AQA A-Level Physics

12.2 Wave-particle duality

Flashcards

What is wave particle duality?

What is wave particle duality?

The idea that particles can also behave like a wave.

Outline Newton's corpuscular theory?

Outline Newton's corpuscular theory?

That light is made up of small particles.

He proposed that white light is made up of different colours which he observed when he split light put in a prism.

Outline briefly Huygens wave theory on light?

Outline briefly Huygens wave theory on light?

- States that all of the points on a wave front are sources for secondary wavelets.
- Light was a longitudinal wave but as longitudinal waves must travel through a medium and space was deemed to be ‘empty’ Huygen also suggested that space was filled with aether, a substance we cannot see and that has no mass.

Explain reflection in terms of Newton's corpuscular theory.

Explain reflection in terms of Newton's corpuscular theory.

Newton suggests that the particles are like balls, and when they bounce of the surface the 'reflect' due to a conservation of momentum between the surface and the particles. As the speed only changes in the direction perpendicular to the surface then it must be reflected at the same angle.

Describe the difference between Newton's theory on refraction and Huygens theory.

Describe the difference between Newton's theory and Huygens theory. on refraction.

Describe the difference between Newton's theory and Huygens theory on refraction.

Newton suggested that light diffracts due to the material exerting an attractive force on the light particles causing them to increase vertical speed as it entered the material. The change is speed is what leads to the change in angle when entering/leaving the medium.

Whereas Huygen's theory suggests that the wavefronts hit the boundary at an angle. This causes the light to take infinite amount of time to slow down at the boundary.

Which theory of light was preferred? Newton's or Huygen's? Why?

Which theory of light was preferred? Newton's or Huygen's?

Newton's was preferred. This is because Newton had a better reputation at the time than Huygen and was seen to be more important.

How did Young's double slit theory support Huygen's wave theory.

How did Young's double slit theory support Huygen's wave theory.

- The double slit theory displayed a pattern of fringes due to interference between different wavefronts.
- Young's double slit theory occurs due to diffraction and only waves can diffract.
- Therefore suggesting that light is a wave like Huygen suggested.

How are fringes formed in Young's double slit?

How are fringes formed in Young's double slit?

- Monochromatic light passes through two slits.
- The two slits act as coherent light sources.
- This causes bright fringes where the light is in phase and constructive interference occurs.
- Dark fringes where destructive interference occurs as the light is out of phase.

Why can Newton's theory NOT explain Young's interference pattern?

Why can Newton's theory NOT explain Young's interference pattern?

Because if light acted like particles like Newton suggested then there would be two light fringes where the slits are, not a repeating pattern of light and dark fringes.

Why was Newton's theory eventually rejected?

Why was Newton's theory eventually rejected?

Newton's theory of light was rejected many years after Young's discovery of interference, in which the speed of light in water was measured and found to be less than the speed in air.

What were Maxwell's predictions about electromagnetic waves?

What were Maxwell's predictions about electromagnetic waves?

He predicted that an electromagnetic wave has an electric and magnetic that oscillate perpendicular to each other. He also derived an equation for the speed of an electromagnetic wave. He showed that light and electromagnetic waves travelled at the same speed in a vacuum therefore showing that light is a EM wave as well as ultraviolet, infrared and others.

What was Maxwell's equation to calculate the speed of light?

What was Maxwell's equation to calculate the speed of light?

$$c = 1/\sqrt{(\varepsilon_0 \mu_0)}$$

What does ε_0 represent? And what does it relate to?

What does ε_0 represent? And what does it relate to?

It represents the permittivity of free space and it related to the strength of the electric field as a result of a charged object in free space.

What is μ_0? What does μ_0 relate to in the equation?

What is μ_0? What does μ_0 relate to in the equation?

It stands for the permeability of free space, which is related to the magnetic flux density because of a current carrying wire in free space.

How are stationary waves produced when radio waves are reflected?

How are stationary waves produced when radio waves are reflected?

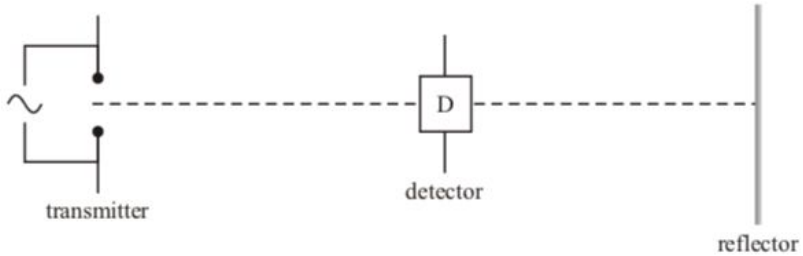
The reflection produces two coherent progressive waves travelling in opposite directions. The two waves interfere and cause constructive interference at antinodes and destructive interference at nodes.

How did Hertz discover radio waves?

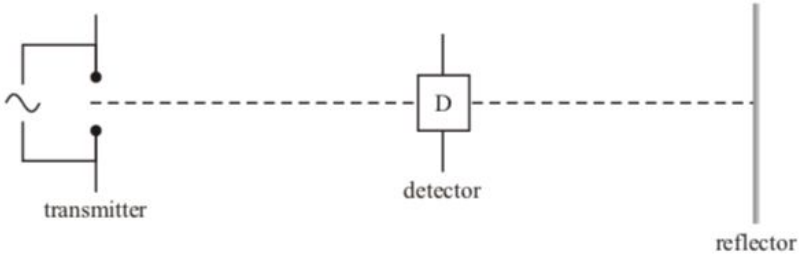
How did Hertz discover radio waves?

Hertz created electromagnetic waves by producing them when a high voltage spark jumped from one metal plate to another. The spark produced radio waves which he detected using a dipole detector. As the radio waves produced a voltage in the detector which causes a spark in the detector.

Explain why the strength of the detector signal varies repeatedly between a minimum and a maximum as the detector is moved slowly away from the transmitter along the dotted line



Explain why the strength of the detector signal varies repeatedly between a minimum and a maximum as the detector is moved slowly away from the transmitter along the dotted line.



The reflected waves and incident waves form a stationary wave so nodes are formed where the signal is a minimum.

What properties did Hertz find out about radio waves in further experiments?

What properties did Hertz find out about radio waves in further experiments?

- They can be reflected by a metal sheet.
- They can produce stationary waves.
- Radio waves cannot be stopped by insulators.
- Radio waves are polarised.

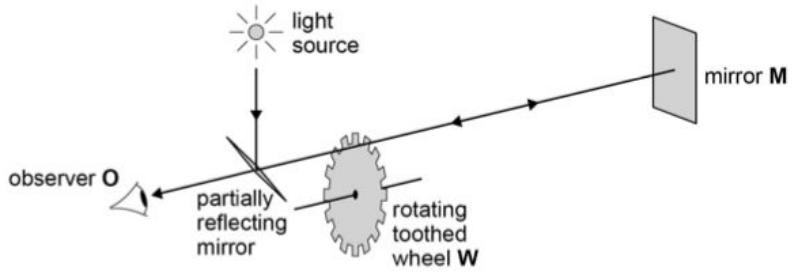
How did Hertz use his experiment to work out the speed of radio waves?

How did Hertz use his experiment to work out the speed of radio waves?

When he produced the stationary waves, Hertz measured the distance between adjacent nodes on the wave (which is 1/2λ). He then used the equation $c=f\lambda$. The value he got was similar to Maxwell's predicted value from his equation.

The figure shows the apparatus Fizeau used to determine the speed of light. He observed (i). When the speed of rotation is low the observer sees the light returning after reflection by the mirror **M**. Explain this.

Figure 2



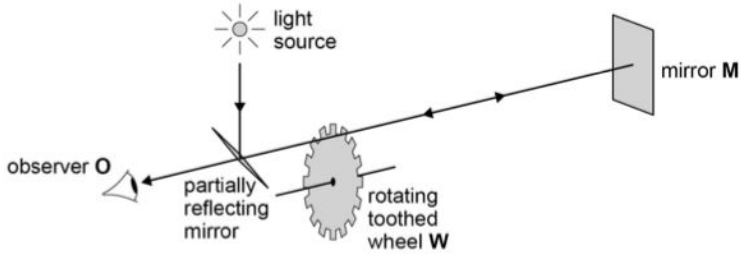
https://filestore.aqa.org.uk/sample-papers-and-mark-schemes/2017/june/AQA-74083BD-QP-JUN17.PDF

The figure shows the apparatus Fizeau used to determine the speed of light. He observed (i). When the speed of rotation is low the observer sees the light returning after reflection by the mirror **M**. Explain this.

When rotation speed is low the light returns through the original gap.

The figure shows the apparatus Fizeau used to determine the speed of light. He observed (ii). When the speed of the wheel is slowly increased the observer continues to see the light until the wheel reaches a certain speed. At this speed the observer cannot see the light. Explain this.

Figure 2



https://filestore.aqa.org.uk/sample-papers-and-mark-schemes/2017/june/AQA-74083BD-QP-JUN17.PDF

The figure shows the apparatus Fizeau used to determine the speed of light. He observed (ii). When the speed of the wheel is slowly increased the observer continues to see the light until the wheel reaches a certain speed. At this speed the observer cannot see the light. Explain this.

The light is blocked when it hits an adjacent tooth on return from the mirror.

True or false? ‘All objects that have a temperature above zero will emit infrared radiation’

True or false? ‘All objects that have a temperature above zero will emit infrared radiation’

True.

What is a black-body?

What is a black-body?

An object that emits and absorbs all parts of the EM spectrum.

What is the ultraviolet catastrophe?

What is the ultraviolet catastrophe?

It was a disagreement between the practical and theoretical predictions of the intensity of energy at different wavelengths.

The theoretical prediction suggested there was an infinite amount of energy at the very low wavelengths.

How did Planck solve the ultraviolet catastrophe?

How did Planck solve the ultraviolet catastrophe?

He suggested that EM radiation is released in photons (which are related to a frequency) and not continuous therefore it is not infinite.

What is the equation to work out the energy of a quantum of EM energy?

What is the equation to work out the energy of a quantum of EM energy?

$$E = hf$$

Where h is Planck's constant.

When was photoelectric emission first discovered?

When was photoelectric emission first discovered?

When Hertz was carrying out experiments with radio waves. He observed that the strengths of the sparks changed with different EM waves, however if the same EM wave was incident on the detector for a extended period of time then it wouldn't cause the strength the vary.

If the frequency of light incident on a metal is below the threshold frequency, can photoelectrons still be admitted?

If the frequency of light incident on a metal is below the threshold frequency, can photoelectrons still be admitted?

No it can not, because the low frequency will mean that each photon of light would not provide the electron with enough energy for the electron to leave the atom.

What is the maximum kinetic energy of photoelectrons dependant on?

What is the maximum kinetic energy of photoelectrons dependant on?

The frequency of the light used.

How do you calculate the energy of a photon?

How do you calculate the energy of a photon?

$$E = hf$$

What is the photoelectric equation?

What is the photoelectric equation?

$$hf = \phi + 1/2mv^2$$

Where ϕ = work function

How does increasing the intensity of light (with a frequency above the threshold) effect the photoelectric emission?

How does increasing the intensity of light (with a frequency above the threshold) effect the photoelectric emission?

A higher intensity means more photons therefore more photon- electron interactions. Which means more electrons are emitted.

Why does the photoelectric effect not support wave theory?

Why does the photoelectric effect not support wave theory?

Because the photoelectric effect causes an instantaneous release of electrons if the frequency is about a certain frequency which is explained by photons. However wave theory suggests the emission won't always happen instantaneously and predicts that any frequency of light will eventually cause the photoelectric effect to occur, as while the wave incident on the metal the electrons gain energy until they have enough to escape.

What is the stopping potential?

What is the stopping potential?

The potential required to stop electrons.

There at the stopping potential(V_s):

$$eV_s = KE_{max}$$

How do you measure the stopping potential?

How do you measure the stopping potential?

You use a photocell which has an anode and cathode. When certain frequencies of light are incident on the anode, releases photoelectrons. These electrons then travel from the anode to the cathode producing a current. A potential difference is put across the plates, making the anode more positive and making it harder for electrons to leave the anode. The stopping potential is the potential needed to ensure that no electrons reach the cathode, meaning no current running.

What is wave particle duality?

What is wave particle duality?

The idea that all particles can behave like waves as well as particles.

What is De Broglie equation? And how did he hypothesise it?

What is De Broglie equation? And how did he hypothesise it?

- $E=mc^2$ and $E=hf$
- Therefore $mc^2 = hf$
- $mc^2 = hc/\lambda$
- $mc = h/\lambda$
- $\lambda = h/mc$ or $p = h/\lambda$

What pattern was observed in electron diffraction and why is the pattern seen?

What pattern was observed in electron diffraction and why is the pattern seen?

A pattern of concentric rings/diffraction rings are seen. This is due to the constructive and destructive interference that occurs from when the electron beam is diffracted.

Why was the experiments on electron diffraction significant?

Why was the experiments on electron diffraction significant?

Because, only waves were known to diffract. Therefore showed that electrons (particles) could also behave like waves as de Broglie previously suggested.

How is the beam of electron used in an electron diffraction experiment created?

How is the beam of electron used in an electron diffraction experiment created?

It is created by producing electrons through thermionic emission and accelerating the electrons from rest using a potential difference. This means that once fully accelerated, all electrons will have the same kinetic energy which is equal to the work done by the potential difference: $1/2mv^2=eV$.

What is de Broglie's wavelength in terms of anode potential (V_A)

What is de Broglie's wavelength in terms of anode potential (V_A)

$$\Lambda = h/\sqrt{(2\ m\ e\ V)}$$

How does increasing the electron speed change the diffraction pattern?

How does increasing the electron speed change the diffraction pattern?

If you increase the electron speed, then you will decrease the wavelength of your wave, which will mean the diffraction rings would appear closer together.

What anode voltage is required for electrons to have a wavelengths of the same order as a atom?

What anode voltage is required for electrons to have a wavelengths of the same order as a atom?

150V

What is resolving power?

What is resolving power?

An object's ability to acknowledge two seperate objects close together are seperate objects, not just one.

How are images formed in the TEM (Transmission electron microscope)?

How are images formed in the TEM (Transmission electron microscope)?

- An electron beam produced by thermionic emission is accelerated using a anode.
- There is than a magnetic lenses which focus the electrons. Meaning any electrons that were falling at an angle near the edge are now are deflected to fall to the centre. The electrons already passing through the centre are unaffected.
- The electrons are then focused on a sample by a condenser lens and pass through our sample.
- There is then an objective lens which forms the image of the sample.
- Then the projector lens creates the final image on a fluorescent screen.

How does decreasing the anode potential affect the detail of the image.

How does decreasing the anode potential affect the detail of the image.

A lower anode potential would mean the electrons gain less kinetic energy, which would therefore mean their wavelength will increase and the resolving power would therefore decrease making it less detailed.

How does the thickness of the sample limit the detail of the image?

How does the thickness of the sample limit the detail of the image?

Because when the electrons pass through the thick sample the electrons slow down, which causes the wavelength to decrease and reducing the detail.

How can lens aberrations limit the detail of a image from a TEM?

How can lens aberrations limit the detail of a image from a TEM?

The electrons are travelling at different speeds due to being scattered. Therefore the lens can't focus and electrons from each point of a sample to a point on the screen.

Why is the pressure inside the TEM really low?

Why is the pressure inside the TEM really low?

In order to reduce the amount of collisions that could occur between the electrons and air particles. If the pressure was high then there would be more frequent collisions between the electrons and air particles, which would cause the a transfer of energy making the electrons lose energy. This would therefore decrease the detail of the image.

How does a STM (scanning tunnelling microscope) work?

How does a STM (scanning tunnelling microscope) work?

A STM creates images using quantum tunneling, a fine probe is placed close to the surface of a material to create a tunneling current between the surface and the probe. A small pd goes between the probe and the surface so electrons cross the gap from negative to positive.

What is an ether (aether)?

What is an ether (aether)?

A substance that was thought to have filled space. Scientists hypothesised that it was the matter that allowed light - as a longitudinal wave - to move through space.