Bannerman High School Physics Department

“Making Accurate Statements”

Higher Physics

Quanta and Waves

Mandatory Key Area: Particle Physics

1. Use your knowledge of physics to estimate the ratio of the smallest known structures in the universe to the largest known structures in the universe.
   You should state any assumptions and generalisations you have made.

   Smallest structures – atomic nuclei (scale of strong force 10^{-15}m)
   Largest structures – observable universe (age of universe x speed of light)

2. What is meant by the planck time?
   This is the notional smallest quantum of time – characterised by manipulating other constants of nature , the "natural" unit of time. Extremely small <<10^{-40}s

3. What is the name of the theory which describes the character of the fundamental particles.
   Standard model of particle physics
4. What type of particles make up matter – fermions or bosons?
   Fermions
5. What is the difference between a fermion and a boson.
   Fermions need space (different quantum numbers) bosons can be arbitrarily close (same quantum numbers)
6. Describe the difference between a lepton, a meson and a baryon.
   Light , middle weight, heavy respectively. Lepton fundamental particle –meson 2x quarks- baryon 3xquarks
7. Is a neutrino a lepton or a baryon
   Lepton
8. Which nuclear process gave the first evidence for the existence of the neutrino
   beta decay (weak force interaction)
9. Why are neutrinos exceptionally difficult to detect
   They don't interact through electromagnetism or the strong nuclear force- therefore very unlikely to interact with matter at all
10. Quarks do not have any more mass than electrons – explain why protons and neutrons which contain only 3 quarks are much, much more massive (2000x) than electrons.
    Binding energy due to strong force interaction $E = mc^2$
11. What bosons carry the weak nuclear force?
    W ,Z bosons
12. Which type of nuclear decay is associated with the weak force?
    Beta
13. What particles carry the electromagnetic force? Give evidence for the existence of the photon.
    Photon- shape of black body radiator curve- threshold frequency for photoelectric effect
14. Describe how the LHC investigates the structure of matter.
    It crashes charged particle into each other at very high energy and examines the debris
15. How are the beams of protons constrained to move in a circular path in a particle accelerator?
    Magnetic fields

16. Which “hand rule” applies to the motion of electrons moving in a magnetic field
    Right hand rule (for electronic current)
17. If an electron moved from left to right across this page and there was a magnetic field acting into the page in which direction would the electron move?
    Up towards the top of the page..but check this with your own right hand !
18. What is antimatter?
    Particle with same properties but opposite electric charge
19. The mass of a Higgs Boson is around 125MeV. Which area of physics makes it justifiable to quote a mass using a unit of energy?
    Special relativity

Mandatory key area : Nuclear reactions

1. What is meant by isotope?

   Nuclei having the same atomic number (protons) but different mass number (neutrons)

2. A carbon nucleus has 6 protons and 6 neutrons. What is its atomic number?
   6
3. A Helium nucleus has 2 protons and 2 neutrons. What is its mass number?
   4
4. In Rutherford's gold leaf experiment a radium source emits alpha particles. What is the product or "daughter" element resulting from this reaction.
   Radon (Rn)
5. A nuclear reaction releases energy. Discuss the comparative masses of the reactants and products.

   Reactants have greater mass than products hence the mass defect responsible for energy release

6. What is meant by mass defect

   Difference between masses of reactants and products in nuclear reaction

7. State the relationship between the mass defect in a nuclear reaction and the energy yield.

   $E=mc^2$

8. How does the energy per reaction in nuclear and chemical reactions compare?

   Nuclear reactions much much stronger(reflecting the relative strengths of strong nuclear and em forces)

9. How many joules are in one electron volt ?

   $1.6x10^{-19}$J (E=QV)

10. State the difference between fission and fusion reactions.
    Fusion nuclei join together, Fission nucleus splits apart

11. Why is it extremely difficult to sustain fusion reactions in environments other than the core of a star?
    Require very high temperature which can't be sustained by normal matter

12. Why is "cold fusion" (which was suggested in the 1980s) extremely unlikely to be possible
    Low temperatures (kinetic energies) do not readily give enough energy to nuclei to overcome their electrical repulsion

13. How might the reactants in a fusion reaction be contained in experimental apparatus on Earth?
    Magnetic fields to place forces on charged plasma without touching it

Mandatory key area: Wave particle duality .

1. A negatively charged electroscope is found to discharge when illuminated with ultraviolet light. What is the name given to this effect.

   Photoelectric effect

2. Why does this not happen with a positively charged electroscope?

   Positive charges are contained in the nucleus and strongly bound – cannot escape

3. What is the name given to the minimum energy required for the emission of an electron in this effect?

   Work Function

4. What is the threshold frequency for photoelectric emission?

   The lowest frequency of light at which photo-emission can take place

5. State the conservation of energy equation in terms of frequency applying to the photoelectric effect- Identify the photon energy and work function.
   $hf = hf_o + 1/2mv^2$ (photon energy = work function = kinetic energy)

6. The threshold frequency for Caesium lies in the red part of the visible spectrum. Would photoemission take place in caesium if it was illuminated with blue light? Explain your answer.

   Yes because f blue is higher than f red so photon energy is higher

7. An appropriately charged electroscope releases photoelectrons when illuminated with UV light of frequency $1x10^{15}$Hz. How does the kinetic energy of the photoelectrons change when the frequency is increased

   Kinetic energy increases (see question 5)

8. Sketch a graph showing the relationship between electron kinetic energy and frequency in the photoelectric effect. Numerical values are not required but the threshold frequency should be labelled on the frequency axis.
   (see notes in jotter/online eg Question 7 at http://www.dronstudy.com/book/dual-nature-previous-years-questions/)

9. X rays incident on a target produce photoelectrons with a speed 70% the speed of light.By considering special relativity and the conservation of energy explain why the photoelectrons emitted by gamma rays of much higher frequency do not exceed the speed of light.

   For higher energy electrons their speed approaches the speed of light and relativistic changes to the mass take place such that the mass increases and contributes more to the kinetic energy than the speed

Mandatory Key Area: Interference and diffraction

1. What is meant by coherence with respect to sources of waves?
   Sources maintain a constant phase relationship over a long period of time. This means additionally that their frequencies must be the same
2. A series of bright and dark fringes is produced in an interferometer. How would you account for the existence of these fringes.
   Constructive and destructive interference respectively (check your notes for path length conditions)
3. What path length condition must be satisfied for the production of constructive interference fringes from coherent sources.
   Path length difference is a whole number of wavelengths
4. The interference pattern produced by a diffraction grating is described by the equation $d\sin\theta = m\lambda$.

   What does "d" stand for in this equation? How can this value sometimes be problematic in calculations ?

   d is the line separation in the grating. This can be problematic because the problems are often stated in terms of a number of lines per mm and so this information has to be processed before substituiion into the diffraction grating formula

5. A diffraction grating is illuminated by white light – describe some differences in the spectra produced by a grating and that produced by a refractive prism.
   Prism produce s only one spectrum with red light being dispersed least. Diffraction grating produces multiple spectra at interference maxima (order >1) and the red light is dispersed most

6. A monochromatic source interference pattern is produced by a diffraction grating. Describe how a larger angular dispersion of light could be achieved. (You might discuss changes to the source and/ or the grating).
   Increase wavelength, decrease line separation of grating

7. If interference is observed what does this imply about the nature of the source ?
   Interference implies wave behaviour of source

Mandatory key Area :Refraction

1. What is meant by refraction?
   Change of speed of a wave as it passes between different substances or media
2. What is total internal reflection?
   Total internal reflection can take place when light travels from a Optically dense medium (high refractive index, low speed) into a less optically dense medium (low refractive index, high speed). This will happen when the angle of incidence exceeds a critical angle θc)
3. To define the absolute refractive index of a substance the speed of light in that substance is compared to a constant of nature. Define the absolute refractive index by stating this relationship.
   $n = v_{air}/v_{substance}$
4. Light of wavelength 600nm passes from glass into air at 10° to the normal.
   a. What happens to its wavelength? increases
   b. What happens to its frequency? No change
   c. What happens to its speed? increases
   d. What happens to its direction? Bends away from the normal
5. State the relationship which links the absolute refractive index to the critical angle for the substance.
   $n = 1/\sin \theta c$
6. Light passes from air into water with a refractive index of 1.33. At what angle of incidence would total internal reflection be expected at this interface?
   48.8°

7. As light passes through a prism blue light is dispersed more than red light. What happens to the refractive index of a substance as the frequency of the incident light is increased within in the visible range.

   As the frequency increases the refractive index increases

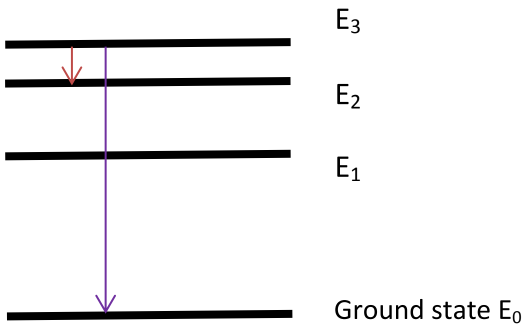
Irradiance and spectra

State the inverse square rule for the irradiance of a point source of light
Id^2=constant

What is meant by an irradiance of 1.56kWm^{-2}
This is an irradiance of 1560joules of energy for every m^2 of area every second.
Give an example of something that is not a point source of light – explain your answer as context could be important.
A laser is not a point source as the beam in collimated and does not spread out over an area. Similarly a beam collimated by a dish reflector (like a torch) is not a point source. An extended object eg a star or strip light can be a point source if the separation from it is much greater than the radius of the star or length of the light.

Whose model of the atom predicts the electrons to have distinct , discrete energy levels.
Niels Bohr

Sketch a schematic diagram showing the energy levels belonging to an electron "orbiting" an atom. You should include the ground state and three other energy levels appropriately spaced out.



Mark on your diagram the electron transition which would be associated with the longest wavelength of light.
E3 to E2
Mark on your diagram the energy transition associated with the highest frequency of light
E3 to E0

How many lines would you expect to find in the emission spectrum of this element?6 (4energy levels means 3 +2 +1 transitions
What is the electrical potential energy of an electron at its ionisation level? 0V

Explain how the absorption lines in the spectrum of a star are formed. What information about the star can be gained by examining these spectra.
A star emits light at all frequencies. Atoms in the star's atmosphere absorb light at frequencies characteristic of the energy levels of those atoms and so the stars light is dimmed at these particular frequencies. Examination of the absorbtion spectrum of the star allows the atoms present in the star to be identified