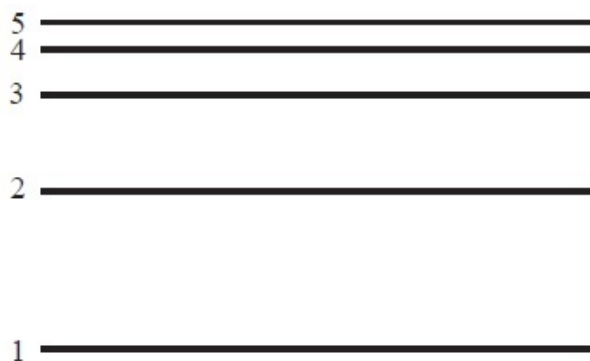


Questions

Q1. The diagram shows five energy levels in an atom.



Electromagnetic radiation is incident on the atom.

Which transition would be caused by the absorption of the lowest frequency of radiation?

☐ **A** 1 to 5

☐ **B** 1 to 2

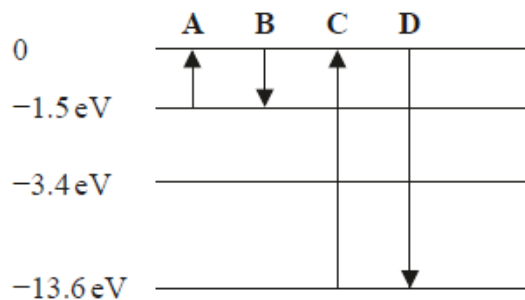
☐ **C** 4 to 5

☐ **D** 5 to 4

(Total for Question = 1 mark)

Q2.

Some of the energy levels of an atom of a gas are shown.



During which transition, A, B, C or D, is electromagnetic radiation with the shortest wavelength emitted?

☐ **A**

☐

B

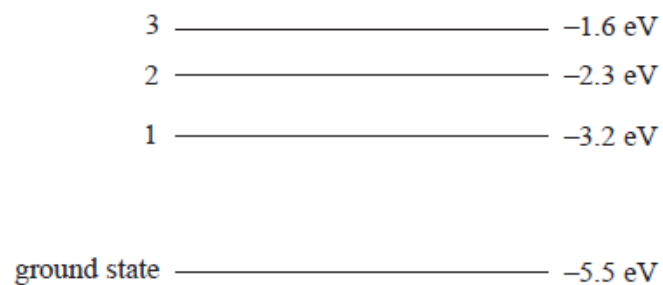
☐ **C**

☐ **D**

(Total for question = 1 mark)

Q3.

The diagram shows the lowest energy levels for a certain atom.



A photon with energy 3.2 eV is absorbed.

An electron could move from

(1)

☐ **A** ground state to level 1.

☐ **B** ground state to level 2.

☐ **C** level 1 to ground state.

☐ **D** level 2 to ground state.

(Total for question = 1 mark)

Q4.

Radiation of frequency f and wavelength λ is emitted when an electron falls from energy level E_2 to energy level E_1 .

$E_2 - E_1$ is equal to

- ☐ **A** $\frac{hc}{f}$
- ☐ **B** $\frac{hc}{\lambda}$
- ☐ **C** $\frac{hf}{c}$
- ☐ **D** $\frac{h\lambda}{c}$

(Total for question = 1 mark)

Q5.

When the light from a star is dispersed to form a spectrum, dark lines are seen at a number of frequencies. This is known as an absorption spectrum and is caused by the presence of certain elements in the star.

Explain how the absorption spectrum is created.

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(Total for question = 3 marks)

Q6.

Read the passage and answer the question that follows.

Atoms can be promoted into an excited state when they absorb energy. This results in the release of radiation at a random time. When several atoms are close together a quantum effect can occur. When one atom emits radiation this affects all the other nearby excited atoms. The excess energy of many of the atoms is released simultaneously and an intense flash of light is produced. This effect is called superradiance and can be used to produce lasers that emit a narrower range of frequencies than conventional lasers.

Superradiance occurs when the distance between atoms is less than the wavelength of the emitted radiation.

An atom is in the ground state. The atom absorbs 6.2 eV of energy. The distance between neighbouring atoms is 140 nm.

Deduce whether superradiance can occur.

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(Total for question = 3 marks)

Q7.

In 1905 Einstein published his equation for the photoelectric effect.

In 1916 Millikan demonstrated that the maximum kinetic energy of photoelectrons is consistent with Einstein's equation.

Millikan's experiments involved using different frequencies of light. These were obtained using a mercury vapour lamp which produced an emission spectrum with a specific number of known frequencies.

The diagram shows some energy levels for a mercury atom.

- 0 eV
- -1.56 eV
- -1.57 eV
- -2.48 eV
- -3.71 eV
- -4.95 eV
- -5.52 eV
- -5.74 eV

Not to
scale

— -10.38 eV

Determine which transition from the -3.71 eV energy level would produce light of wavelength 6.1×10^{-7} m.

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Transition from -3.71 eV to

(Total for question = 4 marks)

Q8.

In 1925 Franck and Hertz were awarded the Nobel Prize in Physics "for their discovery of the laws governing the impact of an electron upon an atom".

In one of their experiments, a beam of high-speed electrons is fired through mercury vapour.

An electron in the beam collides with a mercury atom, which becomes excited. The atom returns to its initial state by emitting electromagnetic radiation of a single frequency.

An electron travelling with a speed of $2.5 \times 10^6 \text{ m s}^{-1}$ collides with a stationary mercury atom and continues at a speed of $2.1 \times 10^6 \text{ m s}^{-1}$.

The table gives a range of wavelengths for ultraviolet, visible and infrared radiation.

Type of radiation	Typical range of wavelengths / m
ultraviolet	2.0×10^{-7} to 4.0×10^{-7}
visible	4.0×10^{-7} to 7.8×10^{-7}
infrared	7.8×10^{-7} to 1.0×10^{-3}

Deduce the type of radiation that is emitted by the stationary mercury atom.

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Type of radiation

(Total for question = 4 marks)

Q9.

Barnard's star is a red dwarf star in the vicinity of the Sun. The wavelength of a line in the spectrum of light emitted from Barnard's star is measured to be 656.0 nm. The same light produced by a source in a laboratory has a wavelength of 656.2 nm.

Visible light from the star originates from the photosphere. In the photosphere of Barnard's star, hydrogen and helium atoms are at a temperature of 3100 K.

(i) Calculate the mean kinetic energy of an atom in the photosphere at a temperature of 3100 K.

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Mean kinetic energy =

(ii) Describe how these atoms emit visible light.

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(Total for question = 4 marks)

Q10.

Our understanding of the atom has developed over time, from early models in which atoms were considered to be hard incompressible spheres, through to the nuclear model of the atom and the ladder model in which electrons exist in a discrete number of allowed energy states.

In the energy ladder model of the atom, electrons exist in a discrete number of allowed energy states. The collision of electrons with gold atoms may lead to the production of high frequency electromagnetic radiation.

Explain how high frequency electromagnetic radiation may be produced when electrons collide with atoms in a metal.

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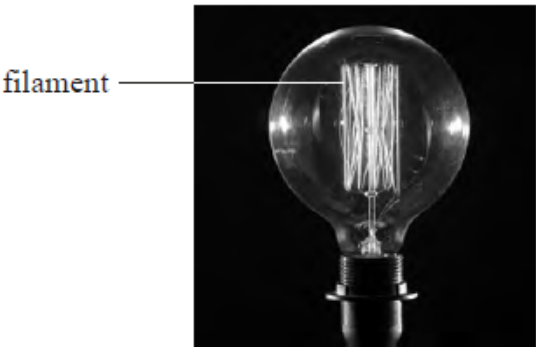
(Total for question = 4 marks)

Q11.

Filament and fluorescent are two types of light bulb.

Filament light bulbs contain a tightly coiled wire filament, surrounded by an inert gas and encased in a thin glass bulb. When the potential difference (p.d.) across the bulb is sufficient, the filament heats up, emitting visible light.

Fluorescent light bulbs use a long tube of glass containing a small amount of mercury. When a sufficient p.d. is applied across the ends of the tube, electrons moving through the tube cause the mercury to become a vapour and emit photons in the ultraviolet part of the electromagnetic spectrum. The collisions of these photons with the phosphor coating of the tube result in the emission of photons of visible light.



Filament bulb



Fluorescent bulb

(i) Explain how the wire in the filament lamp gets hot when a p.d. is applied.

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(ii) Explain how the fluorescent bulb emits photons when sufficient p.d is applied.

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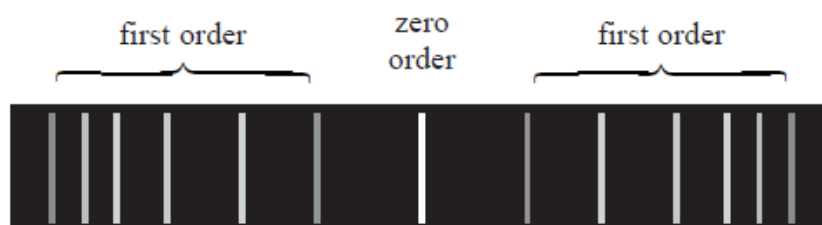
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(Total for question = 4 marks)

Q12.

In a spectrometer, light from a tube of hot gas is passed through a diffraction grating.

The diagram shows the zero order and the first order maxima for the line spectrum produced.



Explain why lines of different wavelengths are produced by the gas.

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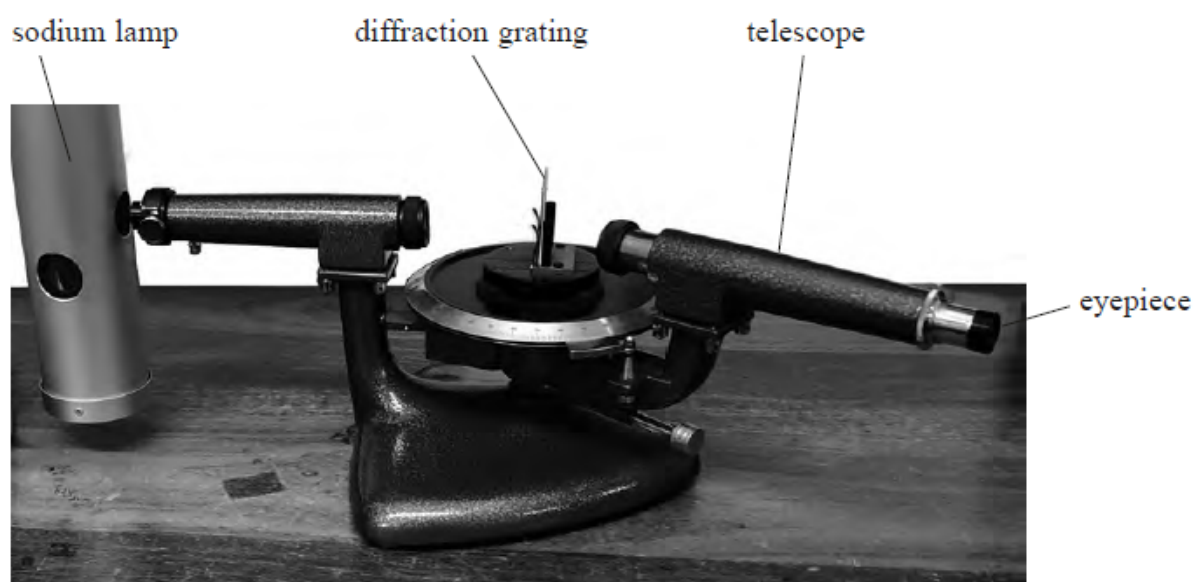
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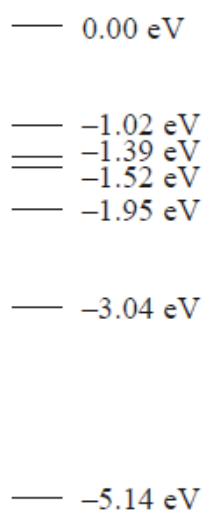
Q13.

The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

The diagram shows some of the energy levels in a sodium atom.



Add an arrow to the diagram to show the transition involved in the emission of yellow light of

wavelength 589 nm.

Show your working below.

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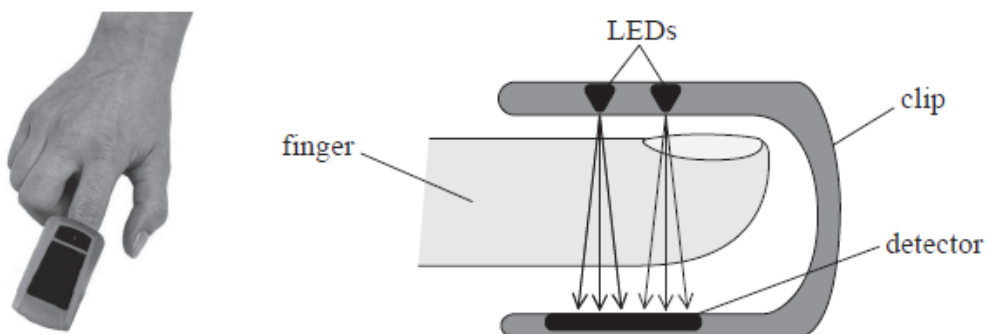
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(Total for question = 4 marks)

Q14.

An oximeter is a device used in hospitals to monitor the oxygen level in a patient's blood.

In an oximeter, two light-emitting diodes (LEDs) are mounted opposite light sensors in a clip and attached to the patient's finger. One of the LEDs produces red light and the other produces infrared.



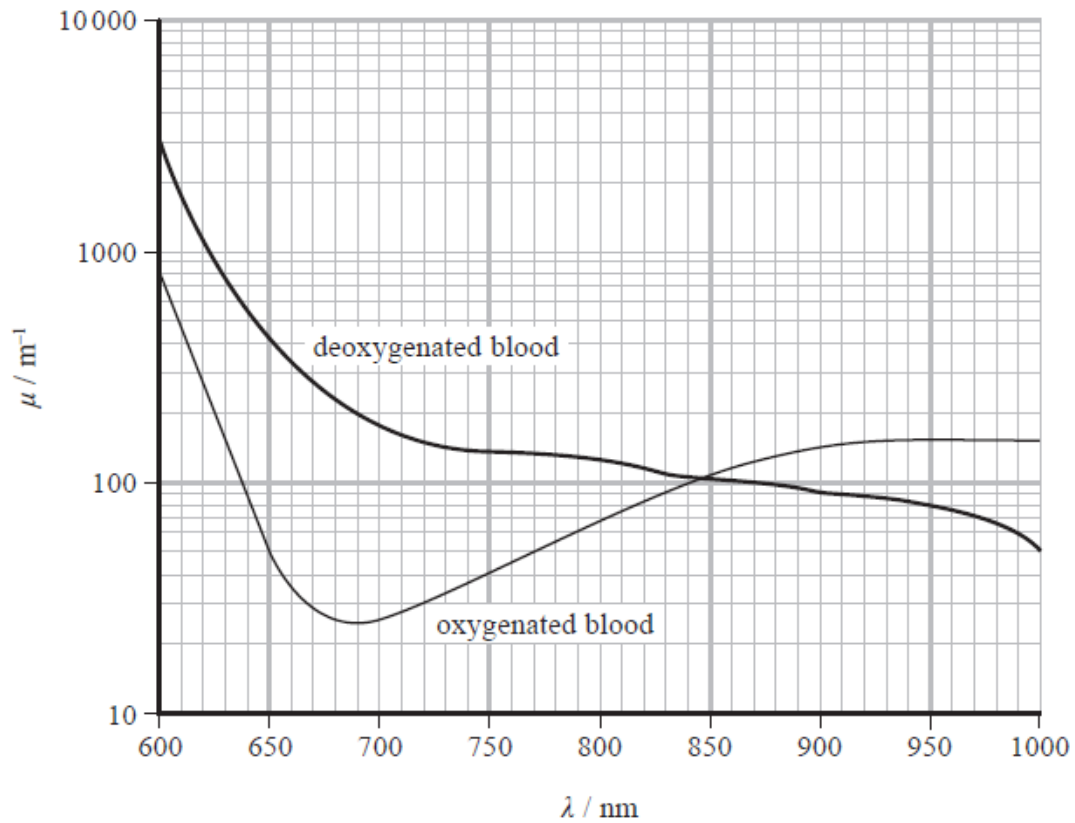
The intensity I of electromagnetic radiation received by the detector, after passing through a thickness x of blood, is given by

$$I = I_0 e^{-\mu x}$$

where I_0 is the intensity that would have been received if the blood were not present and μ is the attenuation coefficient of blood.

The red LED emits visible light of wavelength 650 nm and the infrared LED emits infrared of wavelength 950 nm.

The graph shows how μ varies with wavelength λ for oxygenated blood and deoxygenated blood.



I_0 for the infrared LED is 1.8 W m^{-2} .

Calculate I for the infrared after passing through 1.4 mm of oxygenated blood.

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$I =$

(Total for question = 3 marks)

Q15.

In 1925 Franck and Hertz were awarded the Nobel Prize in Physics "for their discovery of the laws governing the impact of an electron upon an atom".
In one of their experiments, a beam of high-speed electrons is fired through mercury vapour.

An electron in the beam collides with a mercury atom, which becomes excited. The atom returns to its initial state by emitting electromagnetic radiation of a single frequency.

Explain why excited atoms only emit certain frequencies of radiation.

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(Total for question = 5 marks)

Q16.

When a large potential difference is applied to a discharge tube, the gas in the discharge tube emits coloured light. When this light is passed through a diffraction grating, an emission spectrum which is made up of a series of lines of different wavelengths may be seen.

The photographs show the spectra produced from a tube containing hydrogen and a tube containing helium.

Hydrogen:



Helium:



* Explain why different elements produce spectra containing different specific wavelengths of light.

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In 2016 the Breakthrough Starshot initiative was announced. This project intends to send a fleet of small probes to Proxima Centauri, the nearest star to the Sun. This journey would take about twenty years.

The composition of a star can be determined by analysis of its absorption spectrum.

Explain why there are certain specific frequencies missing from the spectrum.

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(Total for question = 5 marks)

Q18.

A solar panel uses electromagnetic radiation from the Sun to generate electricity. In one installation a sensor in the solar panel measures the intensity of radiation arriving from different directions. A motor rotates the solar panel so that it always faces the brightest part of the sky.

When light is incident on an LDR, electrons move to a higher energy level where they become conduction electrons. This causes the resistance of the LDR to decrease.

A student suggests that this is an example of the photoelectric effect. The student is not correct.

Compare and contrast the photoelectric effect with the effect of radiation incident on an LDR.

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(Total for question = 6 marks)

Q19.

Read the passage and answer the question that follows.

Atoms can be promoted into an excited state when they absorb energy. This results in the release of radiation at a random time. When several atoms are close together a quantum effect can occur. When one atom emits radiation this affects all the other nearby excited atoms. The excess energy of many of the atoms is released simultaneously and an intense flash of light is produced. This effect is called superradiance and can be used to produce lasers that emit a narrower range of frequencies than conventional lasers.

When superradiance occurs the atoms all absorb the same amount of energy.

Explain how this results in all the atoms emitting radiation of a particular frequency.

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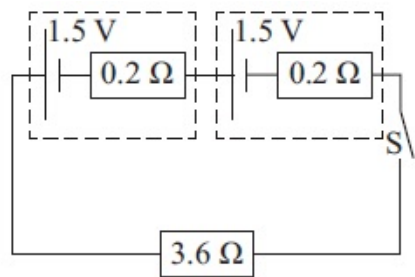
(Total for question = 5 marks)

Q20.

Electrically heated gloves are used by skiers and climbers to provide extra warmth for their hands.



Each glove has a heating element of resistance $3.6\ \Omega$. Two cells each of e.m.f. $1.5\ \text{V}$ and internal resistance $0.2\ \Omega$ are used to operate each heating element.



- (a) When the switch is closed:
- (i) Calculate the total resistance in the circuit

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Total resistance =

(ii) Calculate the current in the heating element

(2)

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Current =

(iii) Calculate the power output from the heating element.

(2)

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Power output =

(b) When in use the internal resistance of each cell gradually increases.

State and explain the effect this will have on the power output of the heating element.

(3)

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(Total for question = 8 marks)

Q21. When the photoelectric effect was first observed in the nineteenth century, scientists could not explain it using the wave theory of light.

In 1905 Albert Einstein published a paper, for which he won a Nobel Prize, explaining the photoelectric effect by using a photon model of light, rather than a wave model.

(a) Explain what is meant by a photon.

(2)

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*(b) Explain why the following observations may be understood by using a photon model of light, rather than a wave model.

- Light above a certain frequency causes the emission of electrons from the surface of a metal. This emission occurs instantaneously.
- Light below a certain frequency will not result in the emission of electrons however long it illuminates the surface.

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(c) Zinc has a work function of 4.3 eV.

(i) Calculate the threshold frequency for zinc.

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Threshold frequency =

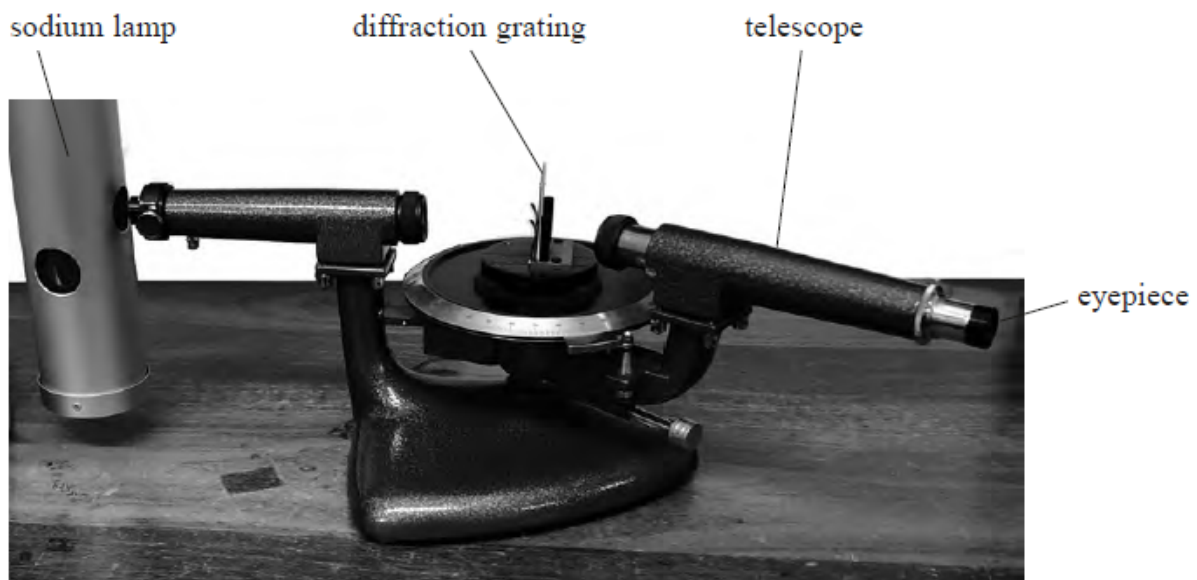
(ii) State the part of the electromagnetic spectrum to which radiation of this frequency belongs.

(1)

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(Total for Question = 11 marks)

Q22.

The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

The spectrometer and diffraction grating are used to analyse the light from a sodium lamp. In the sodium lamp, sodium is heated until it becomes a vapour and an electric current is passed through it. The vapour then emits light.

After the light passes through the diffraction grating a line spectrum is observed.

(i) Explain why only certain wavelengths are observed.

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(ii) Diffraction gratings with the following spacings are available:

$d/10^{-6}\text{ m}$	1.0	1.7	2.0	3.3
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Explain which would be the best spacing to use to measure the diffraction angle for the third order maximum for yellow light of wavelength 589 nm.

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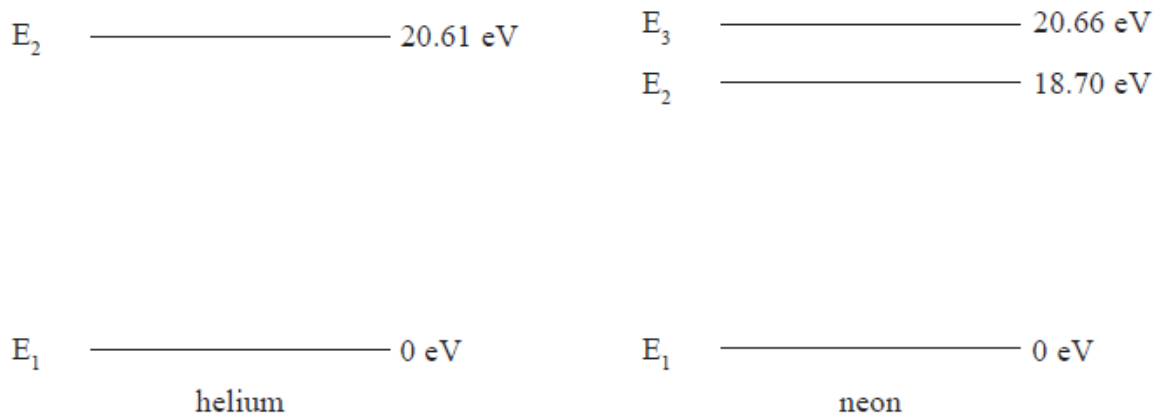
(Total for question = 9 marks)

Q23.

A helium-neon gas laser is often used in the laboratory as a source of high intensity, coherent, monochromatic light.

The diagram shows some of the energy levels above the ground level E_3 for helium atoms and

for neon atoms. The highest shown levels for helium atoms and neon atoms are almost identical.



Helium atoms in the gas are excited to level E_2 by the current passing through the laser. They collide at high speed with neon atoms. Because the energies are so similar, the energy is transferred from the helium atoms to the neon atoms. The neon atoms become excited in turn to level E_3 . As the neon atoms subsequently drop to level E_2 they emit photons.

(a) Explain what is meant by a photon.

(2)

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(b) Calculate the frequency of the photons produced as the neon atoms drop from level E_3 to level E_2 .

(3)

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Frequency =

(c) An electron in level E_3 of neon has 0.05 eV more energy than an electron in level E_2 of helium.

Suggest the source of the energy to make up this difference.

(1)

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(d) The photograph shows a device for making a vertical slit with variable width.



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When the slit is fully open a laser beam is shone through it and a single point of light is seen on a screen.

As the slit is reduced in width the point of light becomes a horizontal line that gets longer as the slit gets narrower.

Explain this observation

(3)

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(Total for question = 9 marks)