2016 SCORING GUIDELINES

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

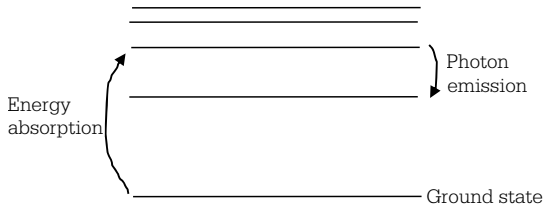
2016 SCORING GUIDELINES

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.