2. (12 points, suggested time 25 minutes)

A student is given a glass block that has been specially treated so that the path of light can be seen as the light travels through the glass. The student is asked to design an experiment to measure the index of refraction of the glass. The light source available in the laboratory is a hydrogen lamp that emits red light of a known wavelength.

(a) A linear graph is to be used to determine the index of refraction of the glass. Indicate the quantities that should be graphed and describe how the graph could be used to determine the index of refraction of the glass.

(b) Outline an experimental procedure that could gather the necessary data. Include sufficient detail so that another student could follow your procedure. In addition to the glass block and the hydrogen lamp, the equipment in a typical classroom laboratory is available.

(c) Predict how the path of the light will change as it enters the glass. Support your prediction using a qualitative comparison of the speed of light in glass and the speed of light in air.

(d) Describe the process(es) by which red light from the lamp is produced by hydrogen atoms that are initially in the ground state. Draw and label an energy level diagram that supports the atomic process(es) you describe.

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Question 2

12 points total **Distribution of points**

(a) 3 points

For graphing angles or functions of angles on the axes — 1 point

For plotting sines of angles on the axes and indicating or implying that the index of refraction of air is 1 — 1 point

For indicating a method to determine the index of refraction of the glass that is consistent with the graph described — 1 point

Example: If 1 refers to air and 2 to the glass, use $n_1 \sin\theta_1 = n_2 \sin\theta_2$ and graph $\sin\theta_1$ as a function of $\sin\theta_2$. Because $n_1 = 1$, the slope of the line is n_2.

(b) 4 points

For indicating that the light from the lamp needs to be a beam when it enters the glass (either referring to a beam, explicitly describing how to create a beam, or showing a beam in a diagram) — 1 point

For describing some method of determining angles with a protractor (or equivalent tool) in both media at an appropriate boundary — 1 point

For using angles with respect to the normal (can measure any angles as long as reference is made to converting them to the correct ones) — 1 point

For repeating the measurement at three or more different incidence angles to obtain sufficient data — 1 point

(c) 2 points

For indicating that when light travels across the boundary from air to glass, the ray bends toward the normal — 1 point

For indicating that the speed of light is slower in glass than in air (or an answer consistent with response for bending of the ray) — 1 point

Question 2 (continued)

Distribution of points

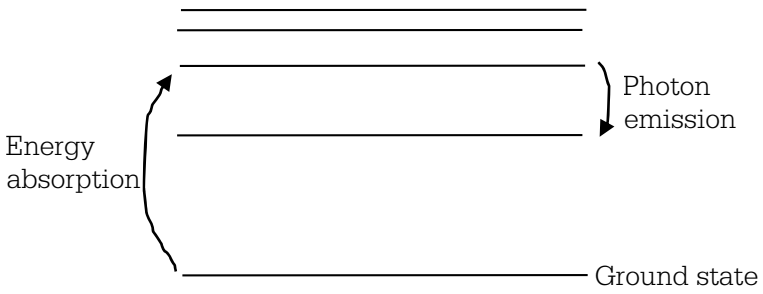
(d) 3 points

For an appropriate energy-level diagram showing absorption from the lowest level and emission — 1 point

For indicating that a hydrogen atom can be excited from the ground state to a higher energy state by absorbing energy — 1 point

For indicating that transitions to lower energy levels cause emission of photons — 1 point

Example:



Atoms in the ground state absorb energy from the electricity delivered to the lamp. The atoms enter an excited state. Then the atoms emit photons as they drop to a lower energy state.