**COMET BAY COLLEGE**

**Physics Unit 3 - Task 9**

**Light Waves Test**

**Name: SOLUTION Total Marks /60**

**Question 1:**

When using different coloured LED’s, the wavelength can be calculated by measuring the potential difference of the voltage across the LED.

1. Using the theories and principles relating to light, explain the relationship between potential difference and wavelength. (2 marks)
2. Estimate the voltage drop of a blue light LED. (3 marks)

**Question 2:**

The following table of data applies to a transformer that is ideal in terms of voltage but only 90.0 % efficient due to current losses. Fill in the data for the blank cells. There is space below the table to show your working. (4 marks)

|  |  |  |
| --- | --- | --- |
|  | **Primary Winding** | **Secondary Winding** |
| **Number of turns** | 480 turns | 288 turns |
| **Voltage** | 240 V | **144 V (1 mark)** |
| **Current** | **0.300 A (1 mark)** | 450 mA |
| **Power** | **72.0 W (1 mark)** | **64.8 W (1 mark)** |

Vs/Vp = Ns/Np Vs = (Ns Vp) / Np = 144 V

Ps = Vs x Is = 144 x 0.45 = 64.8 W

Pp = Ps/0.9 = 72.0 W

Ip = Pp / Vp = 72 / 240 = 0.30 A

|  |  |  |
| --- | --- | --- |
|  | **Primary Winding** | **Secondary Winding** |
| **Number of turns** | 480 turns | 288 turns |
| **Voltage** | 240 V |  |
| **Current** |  | 450 mA |
| **Power** |  |  |

**Question 3:**

Explain the process of fluorescence. You may use the energy level diagram below to aid your response. (3 marks)

Ground state E1

E2

E3

E4

E5

E∞

-12.70 eV

-7.52 eV

-5.62 eV

-4.27 eV

-3.18 eV

zero eV

Excitation by UV photon

De-excitation in smaller steps, emission of visible photons

When an atomic electron absorbs a high energy photon such as a non-visible UV photon then excitation can occur across several energy levels. (1 mark)

On de-excitation the atomic electron makes several smaller steps back to the ground state. These steps result in the emission of photons which can be visible. (1 mark)

Use of diagram or very clear explanation of steps. (1 mark)

(Or similar)

**Question 4:**

A synchrotron produces hard X-rays that travel along a beam line and impact on a sample of crystalline material. ESTIMATE the energy of these hard X-rays in keV. (4 marks)

From the formula and constants sheet the frequency of hard X-rays is approx 1020 Hz. (1 mark)

h = 6,63 x 10-34 J s

E = hf = (6.63 x 10-34) x 1020 (1 mark)

= 6.63 x 10-14 J (1 mark)

1 keV = 1.6 x 10-16 J

so 6.63 x 10-14 = 4.1 x 102 keV (1 mark)

**Question 5:**

Classify the following spectra by circling two (2) of the options beneath each description:

(3 marks)

1. The flame of a burning candle

Emission Absorption

Line Broadband Continuous

1. Light shining from a mercury vapour lamp

Emission Absorption

Line Broadband Continuous

1. Light after white light was passed through a solution of Potassium Permanganate

Emission Absorption

Line Broadband Continuous

**Question 6:**

Aircraft flying through the Earth’s magnetic field are subject to an induced EMF across the wings.

* + - 1. At which places on Earth will the aircraft experience the maximum induced EMF? (1 mark)

The aircraft will experience maximum induced EMF when the magnetic lines of force are closest together. This will occur at the poles of the Earth. (1 mark)

* + - 1. If the maximum magnitude of the Earth’s magnetic field is 5.00 x 10-5 T, calculate the magnitude of the EMF that would be induced across the wings of a Boeing 747 flying at its maximum speed. A Boeing 747 wing span is about 60 m and its maximum speed is about 900 km h-1. (3 marks)

Wingspan of Boeing 747 = approx 60 m

Maximum speed of Boeing 747 = 900 km h-1 = (250 m s-1) (1 mark)

Earth’s magnetic field = 50 x 10-6 T

emf = *l*vB = 60 x 250 x (50 x 10-6) (1 mark)

emf induced across the wings = 0.75 V (1 mark)

* + - 1. Would it be realistic for the induced EMF produced in this way to be used to power appliances on board the aircraft? Justify your answer. (2 marks)

No. (1 mark)

- 0.75 V is a small potential that would not be very useful in providing power for appliances in the aircraft. (1 mark)

**Question 7:**

Explain how a line absorption spectrum could be formed by a collection of atoms. (3 marks)

The atoms form a cloud of relatively cool gas and a continuous spectrum of light is shone through the gas. (1 mark)

Only photons of light from the continuous source will be absorbed if they have energy values corresponding to energy level differences in the cool gas atoms. The photons cause excitation in the cool gas. (1 mark)

On viewing the continuous spectrum after it has passed through the cool gas then distinct black lines are seen where photons have been removed for excitation. (1 mark)

(Or similar)

**Question 8:**

A satellite provides information about the receding glaciers on the Earth’s surface. It has a mass of 395 kg and is in a circular orbit of radius 1.45 x 104 km. By orbiting for 12 days it can map most of the Earth’s glaciers.

* 1. Calculate the orbital speed of the satellite. (3 marks)

r = 1.45 x 107 m

ms = 395 kg

G = 6.67 x 10-11 N m2 kg-2

Me = 5.98 x 1024 (1 mark using this mass in the equation)

v2 = GMe/r

v2 = (6.67 x 10-11) x (5.98 x 1024)/(1.45 x 107) (1 mark)

v2 = 27.508 x 106

v = 5.20 x 103 m s-1 (1 mark)

* 1. At what **altitude** above the Earth is the satellite orbiting? (2 marks)

re = 6.37 x 106 m

rs = 1.45 x 107 m

altitude = rs – re

altitude = (1.45 x 107) – (6.37 x 106) (1 mark)

the altitude of the satellite = 8.13 x 106 m (1 mark)

* 1. List the force(s) that keep the satellite in its stable circular orbit. (2 marks)

The force that keeps the satellite in orbit is the centripetal force that acts towards the centre of the orbit. (1 mark)

This force is provided by the gravitational attraction between the Earth and satellite. (1 mark)

(Or similar)

**Question 9:**

The diagram below details some of the energy levels for a fictitious atom, Michellium.

Ground state E1

E2

E3

E4

E5

E∞

-9.76 eV

-5.65 eV

-3.18 eV

-1.96 eV

-1.34 eV

zero eV

1. Calculate the minimum photon energy in joules that could ionise the atom in its ground state. (2 marks)

Minimum energy (J) = 9.76 x 1.60 x 10-19 (1 mark)

Minimum energy (J) = 1.56 x 10-18 J (1 mark)

1. Calculate the longest wavelength (nm) possible in the emission spectrum of Michellium as the ionised atom returns to its ground state. (3 marks)

Longest wavelength = shortest transition

Shortest transition = 1.96 -1.34 = 0.62 eV

0.62 eV = 0.62 x 1.60 x 10-19 J = 9.92 x 10-20 J (1 mark)

E = hf = h.c / λ

λ = h.c / E = 6.63 x 10-34 x 3 x 108 / 9.92 x 10-20 (1 mark)

λ =2.005 x 10-6 m = 2.01 x 10-6 m (1 mark)

1. For the wavelength you calculated in part b. state which area of the electromagnetic spectrum this belongs to. (1 mark)

infra-red (1 mark) (2.01 🞩 10-6 / 10-9 = 2010 nm )

1. Is it possible for a Michellium atom to absorb a 4.21 eV photon? Explain briefly.

(2 marks)

No – there is no energy level difference that corresponds to 4.21 eV. (1 mark) A photon will only transform all or none of its energy. (1 mark)

1. An atomic electron is at E5. How many lines in the emission spectrum would be possible for the energy levels considered above if it returns to the ground state? Indicate them on the diagram. (2 marks)

Number of lines = 10 (1 mark)

on diagram (1 mark)

**Question 10:**

The work of Michael Faraday led James Clark Maxwell to develop a theory about the origin of electromagnetic waves. In 1864 Maxwell predicted that any accelerated charged particle should generate an electromagnetic wave. In 1887 Heinrich Hertz verified Maxwell’s theory. By causing electrons to accelerate back and forth in a wire loop he generated an electromagnetic wave. The radio waves coming from the loop were detected by a second wire loop on the other side of his laboratory. Worldwide radio communication was developed from this discovery.

Rutherford proposed his model of the atom in 1911 to supersede JJ Thomson’s “plum pudding model”, of 1904. Rutherford envisaged distant electrons following circular orbits around a central positively charged nucleus much like the planets in a solar system orbit a star. The problem with this planetary model is that according to classical Physics any mass that is undergoing circular motion is by definition experiencing a force to give it centripetal acceleration. If this were the case then the electrons would be sending out electromagnetic waves, which would reduce their energy and so send them spiralling into the nucleus. This is not the case and called for a further refinement to the atomic model.

In 1913 Niels Bohr proposed what is now called the Bohr model of the atom. He suggested that electrons could only have certain motions:

* The electrons travel in orbits that have discrete quantized speeds, and therefore quantized energies. That is, not every orbit is possible but only certain specific ones, at certain specific distances from the nucleus.
* The electrons do not continuously lose energy as they travel. They can only gain or lose energy by jumping from one allowed orbit to another.

What made Bohr’s hypothesis brilliant was the derivation of formulae that predicted the radius of the energy levels and the values of the energy levels for the hydrogen atom. These predictions were later verified by experimental data.

Bohr derived the following formula using high school level algebra. The energy level value for electrons in the hydrogen atom is given by:

E = energy level value (J)

K = Coulombs constant = 9.00 × 109N m2 C-2

m = mass of electron (kg)

qe = the charge on an electron (C)

n = the energy level number (1, 2, 3….)

h = Planck’s constant

In 1900 Max Planck had introduced the idea that light is only delivered in quantum amounts. The ‘photon’ model fitted well with Bohr’s energy level model where the energy of an emitted photon given by E = h.f, must match the difference in energy level values (joules) in a de-excitation between energy levels.

In 1924 the French aristocrat Louis de Broglie (pronounced ‘broy’) was able to solve the dilemma that electrons seemed to violate some of the basic principles of classical physics. In a doctoral thesis he introduced the idea that particles have wave characteristics in the same way that light waves have particle characteristics.

By linking the Einstein equation E = mc2 and the Planck equation E = h.f, De Broglie derived an equation for the wavelength λ (m) of any particle of mass m (kg), travelling at a speed v (m s-1) :

*The De Broglie equation for wavelength of a particle:*

Diffraction of electrons through a crystalline solid by GP Thomson demonstrated by experiment the wave nature of matter suggested by De Broglie. The principle that electrons also behave like waves is used in the tunnelling electron microscope to produce clear images of objects that are too small for conventional microscopes.

De Broglie showed that the circumferences of the Bohr energy levels are exactly whole integer multiples of the electron wavelengths. So an electron wavelength fits the circumference a whole number of times leading to an electron standing wave through reinforcement. The ground state is like the “fundamental frequency” and excited states are like the “harmonics” in mechanical standing waves.

The piecemeal quantisation of Physics by Planck, Bohr, Einstein and others was successful but disjointed.

Further work by Schrödinger, Born, Pauli and Dirac led to our current understanding of electron orbitals (regions around the nucleus in which there is a high probability of finding an electron at any given instant).

**Questions**

1. What type of experimental data could have verified Bohr’s energy level values for the hydrogen atom? (2 marks)

Line emission spectrum from hydrogen (1 mark)

Using E = hf to confirm energy level differences from measured frequencies. (1 mark)

Or similar valid explanation

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1. The formula can be simplified to,

Calculate the numerical value of X, showing all working and stating your answer in scientific notation. (2 marks)

= (1 mark)

X = 2.17 × 10-18 J (1 mark)

1. In terms of energy in electron volts the formula in part c) may also be written



Use this formula to calculate the energy level values for hydrogen for n = 1, 2, 3 and 4 (2 marks)

|  |  |
| --- | --- |
| Energy Level Number | Energy level value (eV) |
| 4 | **-0.85** |
| 3 | **-1.51** |
| 2 | **-3.40** |
| 1 | **-13.6** |

|  |  |
| --- | --- |
| Energy Level Number | Energy level value (eV) |
| 4 |  |
| 3 |  |
| 2 |  |
| 1 |  |

1. How did the work of Louis de Broglie link back to the predictions of Niels Bohr?

(2 marks)

It confirmed the circumferences of Bohr energy levels (1 mark)

Circumference is based on radius which Bohr predicted. (1 mark)

1. Use the *De Broglie equation for wavelength of a particle* to calculate the wavelength of a cricket ball of mass 250 g bowled at 20 m s-1 and explain why it is hard to observe wave motion of a cricket ball along its projectile path. (3 marks)

λ = = (1 mark)

λ = 1.33 × 10-34 m (1 mark)

Very small so difficult to measure (1 mark)

1. How is a De Broglie electron orbit similar to a guitar string that has been plucked?

(2 marks)

Principle of standing waves, a guitar string vibrates as a standing wave, (1 mark)

electron orbits seem to reinforce like standing waves. (1 mark)

Or similar valid explanation

1. Rutherford’s planetary model of the atom was considered flawed. Explain why.

(2 marks)

The electron charges are accelerating in circular orbits , (1 mark)

so according to Heinrich Hertz accelerating charge radiates energy, which would lead to energy of electrons decreasing. (1 mark)

This is not the case.

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