**Q1.** Observations of the H-α line in the spectrum of a star indicate the presence of hydrogen. The H-α line has a wavelength of 656 nm and is produced by a transition of electrons into the −3.4 eV energy level.

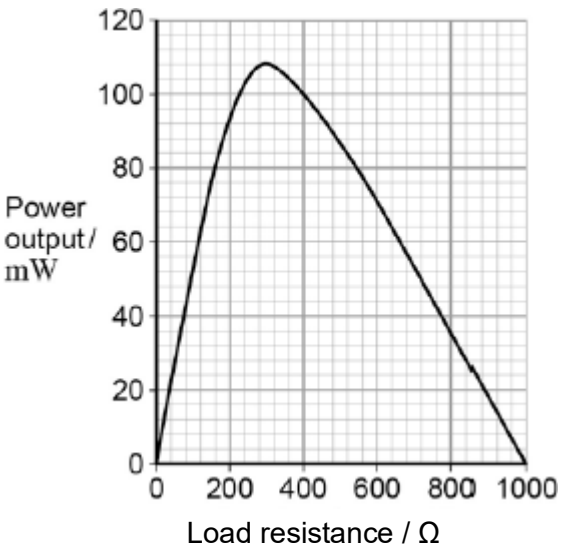
Calculate the energy level that the electron moves from when emitting a photon corresponding to a wavelength of 656 nm. Give your answer in **J**.

energy level ..... J

**(Total 4 marks)**

**Q2. Figure 1** shows data for the variation of the power output of a photovoltaic cell with load resistance. The data were obtained by placing the cell in sunlight. The intensity of the energy from the Sun incident on the surface of the cell was constant.

**Figure 1**




(a) Use data from **Figure 1** to calculate the current in the load at the peak power.

**(3)**

(b) The intensity of the Sun's radiation incident on the cell is 730 W $m^{-2}$. The active area of the cell has dimensions of 60 mm × 60 mm.

Calculate, at the peak power, the ratio $\frac{\textit{electrical energy delivered by the cell}}{\textit{energy arriving at the cell from the Sun}}$

**(3)**

(c) The average wavelength of the light incident on the cell is 500 nm. Estimate the number of photons incident on the active area of the cell every second.

**(2)**

(d) The measurements of the data in **Figure 1** were carried out when the rays from the sun were incident at 90° to the surface of the panel. A householder wants to generate electrical energy using a number of solar panels to produce a particular power output.

Identify **two** pieces of information scientists could provide to inform the production of a suitable system.

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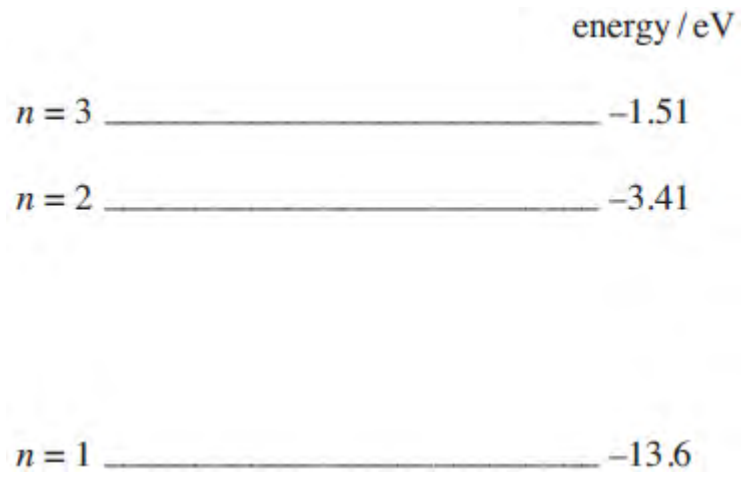
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**(2)**
**(Total 10 marks)**

**Q3.**The diagram below shows the lowest three energy levels of a hydrogen atom.




(a) An electron is incident on a hydrogen atom. As a result an electron in the ground state of the hydrogen atom is excited to the $n = 2$ energy level. The atom then emits a photon of a characteristic frequency.

(i) Explain why the electron in the ground state becomes excited to the $n = 2$ energy level.

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**(2)**

(ii) Calculate the frequency of the photon.

frequency = ..... Hz

**(3)**

(iii) The initial kinetic energy of the incident electron is $1.70 \times 10^{-18}$ J.

Calculate its kinetic energy after the collision.

kinetic energy = ..... J

**(2)**

(iv) Show that the incident electron cannot excite the electron in the ground state to the $n = 3$ energy level.

**(2)**

(b) When electrons in the ground state of hydrogen atoms are excited to the $n = 3$ energy level, photons of more than one frequency are subsequently released.

(i) Explain why different frequencies are possible.

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**(1)**

(ii) State and explain how many possible frequencies could be produced.

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**(2)**

**(Total 12 marks)**

**Q4.** (a) When free electrons collide with atoms in their *ground state*, the atoms can be excited or ionised.

(i) State what is meant by ground state.

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**(1)**

(ii) Explain the difference between excitation and ionisation.

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**(3)**

(b) An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies cause excitation in a particular atom.

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**(4)**

(c) The ionisation energy of hydrogen is 13.6 eV. Calculate the minimum frequency necessary for a photon to cause the ionisation of a hydrogen atom. Give your answer to an appropriate number of significant figures.

answer .....Hz

**(4)**

**(Total 12 marks)**

**Q5.** (a) A fluorescent tube is filled with mercury vapour at low pressure. In order to emit electromagnetic radiation the mercury atoms must first be *excited*.

(i) What is meant by an excited atom?

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**(1)**

(ii) Describe the process by which mercury atoms become excited in a fluorescent tube.

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**(3)**

(iii) What is the purpose of the coating on the inside surface of the glass in a fluorescent tube?

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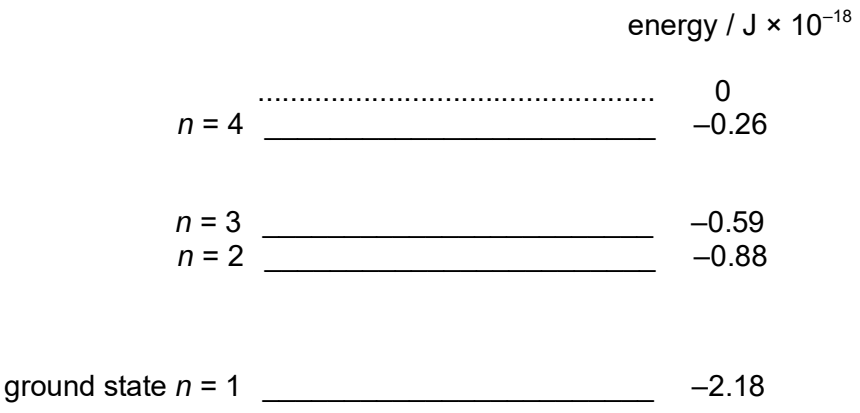
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**(3)**

(b) The lowest energy levels of a mercury atom are shown in the diagram below. The diagram is **not** to scale.




(i) Calculate the frequency of an emitted photon due to the transition level $n = 4$ to level $n = 3$.

answer = ..... Hz

**(3)**

(ii) Draw an arrow on the diagram above to show a transition which emits a photon of a longer wavelength than that emitted in the transition from level $n = 4$ to level $n = 3$.

**(2)**

**(Total 12 marks)**