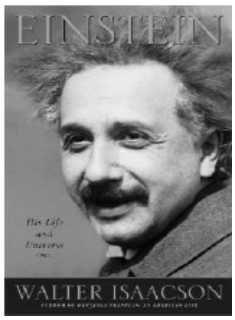
State Examination Commission – Physics Higher Level, 2008

Question 11

Read the following passage and answer the accompanying questions.

The Miracle Year: 1905

"There is nothing new to be discovered in physics now," Lord Kelvin reportedly said in 1900. He was wrong. Isaac Newton had laid the foundations of classical physics in the late seventeenth century. He developed laws thatdescribed a mechanical universe: a falling apple and an orbiting moon governed by the same rules of gravity, mass, force and motion. In the mid-1800s, Newtonian mechanics was joined by another great advance. Michael Faraday discovered the properties of electric and magnetic fields. James Clerk Maxwell subsequently showed how changing electric and magnetic fields united to form electromagnetic radiation. Physics was upended in the early twentieth century by Albert Einstein. In 1905 he devised a revolutionary quantum theory of light to explain the photoelectric effect, helped prove the existence of atoms, united the concepts of space and time, and produced science's best-known equation.



(Adapted from "Einstein: His Life and Universe"; Isaacson; 2007)

(*a*) The SI unit is named in honour of Lord Kelvin. What is the temperature of the boiling point of water in kelvin? (7)
(*b*) Define the newton, the unit of force. (7)
(*c*) A force of 9 kN is applied to a golf ball by a golf club. The ball and club are in contact for 0.6 ms. Using Newton's laws of motion, calculate the change in momentum of the ball. (7)
(*d*) Name three different electromagnetic radiations. (7)
(*e*) What is the photoelectric effect? (7)
(*f*) Why was the quantum theory of light revolutionary? (7)
(*g*) High-energy radiation of frequency 3.3×10^{14} Hz is used in medicine. What is the energy of a photon of this radiation? (7)
(*h*) 100 MJ of energy are released in a nuclear reaction. Calculate the loss of mass during the reaction. (7)
(Planck constant = 6.6×10^{-34} J s; speed of light = 3.0×10^{8} m s^{-1})

(*a*) The SI unit is named in honour of Lord Kelvin. What is the temperature of the boiling point of water in kelvin? (7)

373.15 K

(*b*) Define the newton, the unit of force. (7)

basic definition

(*c*) A force of 9 kN is applied to a golf ball by a golf club. The ball and club are in contact for 0.6 ms. Using Newton's laws of motion, calculate the change in momentum of the ball. (7)

Force = change in momentum/time
So, change in momentum = Force x time
= $9 \times 10^{3} \times 0.6 \times 10^{-3}$
= 5.4 kg m s^{-1}

(*d*) Name three different electromagnetic radiations. (7)

ultra-violet, visible and infra-red

(*e*) What is the photoelectric effect? (7)

The emission of electrons from the surface of a metal when em radiation of suitable frequency falls upon it.

(*f*) Why was the quantum theory of light revolutionary? (7)

Because it said that em radiation is emitted only as discrete tiny packets of energy, or quanta, which he called photons. Einstein asserted that the energy of a photon is proportional to its frequency. More generally, the theory states that everything has both a particle nature and a wave nature, and various experiments can be done to bring out one or

the other

(*g*) High-energy radiation of frequency 3.3×10^{14} Hz is used in medicine. What is the energy of a photon of this radiation? (7)

$$E = hf$$
$$= 6.6 \times 10^{-34} \times 3.3 \times 10^{14}$$
$$= 2.2 \times 10^{-19} \text{ J}$$

(*h*) 100 MJ of energy are released in a nuclear reaction. Calculate the loss of mass during the reaction. (7)

$$m = E/c^2$$
$$= 100 \text{ x } 10^6 /(3.0 \text{ x } 10^8)^2$$
$$= 1.1 \text{ x } 10^{-9} \text{ kg}$$