Shenton College

Physics 3B

/45

Name ______________________

Teacher ______________________

Waves Test 2 – Electromagnetic Radiation

1. Young's double slit experiment is set up by students in a laboratory as shown in Figure 2. Monochromatic light is shone onto the slits which are placed at a large distance from the screen. The intensity pattern produced on the screen is a pattern of light and dark bands.

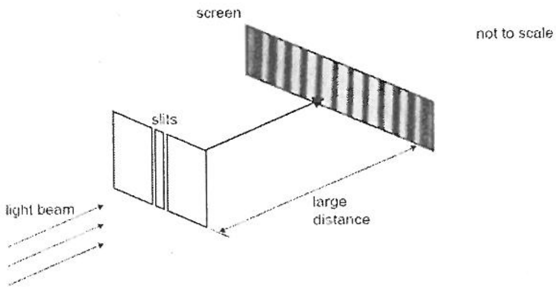


Figure 2

a) Explain why this experiment proves that light has wave properties. (2 marks)

diffraction – wave phenomena
If particles then only two bands.

b) Briefly describe an experiment that proves that light has a particle property. (2 marks)

photoelectric effect – energy = h × f
– discreet amount.
– two photons cannot add OR.

compton effect – X rays have momentum.

2. Part of the emission spectrum of sodium vapour produces a photon of energy 1.65 eV.

(a) Which **one** of the following transitions (**A–D**) on the energy level diagram of Figure 1 demonstrates the change in atomic energy levels for the emission of a photon of energy 1.65 eV? (1 mark)

A

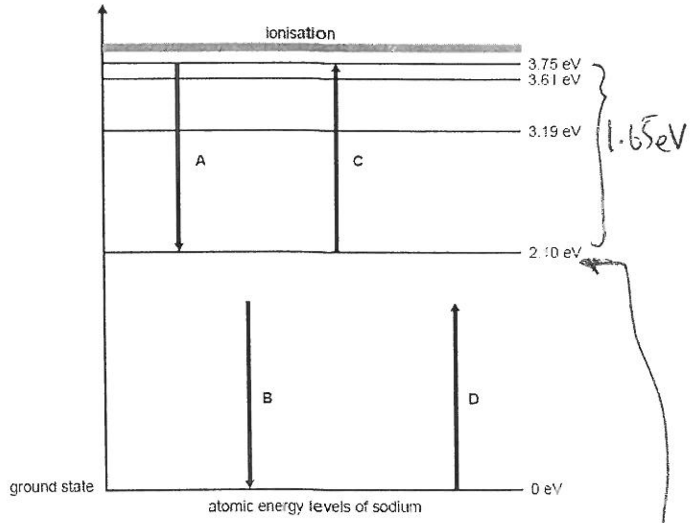


Figure 1

The electron of the sodium atom is in the first excited state.

2.10eV !!

(b) Calculate the wavelength of the photon of energy emitted as the excited atom returns to the ground state. (2 marks)

λ of B . $E = 2.10\ eV = 2.10 \times 1.60\times10^{-19}\ J$

$E = hf \quad f = \frac{E}{h} = \frac{2.10\times1.60\times10^{-19}}{6.63\times10^{-34}} = 5.07\times10^{14}\ Hz$

$\lambda = \frac{c}{f} = \frac{3.00\times10^{8}}{5.07\times10^{14}} = 5.9\times10^{-7}\ m$

Some will use

$E = 1.65\ eV$

max of (1)

3. A microwave has a frequency of 3.40 x 10^{10} Hz. If the microwave has a power output of 900 W, how many photons per second are transmitted? (2 marks)

$E/sec = 900\ W$

$E_{photon} = hf = 3.40\times10^{10} \times 6.63\times10^{-34} = 2.26\times10^{-23}\ J$

$photons/sec = \frac{E}{photon} = \frac{900}{2.26\times10^{-23}} = 3.99\times10^{25}\ photons/sec$

4. Figure 3 shows the spectrum of light emitted from a hydrogen vapour lamp.

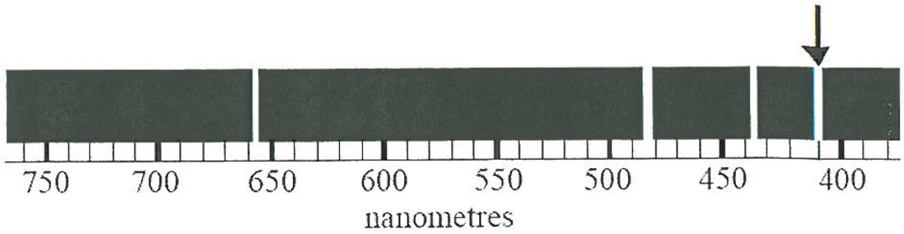


Figure 3

(a) The spectral line, indicated with the arrow on Figure 3, is in the visible region of the spectrum. What is the energy, in eV, of a photon of this wavelength? Show working. (2 marks)

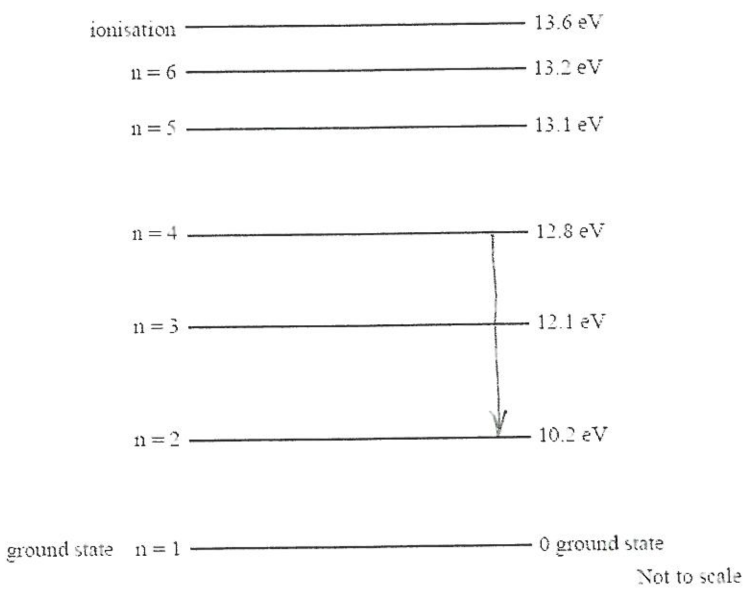
$\lambda = 410$ nm

$E = \frac{ch}{\lambda} = \frac{3.00 \times 10^{8} \times 6.63 \times 10^{-34}}{4.10 \times 10^{2} \times 10^{-9}}$ J $= 4.85 \times 10^{-19}$

$= \frac{4.85 \times 10^{-19}}{1.60 \times 10^{-19}} = \underline{3.03}$ eV

Use the following information to answer Questions (b) and (c).

Figure 4 shows the quantised energy levels in the hydrogen atom, relative to the ground state.



12.8 − 10.2 = $\underline{2.6 \text{ eV}}$

Figure 4

(b) A photon has an energy of 2.6 eV. Indicate, by an arrow, on the energy level diagram in Figure 4, the transition corresponding to the emission of this photon. (2 marks)

(c) What is the shortest wavelength photon that can be emitted when an atom emits from the n = 4 level? (2 marks)

$E = 12.8 eV$

$\lambda = ?$

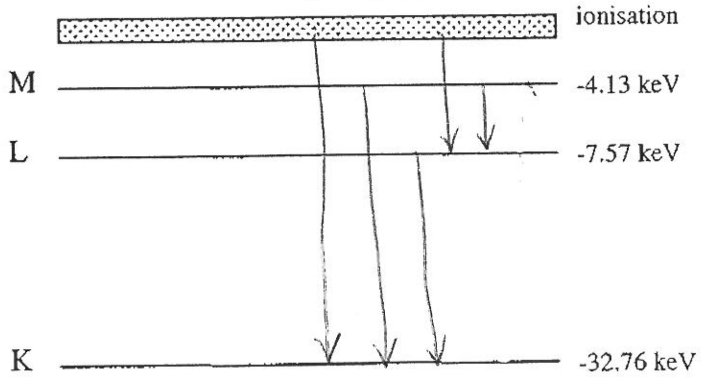
$E = \frac{ch}{\lambda} \Rightarrow \lambda = \frac{ch}{E} = \frac{3.00\times10^{8} \times 6.63\times10^{-34}}{12.8 \times 1.60\times10^{-19}}$

$= 9.71\times10^{-8}$ m

$= 97.1$ nm

Some put 0.7eV = ① if correct calcs.

5. (a) On the energy level diagram for tin **show all possible** transitions that would result in the emission of electromagnetic radiation.



if forget ∞ ↓ only ①

(2 marks)

(b) What type of electromagnetic radiation would be required to move an electron from the K shell to the M shell? (2 marks)

$E = -4.13 - -32.76 = 28.63 keV$

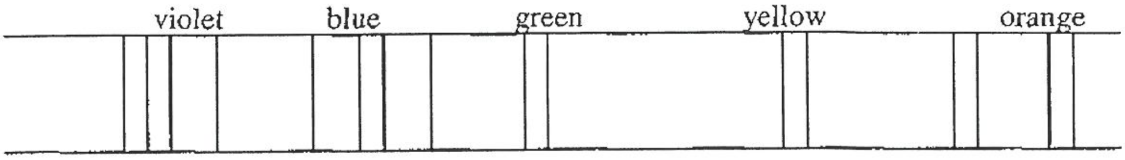
$= 4.58\times10^{-15}$ J

$E = hf$

$f = \frac{E}{h} = \frac{4.58\times10^{-15}}{6.63\times10^{-34}} = 6.96\times10^{18}$ Hz

= ~~UV~~ X Ray

6. Amanda, a year 12 physics student, was waiting at the Cottesloe railway crossing when the overhead lights were being switched on. Initially they appeared a light violet colour and then they went yellow and the light intensified. At school next day, Amanda asked her physics teacher for an explanation of her observations. The physics teacher showed her a sodium vapour lamp, a lamp similar to the station lights, and told her to view it through a spectroscope. Amanda saw a pattern of coloured lines on a dark background similar to the one shown below.



(a) What type of spectrum did Amanda observe? (1 mark)

line

(b) Briefly explain the events occurring in the lamp when it is first switched on. (2 marks)

- sodium is vaporised
- electrons hit with electrons
- electrons in lower shells excited or ionised
- electrons falling emit frequencies of radiation.

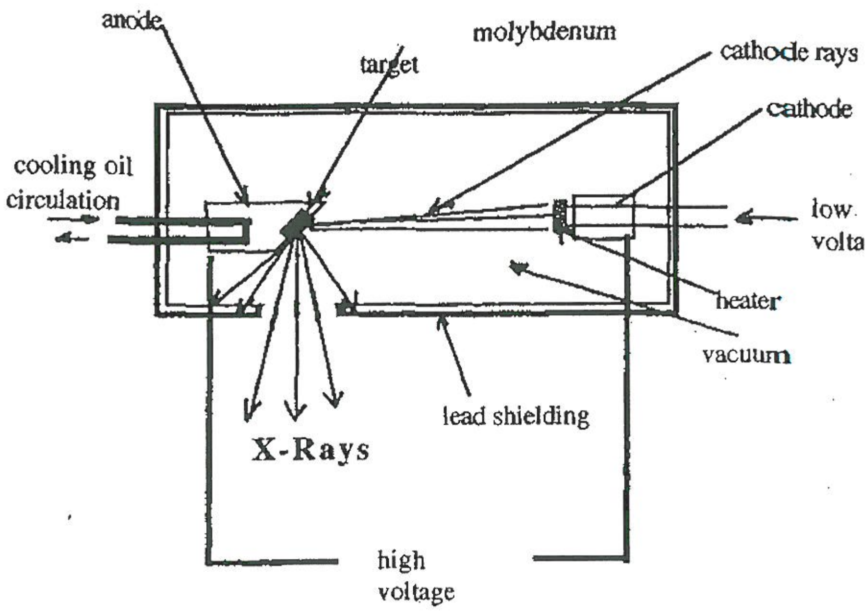
(c) What would Amanda see through the spectroscope if she shone a bright white light through the vapour of the sodium lamp? (2 marks)

line absorption spectrum – spectrum with the above lines missing.
(1) (1)

(d) Amanda used the spectroscope to observe the Fraunhofer lines in sunlight. What is the cause of these lines? (2 marks)

Gases in the sun's corona absorbing (1) frequencies of light and re emitting them at lower freqs (longer λ).
(1)

7. The figure below shows X-Rays being produced from an X-Ray tube with a molybdenum target that has an accelerating voltage of 37.3 kiloVolts.



(a) Explain what occurs that results in the production of X-rays. (2 marks)

electrons are accelerated and given energies of 37.3keV. (1)
these crash into Mo atoms and remove K shell or L shell electrons. (1)
electrons replace these and Xrays are formed. ↑ need Bremsstrahlung

(b) Calculate the maximum energy of the bombarding electrons (cathode rays) in both electron-volts and joules. (3 marks)

$E = Vq = 37.3 \times 10^{3} \times 1.60 \times 10^{-19} = 5.97 \times 10^{-15}$ J (2)

$= 37.3$ keV $= 37.3 \times 10^{3}$ eV (1)

(c) Calculate the maximum frequency of the emitted X-Rays, assuming 100% transfer of energy from the cathode rays. (2 marks)

$f = \frac{E}{h} = \frac{5.97 \times 10^{-15}}{6.63 \times 10^{-34}} = 9.00 \times 10^{18}$ Hz (2)

8. Katie and Jane are discussing wave-particle duality. Jane wonders whether wave-particle duality might explain why she missed hitting the softball in a recent match – maybe the wave nature of the softball allowed it to diffract around the bat!

Katie said that this was not a reasonable explanation and that we cannot see the wave nature of a softball.

A softball has a mass of 0.20 kg and the pitcher throws it at about 30 m s^{-1}.

a) Explain to Jane, using an appropriate calculation, why she would be unable to see the wave nature of a moving softball. ($\lambda = h / p$)

(2 marks)

$p = mv$

$= 6 \text{ kgms}^{-1}$

$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{6}$

$= 1.1\times10^{-34}$ m (1)

λ is very small, impossible to measure/see (1)

b) What would be the de Broglie wavelength of an **electron** travelling with a speed of 2.00 x 10^6 m s^{-1}.

(2 marks)

$p = mv$

$= 9.11\times10^{-31} \times 2.00\times10^{6}$

$= 1.822\times10^{-24} \text{ kgms}^{-1}$

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

$= \frac{6.63\times10^{-34}}{1.822\times10^{-24}}$

$= 3.64\times10^{-10}$ m (2)

SECTION C Comprehension **(8 marks)**

Read the information on the attached pages and answer ALL questions in the spaces provided.

THERMAL IMAGING ('*Australian Science Magazine*', Issue 3, 1986)

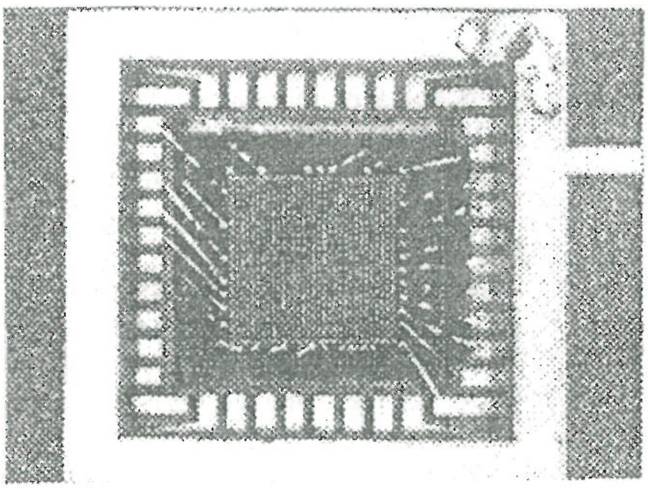
Scientists at the University of NSW have developed a microelectronic sensor chip that can create television images in total darkness by imaging objects in their own heat radiation.

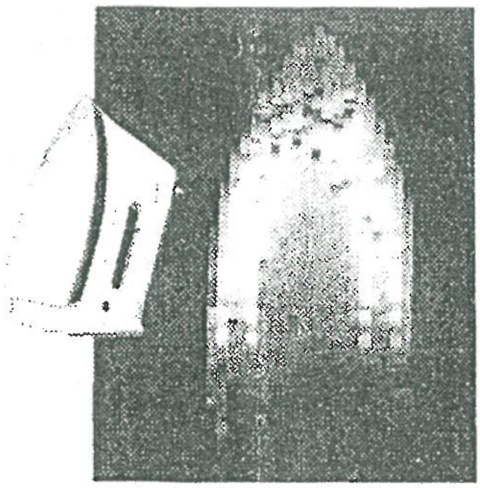
The ultimate aim of the project is to produce an inexpensive, portable, infrared TV camera. *'Such a device has enormous implications for industry, mining astronomy and medicine. However, it is in astronomy, remote sensing, and defence that the most immediate and revolutionary applications are to be found'*, according to one of the team research leaders, Dr John Storey, of the University's School of Physics.

Known as an Infrared Schottky Charge Coupled Device, the sensor chip contains more than two thousand separate pixels, or picture elements. Each pixel incorporates an ultra-thin layer of palladium, which converts the infrared radiation into an electronic charge.

The sensor chips are fabricated in the extensive facilities of the Join Microelectronics Research Centre on the UNSW campus. After testing and packaging, the devices are taken to the School of Physics where they are cooled to -200°C to prevent the weak infrared signal being swamped by thermal noise in the detector itself. An image of the particular object of interest is then formed, using a special calcium fluoride and sapphire optical system that can focus the infrared rays. A small computer then processes the image before being presented on the TV screen.

Not only can images be taken in total darkness, but by examination of the 'thermal signature' or temperature profile of a scene, information is revealed which is completely hidden at normal visible wavelengths. In medicine, for example, thermal images of a human body can reveal abnormalities in the heat distribution and blood circulation, thus pointing the way towards diagnosis of an underlying malady. In industry, too, the ability to assess instantly the heat loss of an entire machine or facility is invaluable.





(a) "Thermal noise" is an undesirable feature of the system? What causes it and what effect does it have on the results? sensor device [2 marks]

It is IR radiation emitted from ~~hot objects~~ (IR) (1) - gives false signal (1)

(b) How can an image of something, such as the iron, be taken in **total** darkness; that is, without any light at all? [2 marks]

i.e. Iron will produce IR → Use infra red. — (1)

and then convert this image to light (1)

to a signal etc

(c) A special "calcium fluoride and sapphire optical system" is needed to focus the infra-red rays as a normal glass lens does not work. Why? [2 marks]

Infra red requires special material to act as a lens.

Glass acts as a lens for light. (1)

CaF_2 & sapphire refract IR (1)

(e) Assuming that palladium is sensitive to all infra-red radiation, what is the lowest energy photon that it can detect? Refer to the electromagnetic spectrum chart. [2 marks]

$\lambda = ?$ 10^{3} $f = 1 \times 10^{11}$ Hz

$E = hf$ or $E = \frac{ch}{\lambda}$

$= \underline{6 \times 10^{-23}}$ J = ____ J

eV eV

END OF TEST