8.1 Energy Sources

Question Paper

Course	DP IB Physics
Section	8. Energy Production
Topic	8.1 Energy Sources
Difficulty	Medium

Time allowed: 80

Score: /65

Percentage: /100

Question 1a

A tidal power station traps water when the tide rises above the level of the power station turbines. The trapped water is released in a controlled manner over a period of 7 hours.

The following data are available:

Difference between high and low tide water level = 3.0 m
Density of sea water = 1.1×10^3 kg m^{-3}
Area of tidal basin = 250 km^2
Overall efficiency of power station = 24%

a)
Calculate the mass of trapped water.

[2 marks]

Question 1b

(b)
Determine the average loss of potential energy per second over the seven hours of controlled release of water.

[3 marks]

Question 1c

(c)
For the tidal power station:

(i)
Calculate the electrical power generated between successive high and low tides.

[2]

(ii)
Identify one mechanism through which energy is transferred to the surroundings during the electricity generation process.

[1]

[3 marks]

Question 1d

(d)
A certain proportion of the water's gravitational potential energy is transferred to the surroundings.

(i)
State the term used to describe energy which has been transferred in this way.

[1]

(ii)
Explain the meaning of the term stated in part (i).

[1]

[2 marks]

Question 2a

A horizontal-axis wind turbine with blades of length 12 m is sited in an area which has a reasonably constant average wind speed of 13 m s^{-1} for significant parts of the day.

(a)
Calculate the average mass of air per second that passes through the area swept out by the blades of the turbine. Assume the density of air = 1.2 kg m^{-3}.

[4 marks]

Question 2b

The power which is available from this turbine is about 36% of the kinetic energy per second of the incident wind.

(b)
Calculate the output power available, in watts, at this wind speed from this generator.

[3 marks]

Question 2c

(c)
Outline the construction and operation of a horizontal-axis wind generator, by:

(i)
Stating the main components and arrangement of the wind turbine

[3]

(ii)
Discussing the energy conversions in the machinery of the turbine and the generator.

[2]

[5 marks]

Question 2d

The total incident kinetic energy incident on a rotating turbine driven by the wind can never be fully converted to rotational kinetic energy of the blades.

(d)
Discuss reasons why this is the case.

[3 marks]

Question 3a

The Sizewell B Pressurised Water Reactor (PWR) in the UK uses Uranium-235 as fuel and water as both coolant and steam to drive a generator.

(a)
Outline the processes which lead to the production of thermal energy in the PWR.

[3 marks]

Question 3b

(b)
A nuclear reactor has several key components. In generating electricity, outline the role of the:

(i)
Heat exchanger of a PWR

[2]

(ii)
Turbine and generator.

[2]

[4 marks]

Question 3c

(c)
Uranium-235 is the primary energy source in the PWR. It has an energy density in the region of 1.3×10^{18} J m^{-3} and a specific energy of 7.0×10^{13} J kg^{-1}.

(i)
Explain the terms primary energy source and energy density.

[2]

(ii)
Calculate the density of uranium-235.

[2]

[4 marks]

Question 3d

In the nuclear reactor the number of uranium–235 nuclei undergoing fission per second is 8.70×10^{20}. Each fission gives rise to 250 MeV of energy which is available to be converted to electrical energy by the power station.

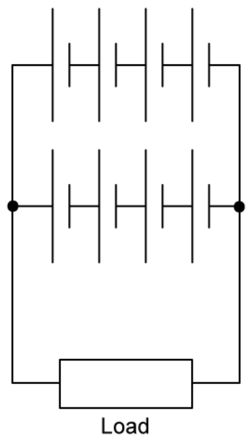
(d)
If the overall efficiency of the power station is 37%, calculate the power output of the power station.

[3 marks]

Question 4a

A remote community requires a peak power of 900 kW. Two systems are available for energy generation: photovoltaic cells for electrical energy and a power station burning waste material as its source of heat.

The diagram shows an arrangement of eight photovoltaic cells, which forms a single module. Each cell in the module has an emf of 0.75 V and an internal resistance of 1.9 Ω.



(a)
For the module, calculate:

(i)
the total emf

[1]

(ii)
the total internal resistance.

[2]

[3 marks]

Question 4b

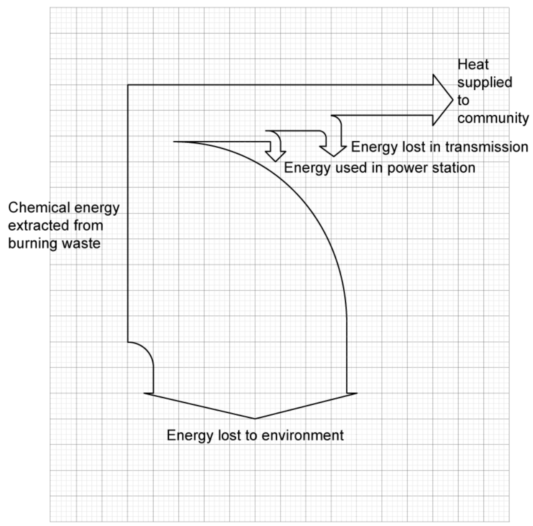
The intensity of solar radiation incident on the module is 3.5×10^{2} W m^{-2}. The photovoltaic cells are 22% efficient.

(b)
Calculate the minimum area required per module to fulfil the community's energy needs.

[3 marks]

Question 4c

The Sankey diagram shows the energy flow in a power station burning waste material to convert to heat which is then supplied through pipes to the homes and businesses of the local community.



(c)
For the power station:

(i)
determine its efficiency

[2]

(ii)
identify the primary and secondary energy sources.

[2]

[4 marks]

Question 4d

Another mechanism of heating water for use in the home uses solar heating panels.

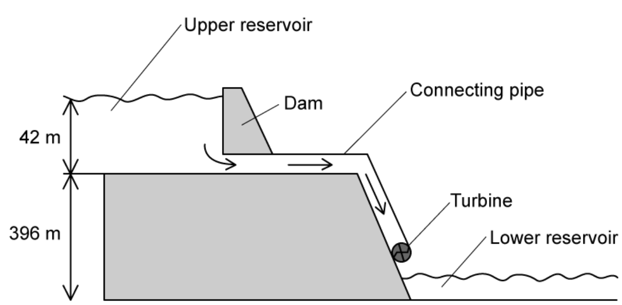
(d)
Distinguish between a photovoltaic cell and a solar heating panel by referring to the operation of each and the energy transformations involved.

[2 marks]

Question 5a

Pumped hydroelectric systems store water behind a dam. When electricity is needed in the grid the water is released to turn a turbine.

The system shown has an upper reservoir 42 m in depth when full and allows water to fall a vertical distance of 396 m before reaching the turbine.



Cruachan power station

(a)
Estimate the specific energy of the water held in the reservoir.

[3 marks]

Question 5b

Water is made to flow out of the upper reservoir through connecting pipes at a rate of 12 000 m^3 per minute. The density of water is 1.0×10^3 kg m^{-3}.

(b)
Calculate the transfer rate of gravitational potential energy of the water stored in the reservoir.

[4 marks]

Question 5c

The pumped storage system produces 0.62 GW of power and it can operate continuously for 22 hours before the water in the upper reservoir is depleted.

(c)
For the pumped storage system:

(i)
calculate its efficiency

[1]

(ii)
calculate the total energy supplied by the system

[2]

(iii)
state an assumption you made to calculate part (ii).

[1]

[4 marks]

Question 5d

After the upper reservoir is drained it is refilled with water from the lower reservoir. Pumping this water uphill requires energy.

(d)
Explain how the operating company makes a profit on the energy they sell to the National Grid.

[3 marks]