NAME______________________________

IB PHYSICS HL

REVIEW PACKET: ATOMIC PHYSICS

1. This question is about atomic and nuclear structure.

In a nuclear model of the atom, most of the atom is regarded as empty space. A tiny nucleus is surrounded by a number of electrons.

(a) Outline **one** piece of experimental evidence that supports this **nuclear** model of the atom.

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(3)

(b) Explain why the protons in a nucleus do not fly apart from each other.

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(2)

(c) In total, there are approximately 10^{29} electrons in the atoms making up a person.

(i) Estimate the electrostatic force of repulsion between two people standing 100 m apart as a result of these electrons.

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(4)

(ii) Explain why two people standing 100 m apart would not feel the force that you have calculated in part (i).

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(2)
(Total 11 marks)

2. This question is about atomic models.

The Bohr model was developed in order to explain the atomic spectrum of hydrogen.

(a) Explain how the Bohr model was used to explain the spectrum of atomic hydrogen.

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(4)

(b) State **one** limitation of the Bohr model.

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(1)

A later model of the atom was developed by Schrödinger.

(c) (i) State **two** differences between the model of Bohr and the model of Schrödinger.

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(2)

(ii) Explain how the Schrödinger theory is consistent with the Heisenberg uncertainty principle.

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(3)
(Total 10 marks)

3. This question is about wave-particle duality.

(a) Describe the de Broglie hypothesis.

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(b) An electron is accelerated from rest through a potential difference of 1250 V. Determine the associated de Broglie wavelength of the accelerated electron.

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(4)

(Total 6 marks)

4. This question is about line spectra.

(a) Light is emitted from a gas discharge tube. Outline briefly how the visible line spectrum of this light may be obtained.

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(2)

The table below gives information relating to three of the wavelengths in the line spectrum of atomic hydrogen.

Wavelength / $\times 10^{-9}$ m	**Photon energy / $\times 10^{-19}$ J**
1880	1.06
656	3.03
486	4.09

(b) Deduce that the photon energy for the wavelength of 486×10^{-9} m is 4.09×10^{-19} J.

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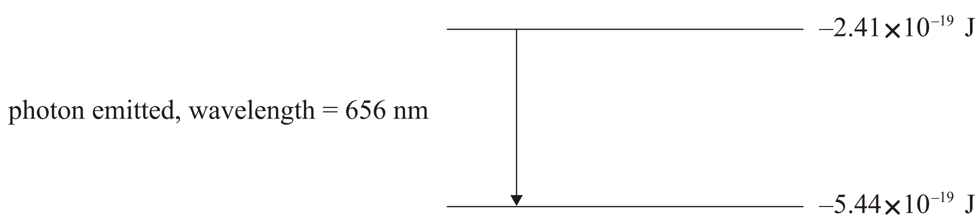
(2)

The diagram below shows two of the energy levels of the hydrogen atom, using data from the table above. An electron transition between these levels is also shown.



(c) (i) On the diagram above, construct the other energy level needed to produce the energy changes shown in the table above.

(1)

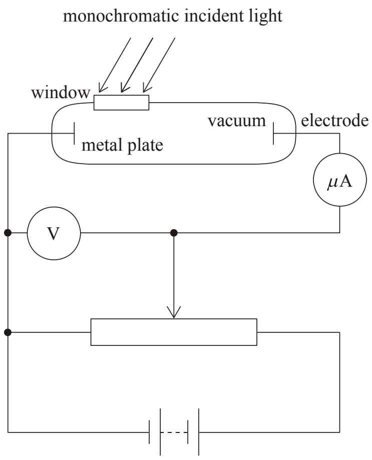
(ii) Draw arrows to represent the energy changes for the two other wavelengths shown in the table above.

(1)

(Total 6 marks)

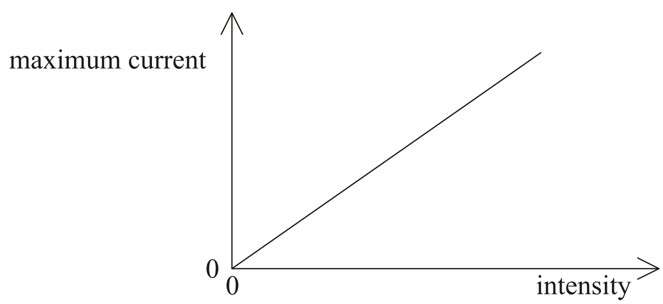
5. This question is about the photoelectric effect.

The apparatus shown below may be used to investigate the photoelectric effect.



The potential difference V applied between the metal plate and electrode may be varied in magnitude and in direction. This is repeated for different values of intensity for the same frequency of light.

(a) Monochromatic light is incident on the metal plate. The potential difference between the plate and the electrode is adjusted so that the reading on the microammeter is a maximum. The graph below shows the variation with intensity of the monochromatic light of the maximum current.



Explain the features of this graph.

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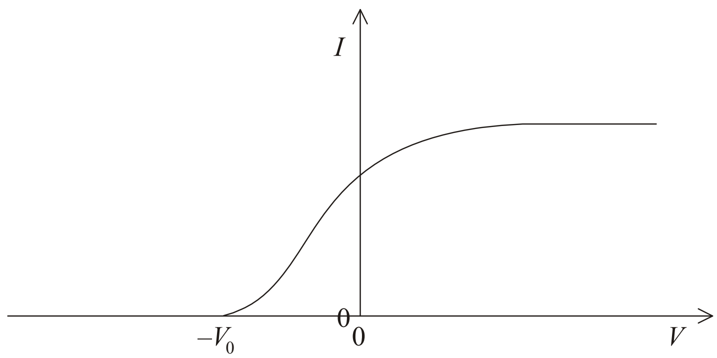
(4)

(b) The frequency and the intensity of the light are held constant. The graph below shows the variation with the potential difference V of the current I measured on the microammeter.



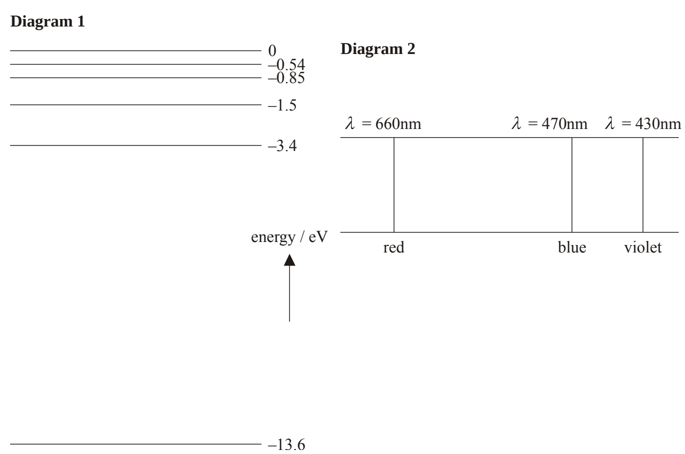
The frequency of the light is doubled at a constant intensity. On the graph above, draw a second line to show the variation with potential difference of the current in the microammeter.

(3)

(Total 7 marks)

6. This question is about energy levels and atomic models.

(a) Diagram 1 below shows some of the energy levels (measured in electron-volts) of the hydrogen atom. Diagram 2 is a representation of part of the visible spectrum of atomic hydrogen (not to scale).



(i) State the value of the ionization energy of hydrogen.

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(1)

(ii) The wavelength corresponding to the red line in the visible spectrum of atomic hydrogen is 660 nm. Deduce that the energy of a photon of wavelength 660 nm is 1.9 eV.

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(3)

(iii) On **diagram 1**, draw an arrow to show the electron transition between energy levels that gives rise to a photon of energy 1.9 eV. Label this arrow with the letter R.

(1)

(iv) On **diagram 1** and using your answer to (iii), draw arrows to show the electron transitions that give rise to the blue line and to the violet line in the visible spectrum of atomic hydrogen. Label these arrows B and V respectively.(1)

(b) The kinetic energy of an electron in the ground state of a hydrogen atom is 13.6 eV. Deduce that an electron in the ground state of the hydrogen atom has a de Broglie wavelength of approximately 3.3×10^{-10} m (mass of electron = 9.1×10^{-31} kg).

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(4)

(c) The "radius" of the hydrogen atom is of the order of 10^{-10} m. Outline how the value of the de Broglie wavelength in (b) is consistent with the Schrödinger model of the hydrogen atom.

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(3)
(Total 13 marks)

7. This question is about photoelectric emission.

A piece of metal is placed in an evacuated container. Light of wavelength 444 nm is incident on the surface of the metal. The surface has a work function of 4.60 eV.

(a) (i) Calculate the energy, in joule, of a photon of light of wavelength 444 nm.

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(1)

(ii) Deduce whether photoelectric emission of electrons will occur.

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(3)

(b) The wavelength of the light incident on the surface is now reduced to 222 nm. State and explain why electrons having a range of kinetic energy from zero to approximately 1.0 eV will be emitted.

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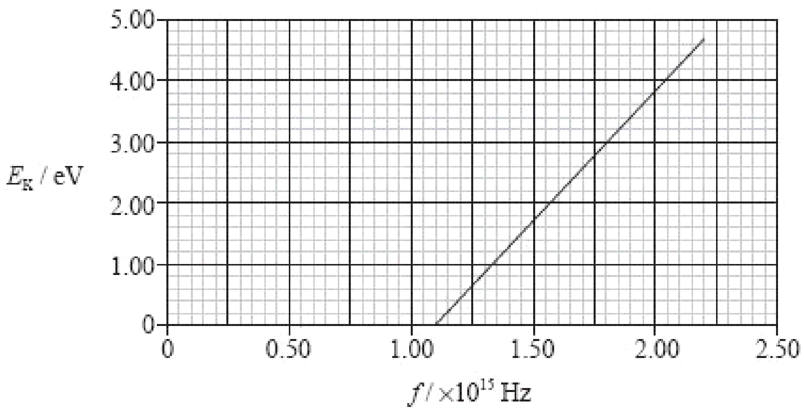
(4)
(Total 8 marks)

8. Photoelectric effect

A metal is placed in a vacuum and light of frequency f is incident on its surface. As a result, electrons are emitted from the surface. The graph below shows the variation with frequency f of the maximum kinetic energy E_K of the emitted electrons.



(a) The graph above shows that there is a threshold frequency of the incident light below which no electrons are emitted from the surface. With reference to the Planck constant and the photoelectric work function, explain how Einstein's photoelectric theory accounts for this threshold frequency.

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(4)

(b) Use the graph in (a) to calculate the

(i) threshold frequency.

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(1)

(ii) Planck constant.

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(4)

(iii) work function of the metal.

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(2)

(Total 11 marks)

MARK SCHEME!

1. (a) ***[1]** for any valid and relevant point eg*
Geiger-Marsden experiment involved bombardment of gold foil by alpha particles;
most passed straight through / were deviated through small angles but, some deflected through large angles;
these alpha particles were heading towards central nucleus; 3 max

(b) ***[1]** for any valid and relevant point eg*
protons in nucleus repel each other (seen or implied);
but are held together by the strong nuclear force / or neutrons are involved keeping it bound together / *OWTTE*; 2 max

(c) (i) attempted use of $F = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$;
with $q_1 = q_2 = 10^{29}\ e = 1.6 \times 10^{-10}$ C;
and $r = 100$ m;
to get $F = 2.3 \times 10^{26}$ N $\approx 10^{26}$ N; 4 max

(ii) people are overall electrically neutral;
equal numbers of positive charges mean that overall the electrical force is zero / *OWTTE*; 2 max

[11]

2. (a) the Bohr model predicts the electrons in the hydrogen atom exists in discrete energy levels;
an electron emits a photon every time a transition to a lower energy level is made;
the photon has an energy given by the difference of the energy levels involved in the transitions;
photon frequency determined by its energy / each transition gives rise to a single / discrete wavelength (as observed in spectrum); 4

*Award **[1]** for any other relevant and appropriate comments up to **[4 max]**.*

(b) it cannot be applied to many electron atoms / it does not predict the intensity of different lines; 1

(c) (i) Bohr's model has the electron in specific orbits of specific radius;
Schrödinger's theory attaches to the electron a probability wave; 2

Accept any sensible and appropriate comparison.

(ii) the Schrödinger theory attaches to an electron a probability wave;
and hence the electron cannot be pinpointed with absolute certainty at any one point;
which is what the Heisenberg principle demands since Δx (the uncertainty in position) is always $\neq 0$; 3

[10]

3. (a) all particles have a wavelength associated with them;

given by $\lambda = \frac{h}{p}$, with h and p explained

(b) kinetic energy of electron = qV;

$= 2.00 \times 10^{-16}$ J;

$E_K = \frac{P^2}{2m}$ *or* $v^2 = \frac{2E}{m}$ and $p = mv$ ($v = 2.1 \times 10^7\ ms^{-1}$)

$p = 1.91 \times 10^{-23}$ Ns;

$\lambda = \frac{h}{p}$

$= 3.47 \times 10^{-11}$ m; *(allow 2 significant digits)* 4

[6]

4. (a) use of diffraction grating / prism and screen / telescope;
observe <u>diffracted</u> / <u>refracted</u> light <u>or</u> first / second orders; 2

(b) $E = \frac{hc}{\lambda}$ or $E = hf$ and $c = f\lambda$;
correct substitution into relevant formula clear; 2
to give energy = 4.09×10^{-19} J
Award **[0]** for answer alone.

(c) (i) ______________________ -1.35×10^{-19} J

______________________ -2.41×10^{-19} J

______________________ -5.44×10^{-19} J

level shown in "reasonable" position (spacing of lines not important); 1

To receive the mark answers must quote -1.35×10^{-19} J.

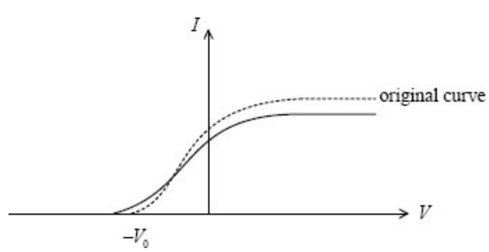
(ii) transition $-1.35 \times 10^{-19} \rightarrow -5.44 \times 10^{-19}$ (and labelled 486 nm)

transition $-1.35 \times 10^{-19} \rightarrow -2.41 \times 10^{-19}$ (and labelled 1880 nm); 1

[6]

5. (a) light consists of photons;
number of photons / sec determines intensity of light;
each photon extracts an electron (from metal);
therefore, current is proportional to intensity of light; 4

(b)



V_0 is lower / more negative;
general shape of curve (same);
saturation current smaller; 3

[7]

6. (a) (i) substitution into formula $E = \frac{hc}{\lambda}$

to give $E = 4.48 \times 10^{-19}$ J; 1

Units need not be stated.

(ii) photon energy = 2.8eV ***or*** work function = 7.36×10^{-19}J;
photon energy < work function;
<u>hence</u> no emission; 3

(b) electron emitted <u>from surface</u> will have energy (2 × 2.8 – 4.6) = 1.0eV;

photon can interact with an electron below surface;
so energy is required to bring the electron to the surface;
this energy is deducted from maximum kinetic energy of electron; 4

[8]

7. (a) (i) 13.6eV 1

(ii) $E = \frac{hc}{\lambda}$;

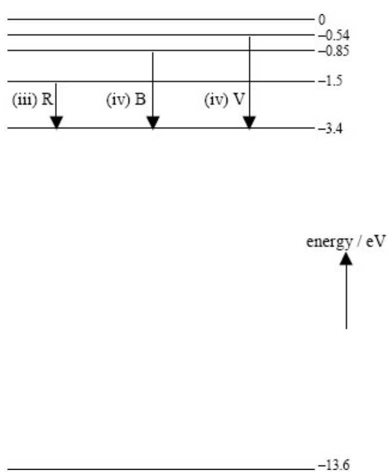
$= \frac{6.6\times10^{-34}\times3\times10^{8}}{6.6\times10^{-7}} = 3\times10^{-19}$ J;

$= \frac{3\times10^{-19}}{1.6\times10^{-19}}$;

= 1.9eV 3

(iii) *see diagram below.* 1

(iv) *see diagram below.* 1
Both must be correct to award ***[1]****.*



(b) $p^2 = 2mE$;

$= 2 \times 9.1 \times 10^{-31} \times 13.6 \times 1.6 \times 10^{-19}$;

to give $p = 2.0 \times 10^{-24}$ Ns;

$\lambda = \frac{h}{p} = \frac{6.6\times10^{-34}}{2.0\times10^{-24}}$;

$= 3.3 \times 10^{-10}$ m 4

(c) (the model) assumes that electrons are described by wave functions / *OWTTE*;
wave(s) associated with electron(s) is / are bounded by the atom;
this means that for the electron in the ground state the wavelength is
$\approx 10^{-10}$ m / *OWTTE*; 3

These are the basic marking points but candidates might answer with a diagram as well.

[13]

8. Photoelectric effect

(a) light consists of photons;
the energy of each photon = hf where h is the Planck constant;
a certain amount of energy, the work function ϕ is required to remove an electron from the metal surface;

if $f < \frac{\phi}{h}$ then no electrons will be emitted; 4

Award **[4]** *for these precise points as they are needed in view of the question.*
Award **[2 max]** *for a purely qualitative answer.*

(b) (i) 1.1×10^{15} Hz; 1

(ii) $E_K = hf - \phi = Ve$;

slope of graph = $\frac{h}{e}$;

slope = $4.2(\pm 0.4) \times 10^{-15}$;

$h = 4.2(\pm 0.4) \times 10^{-15} \times 1.6 \times 10^{-19} = 6.7\ (\pm 0.4) \times 10^{-34}$ J s;

Note*: the answer must show that the graph has been used – if not, award* **[0]** *for a bald answer as this could have been taken from the data book.* 4

(iii) $\phi = hf_0$;

$= 1.1 \times 10^{15} \times 6.7 \times 10^{-34} = 7.4 \times 10^{-19}$ J;

The value of h from (b)(ii) must be used.

or

from the intercept on E_K axis;

= 4.5(±0.2) eV; 2

[11]