State Examination Commission – Physics Higher Level, 2007

Question 11

Read the following passage and answer the accompanying questions.

At present, nuclear fission reactors supply a sixth of the world's electricity. Along with hydroelectric stations they are the major source of 'carbon-free' energy today. Nuclear reactors have shown remarkable reliability and efficiency even though the development of nuclear technology was held back by the nuclear accidents at Chernobyl and Three Mile Island.

A nuclear revival is possible. The global reserves of uranium could support a much large number of reactors than exist today. Nuclear power generation could increase from three hundred gigawatts today to one thousand gigawatts by the year 2050, saving the earth from 1.5 billion tonnes of carbon emissions a year. Already more than twenty gigawatts of nuclear capacity have come online since 2000. Nuclear power would significantly contribute to the stabilisation of greenhouse gas emissions.

The type of reactor that will continue to dominate for the next two decades is the light water reactor, which uses ordinary water (as opposed to heavy water, containing deuterium) as the coolant and moderator.

Solar cells, wind turbines and biofuels are becoming viable energy sources. Solar cells use semiconductor materials, such as silicon, to convert sunlight into electricity, but at the moment they provide only 0.15% of the world's energy needs. Yet sunlight could be harnessed to supply 5000 times as much energy as the world currently consumes.

(Adapted from "Scientific American; Energy's Future beyond Carbon"; September 2006)

(a) What is nuclear fission? (7)
(b) How much energy is generated worldwide every minute by nuclear power today? (7)
(c) At present, why is a fission reactor a more viable source of energy than a fusion reactor? (7)
(d) Deuterium is an isotope of hydrogen, what is an isotope? (7)
(e) What is the function of a moderator in a fission reactor? (7)
(f) Why is silicon a semiconductor? (7)
(g) A large number of solar cells are joined together in series and cover an area of 20 m^2. The efficiency of the solar cells is 20%. If the solar constant is 1400 W m^{-2}, what is the maximum power generated by the solar cells? (7)
(h) What is the source of the sun's energy? (7)

(a) What is nuclear fission? (7)

basic term

(b) How much energy is generated worldwide every minute by nuclear power today? (7)

300 gigawatts => 300 x 10^9 J s^{-1}

=> 300 x 10^9 x 60 J each minute. = 1.8 x 10^{12} J

(c) At present, why is a fission reactor a more viable source of energy than a fusion reactor? (7)

Fusion has proved very difficult to control

(d) Deuterium is an isotope of hydrogen, what is an isotope? (7)

atoms of the same element that differ in the number of neutrons in their nuclei

(e) What is the function of a moderator in a fission reactor? (7)

To moderate (slow down) fast neutrons, therby increasing their chance of capture by U-235 and causing further fission.

(f) Why is silicon a semiconductor? (7)

Its conductivity lies between that of a conductor and an insulator

(g) A large number of solar cells are joined together in series and cover an area of 20 m^2. The efficiency of the solar cells is 20%. If the solar constant is 1400 W m^{-2}, what is the maximum power generated by the solar cells? (7)

Over 20 m^2 , 20 x 1400 J falls each second. That is, 28 kJ falls per second.
20% efficiency => electrical output of array of cells has max value of 5.6 kJ per sec, i.e., 5.6 kW

(h) What is the source of the sun's energy?

Nuclear fusion