

Atomic energy levels and line spectra

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab answers

The model answers use the sample readings in the table. Your own values will differ slightly, but the wavelengths should agree with the accepted values to within about 1 %, and the transitions should be the same.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB E.1

Question 1 Averaging both sides

If the grating is not exactly centred or the slit is not on the middle mark, one side reads too large and the other too small by the same amount. Averaging cancels this. **The mean x is a better value than either single reading.**

Question 2 Grating spacing

$$d = 1 / 600 \text{ mm} = 1.667 \times 10^{-3} \text{ mm} = \mathbf{1.67 \times 10^{-6} \text{ m}} \text{ (1667 nm)}.$$

Question 3 Calculating wavelengths

For each line $\tan \theta = x / L$, then $\lambda = d \sin \theta$ for the first order.

red: $\tan \theta = 42.80 / 100.0 = 0.4280$, $\theta = 23.17^\circ$, $\sin \theta = 0.3935$, $\lambda = 1667 \times 0.3935 = \mathbf{656 \text{ nm}}$.

blue-green: $\tan \theta = 30.55 / 100.0 = 0.3055$, $\theta = 16.99^\circ$, $\sin \theta = 0.2922$, $\lambda = 1667 \times 0.2922 = \mathbf{487 \text{ nm}}$.

violet: $\tan \theta = 27.00 / 100.0 = 0.2700$, $\theta = 15.11^\circ$, $\sin \theta = 0.2607$, $\lambda = 1667 \times 0.2607 = \mathbf{434 \text{ nm}}$.

Question 4 Comparing with accepted values

Percentage difference = $|\text{measured} - \text{accepted}| / \text{accepted} \times 100 \%$.

red: $|656 - 656| / 656 = \mathbf{0 \%}$.

blue-green: $|487 - 486| / 486 = \mathbf{0.21 \%}$.

violet: $|434 - 434| / 434 = \mathbf{0 \%}$.

All three agree within about 0.5 %, which is good for a school grating.

Question 5 Identifying transitions

Photon energy = $1240 / \lambda$.

red: 1.89 eV

blue-green: 2.55 eV

violet: 2.86 eV

These match the hydrogen gaps $3 \rightarrow 2$ (1.89 eV), $4 \rightarrow 2$ (2.55 eV) and $5 \rightarrow 2$ (2.86 eV). **Red is $3 \rightarrow 2$, blue-green is $4 \rightarrow 2$, violet is $5 \rightarrow 2$** ; all end on $n = 2$.

Question 6 Uncertainty in the red line

Percentage uncertainty in $x = 0.1 / 42.8 \times 100 \% = \mathbf{0.23 \%}$. Because $\lambda = d \sin \theta$ and $\sin \theta$ increases with x , a small fractional change in x gives a slightly smaller fractional change in λ (about 0.2 %, roughly ± 1 nm). Using a longer L (such as 2 m) makes x larger, so the same ± 0.1 cm is a smaller fraction.

Question 7 Second order

For the second order $\sin \theta = 2\lambda / d = 2 \times 656 / 1667 = 0.787$, so $\theta = 51.9^\circ$ and $x = L \tan \theta = \mathbf{128 \text{ cm}}$. This is beyond the end of a one-metre scale, and the line is also dimmer, so it is hard to see.