASTRO 100/G – Experiment 4

Spectroscopy

Links to Lectures 5, 16, 18, and 21

Much of the information we can deduce about the composition, temperature and gravity of stars comes from examining the spectra of light they emit as every body/element is characterised by their unique spectrum.

This is because hot objects emit a **continuous spectrum**, which follows the shape of a **blackbody curve** – the peak intensity of which depends on its temperature (T) according to Wien's Law. The hotter an object is, the shorter its peak wavelength (λ_{peak}), and therefore the bluer it appears to be.

$$\lambda_{\text{peak}} = \frac{3 \times 10^6}{T}$$

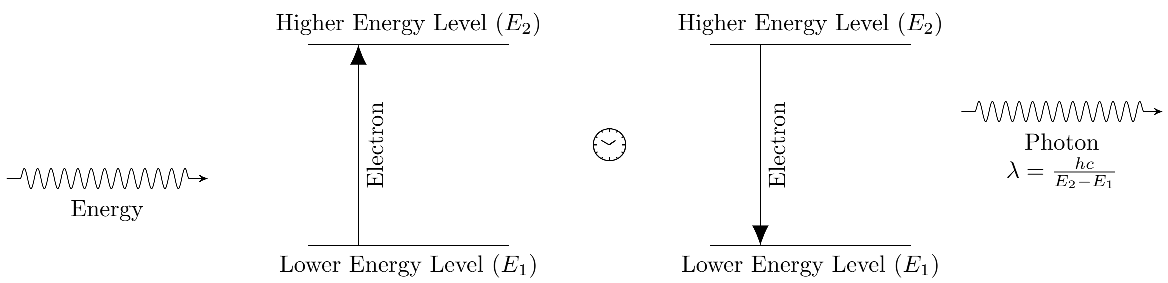
When white light interacts with a prism – such as the triangular one in front of you – it **refracts** and spreads out into a continuum of colour, commonly called a rainbow. Depending on the wavelength of the light, it will refract more or less (i.e. colors with the shorter wavelength will refract more, and vice-versa).

Different elements in a star's atmosphere – or along the line-of-sight – absorb and emit light at specific wavelengths (or colours) forming spectral lines. When energy is absorbed by an element, the electrons orbiting around the atom get excited and will start moving up and down energy levels; when the electrons drop back down to a lower energy level, the excess energy is emitted in the form of light producing **emission spectra**. This is shown as a picture at the bottom of this page. On the contrary, light absorbed by a gas excites the electrons to a higher energy level leaving an absorption spectrum. The relationship between the energy of the emitted photon (E), its wavelength (λ), and its frequency (f) is

$$E = hf = \frac{hc}{\lambda} \,,$$

where h is called Planck's constant ($h = 6.626 \times 10^{-34}$), and c is the speed of light ($c = 3 \times 10^8$ metres per second, or about one billion kilometres per hour). The lamps on the bench are gas discharge tubes – this means they excite the atoms by applying electricity across a sample of the gas. This electricity provides the energy to excite the electrons. In a real star, the excitation is provided by the core. Because the energy levels are **quantised** – they are multiples of hf – they are very thin and well-defined. Any lines you see that are not well-defined or look like an amorphous blob are usually there due to contamination of the element.

Since every element is sensitive to slightly different wavelengths of light (because they all have unique electron configurations), they each have their own unique "fingerprint" of spectral lines. Therefore studying these lines can tell us about the temperature of a gas and its composition.



At the end of this lab, students will be able to:

- **Qualitatively describe** how white light is refracted by a prism.
- **Recall** how the energy of a photon is related to wavelength.
- **Recall** the order of visible colours, infrared, and ultraviolet in a spectrum, ordered by wavelength.
- **Contrast** a continuous spectrum, an emission spectrum, and an absorption spectrum.

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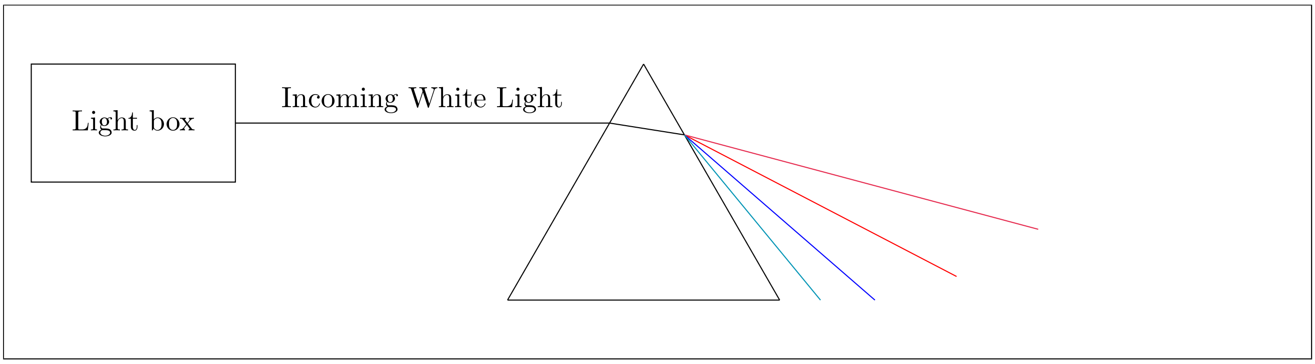
Name:	**Grade**
ID:	
UPI/Username:	/10

1. (1½ marks) Set your light box and prism up so it looks like the image below. You should see a clear separation of the colours in the visible spectrum. Complete the diagram below, marking on it the path of the **incoming white light**, the **red light**, and **the violet light**.



2. (a) (½ mark) Which colour is refracted (i.e. bent) the most? **Blue**

   (b) (½ mark) Which colour has the shortest wavelength? **Blue**

   (c) (½ mark) Which colour has the longest wavelength? **Red**

   (d) (1 mark) Which colour has the highest energy? **Blue – shortest wavelength**

3. (1 mark) Sketch two additional lines on your diagram above showing roughly where you would expect refracted rays for **infrared light** and **ultraviolet light**. **(Shown in pink for IR and teal for UV)**

4. (1 mark) Now look at the spectra from the two lamps on the demonstration bench and compare them to the reference sheet. Which element is in each of the lamps? *You can do this question out of order.*

   Element 1: **Mercury** . Element 2: **Hydrogen** .

5. For the **light box**:

   (a) (½ mark) What kind of spectrum is this? **Emission** / **Absorption** / **Continuous**. (Circle one)

   (b) (1 mark) In your own words, briefly explain how the spectrum is produced. *Hint: touch the box.*

   Solution: The lightbox emits light at every wavelength and the prism refracts it. Higher energy light is bent more and thus a continuous spectrum is produced.

6. For the **element lamps**:

   (a) (½ mark) What kind of spectrum is this? **Emission** / **Absorption** / **Continuous**. (Circle one)

   (b) (1 mark) In your own words, briefly explain how the spectrum is produced.

   Solution: The lamp spectra are produced by the excitation and decay of electrons in different energy levels. When an electron is excited, it gains energy. After time, it decays down to its original state. The wavelength of the light emitted from a transition from E_2 to E_1 is given by $\lambda = \frac{E_2 - E_1}{hc}$. Since every element has a unique configuration of energy levels, the photons emitted are unique to each element, and thus the emission spectrum is different for each element.

   Award part marks by discretion.

You are now finished. Please hand your sheet to the demonstrator for marking.