Name: _____

Quantum Physics

Questions

Date:

Time:

Total marks available:

Total marks achieved: _____

Questions

Q1.

Which of the following can be explained only by the wave nature of electromagnetic radiation?

☒ **A** atomic line spectra

☒ **B** electron diffraction

☒ **C** photoelectric effect

☒ **D** X-ray diffraction

(Total for question = 1 mark)

Q2.

An electron gun uses a potential difference V to accelerate electrons of mass m and charge e from rest to a speed v.
The potential difference V can be expressed as

☒ **A** $\frac{mv^2}{2e}$

☒ **B** $\frac{2ev^2}{m}$

☒ **C** $\sqrt{\frac{2ev}{m}}$

☒ **D** $\sqrt{\frac{mv}{2e}}$

(Total for question = 1 mark)

Q3.

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)

Q4.

An electron is accelerated from rest through a potential difference of 5.0 kV.

The kinetic energy gained by the electron is

☒ **A** 8.0×10^{-16} J

☒ **B** 8.0×10^{-19} J

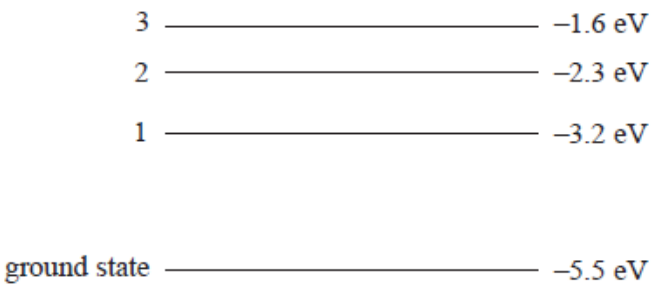
☒ **C** 3.2×10^{-20} J

☒ **D** 3.2×10^{-23} J

(Total for question = 1 marks)

Q5.

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

☒ **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)

Q6. The de Broglie wavelength for neutrons used to study crystal structure is 1.2 nm. mass of a neutron = 1.67×10^{-27} kg

The speed of these neutrons would be

☒ **A** 3.0×10^{6} m s^{-1}

☒ **B** 3.3×10^{2} m s^{-1}

☒ **C** 3.0×10^{-3} m s^{-1}

☒ **D** 3.3×10^{-7} m s^{-1}

(Total for Question = 1 mark)

Q7.

Which variables are linked in the de Broglie equation?

☒ **A** frequency and wavelength of a photon

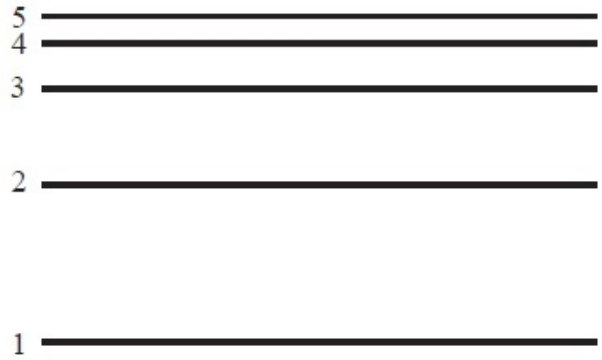
☒ **B** wavelength and momentum of a moving electron

☒ **C** energy and frequency of a photon

☒ **D** work function and threshold frequency of a metal

(Total for question = 1 mark)

Q8. 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)

Q9. The de Broglie wavelength associated with electrons moving at 2.5×10^{6} m s^{-1} is

☒ **A** 2.9×10^{-4} m

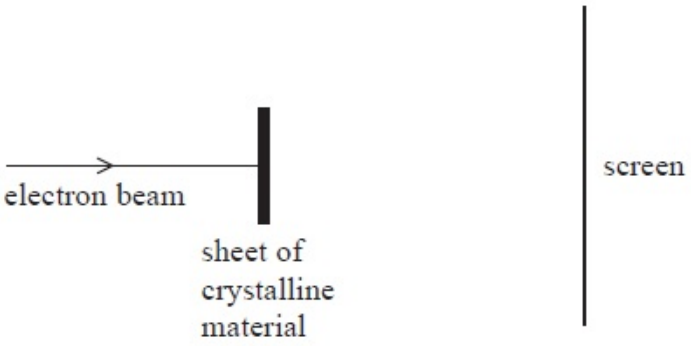
☒ **B** 2.4×10^{-8} m

☒ **C** 2.9×10^{-10} m

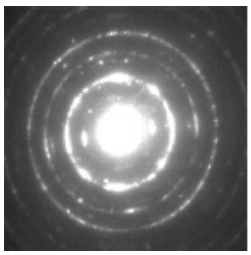
☒ **D** 2.4×10^{-39} m

(Total for Question = 1 mark)

Q10. A beam of electrons is directed towards a section of crystalline material.



The following pattern is produced by the electrons on the screen.



This pattern demonstrates

☒ **A** diffraction.

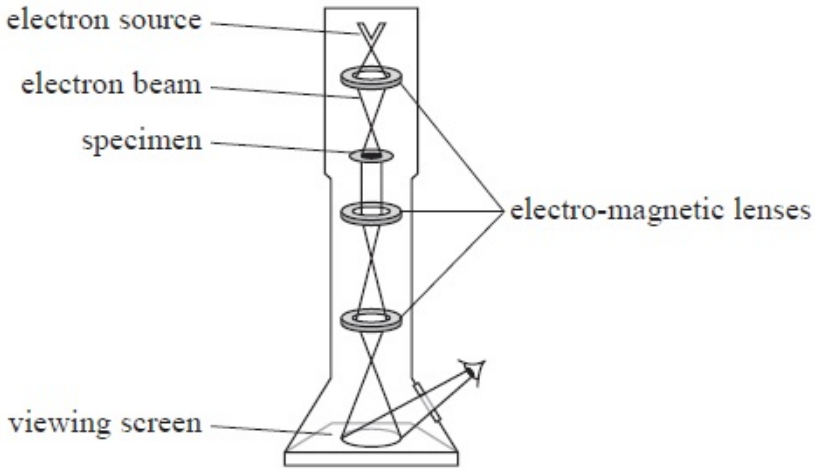
☒ **B** polarisation.

☒ **C** reflection.

☒ **D** refraction.

(Total for Question = 1 mark)

Q11. A transmission electron microscope passes a beam of electrons through a tiny specimen to form an image on a viewing screen.



Due to the wave nature of electrons, diffraction occurs which can blur the image. To reduce this effect when viewing a smaller object the beam must contain

- ☒ **A** more electrons per second.
- ☒ **B** fewer electrons per second.
- ☒ **C** faster moving electrons.
- ☒ **D** slower moving electrons.

(Total for Question = 1 mark)

Q12.

A beam of electrons spreads out into several distinct beams after passing through a crystalline material.

This demonstrates that

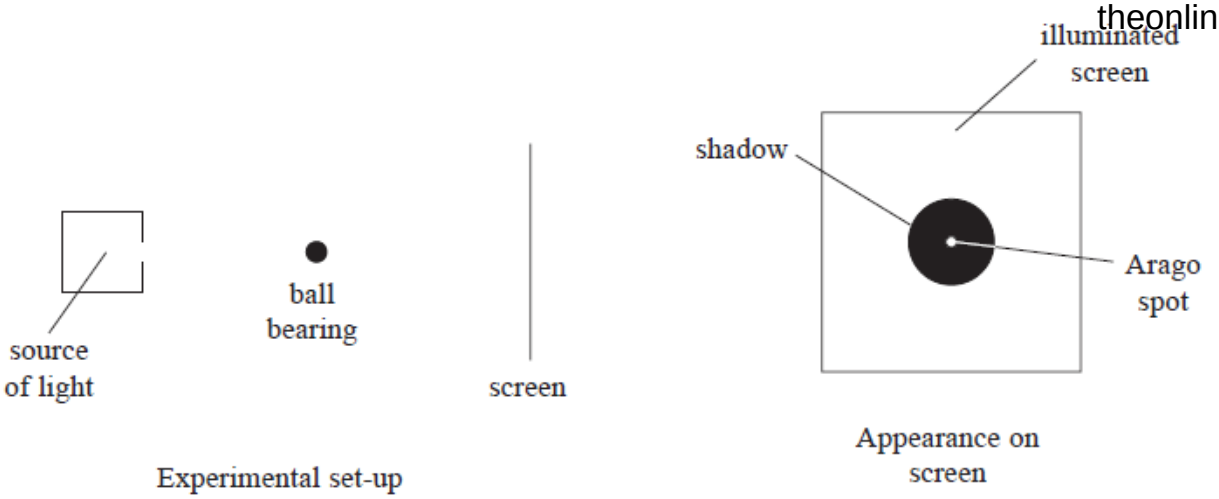
- ☒ **A** electrons behave as particles.
- ☒ **B** electrons behave as waves.
- ☒ **C** electrons exist in energy levels.
- ☒ **D** electrons have negative charge.

(Total for question = 1 mark)

Q13.

The diagram shows a coherent beam of light incident on a metal ball bearing.

A dark shadow is seen on a screen behind the ball bearing. There is a small spot of light in the centre of the shadow. This spot of light is known as the Arago spot.



François Arago first demonstrated this experiment in 1818 for a group of eminent scientists, to show the behaviour of light.

State the model for the behaviour of light that this experiment demonstrated and explain why the scientific community accepted this model.

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(Total for question = 3 marks)

Q14.

In the 19th century experiments with magnetic and electric field deflections were used to determine the charge to mass ratio of electrons.
Later experiments showed the diffraction of electrons as they passed through thin metal foils.
Deduce what these experiments tell us about electrons.

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(Total for question = 3 marks)

Q15.

In the 1920s Louis de Broglie proposed that an electron could behave as a wave.

Calculate the wavelength of an electron that is travelling at a speed of $2.2 \times 10^{7} ms^{-1}$.

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Wavelength = ...

(Total for question = 3 marks)

Q16.

(a) State what is meant by the de Broglie wavelength.

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(b) An electron is accelerated from rest, in a vacuum, through a potential difference of 500 V.

(i) Show that the final momentum of the electron is about 1×10^{-23} N s.

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(ii) Calculate the de Broglie wavelength for this electron.

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de Broglie wavelength = ...

(Total for question = 7 marks)

Q17.

The electron in a hydrogen atom can be described by a stationary wave which is confined within the atom. This means that the de Broglie wavelength associated with it must be similar to the size of the atom which is of the order of 10^{-10} m.

(a) (i) Calculate the speed of an electron whose de Broglie wavelength is 1.00×10^{-10} m.

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Speed = ...

(ii) Calculate the kinetic energy of this electron in electronvolts.

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Kinetic energy = ... eV

(b) When β radiation was first discovered, it was suggested that there were electrons in the atomic nucleus, but it was soon realised that this was impossible because the energy of such an electron would be too great.

Suggest why an electron confined within a nucleus would have a much greater energy than the energy calculated in (a)(ii).

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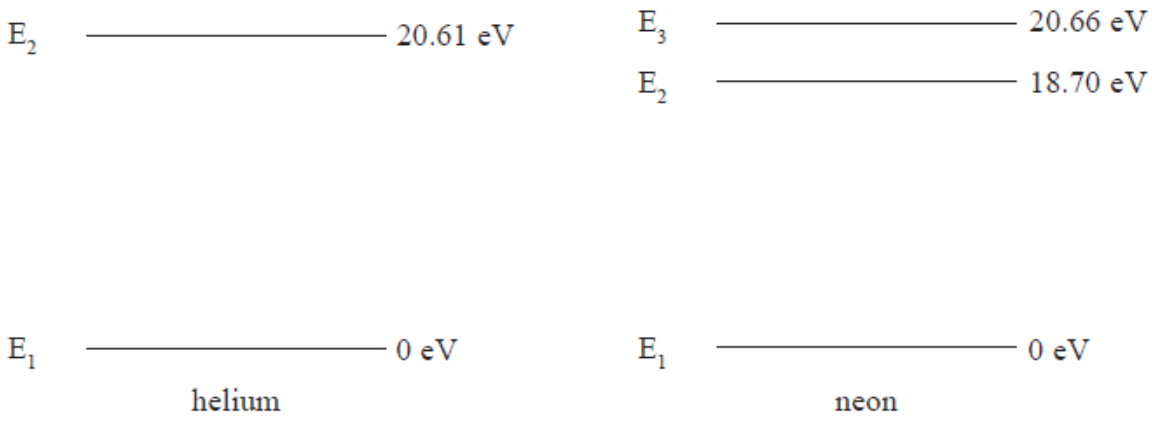
(Total for question = 8 marks)

Q18.

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.

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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.

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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.

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

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

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(Total for question = 9 marks)

Q19. Analysing the light from a star allows elements present in its outer atmosphere to be identified because each element produces a distinctive set of spectral lines.

*(a) Describe how a spectral line is produced by a hot gas, explaining why a particular element can only give rise to particular frequencies.

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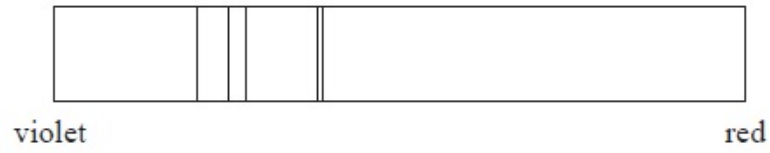
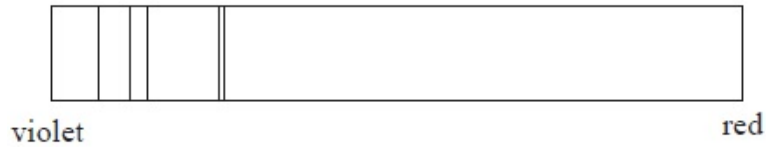
(b) The diagram shows the spectral lines produced by a particular element when observed in a laboratory.



The diagram below shows the spectral lines obtained by analysing the light from a star. This shows the same pattern of lines, but in a different part of the spectrum.



Name this effect and explain what may be deduced about the motion of this star relative to the Earth.

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(c) Suggest what the phenomena in parts (a) and (b) imply about the nature of light.

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(Total for Question = 10 marks)

Q20.

Helium was first discovered because of dark lines observed in the continuous spectrum of light from the Sun. The lines were caused by a few specific frequencies of light in the spectrum being present at very much lower intensity than the rest.

Scientists deduced that this was due to an unknown element in the Sun's atmosphere.

(a) Explain how helium in the Sun's atmosphere caused this set of dark lines.

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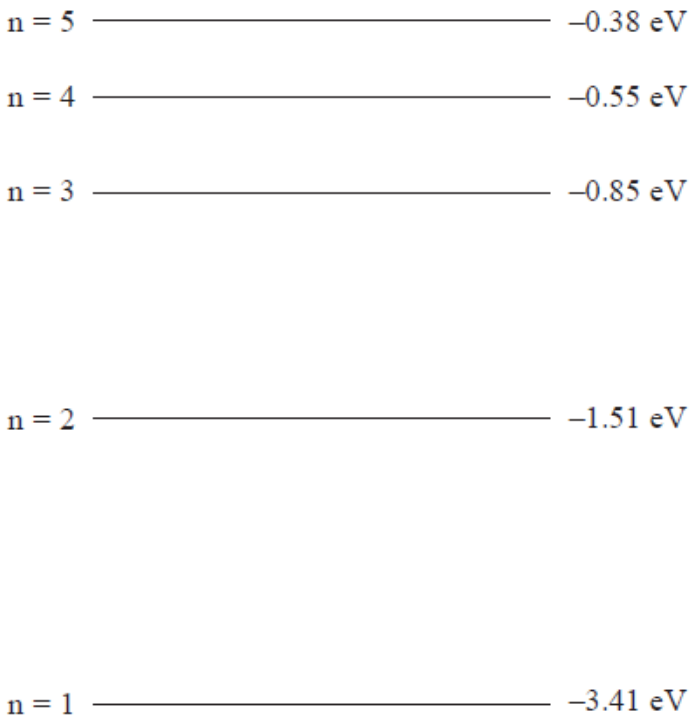
(b) The diagram shows some of the energy levels for an atom of another element.



(i) Determine which energy levels are associated with photons of frequency 4.6×10^{14} Hz.

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(ii) Suggest why the energy levels all have a negative value.

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(c) Lines such as those described in (a) can be used to determine the motion of stars relative to

the Earth.

Suggest how these lines may be used to determine the motion of stars.

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(Total for question = 14 marks)