8.1 Energy Sources

Question Paper

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

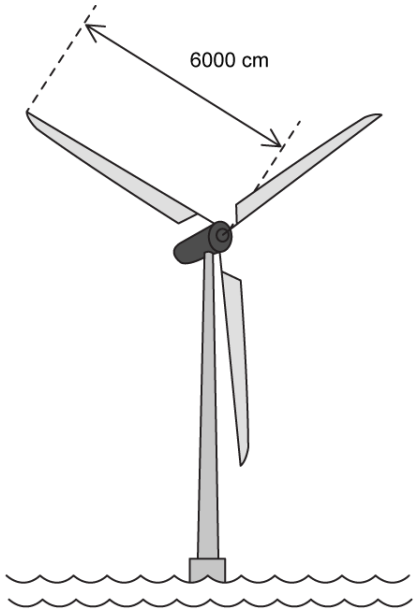
Time allowed: 70

Score: /52

Percentage: /100

Question 1a

A new model wind turbine has a blade of length 6000 cm and is positioned offshore where the wind speed is an average of $4.2\,\text{km hr}^{-1}$ and the air density is $1.2 \times 10^{-6}\,\text{g mm}^{-3}$.



(a)
Calculate the number of wind turbines required in the wind farm to power a town of 30 million houses for 2 years.

An average household consumes 28.8 kWh of electricity in 1 day.

[4]

[4 marks]

Question 1b

(b)
Outline **two** assumptions made in calculating the power output of one turbine from part (a) and explain how each assumption simplifies your calculation.

[4]

[4 marks]

Question 1c

(c)
Analyse the validity of the **two** assumptions made in part (b)

[4]

[4 marks]

Question 1d

In reality, wind turbines currently have a capacity factor of 60%

$$\text{Capacity factor} = \frac{actual\ output}{maximum\ possible\ output}$$

(d)
Calculate the average wind speed for the actual output of the turbine.

[2]

[2 marks]

Question 1e

(e)
Show that the turbine is required to operate at the maximum possible wind speed for 14.4 hours a day to obtain a power output equivalent to the actual power output.

[3]

[3 marks]

Question 2a

A hydropower station in India has a semicircular dam of diameter 1.53 km and a depth of 53 m when full. The dam fills up during the monsoon season but is emptied at a steady rate over 8 days and 17 hours in the dry season. Water is released from the dam and falls a vertical distance of 305 m before reaching the turbine.

The water has a density of 1.1×10^3 kg m^{-3} and the efficiency of the power station is 31%.

(a)
Calculate the electrical power generated by the release of the water from the dam.

[3]

[3 marks]

Question 2b

(b)
Identify **two** ways that the hydropower station could increase its power output.

[2]

[2 marks]

Question 2c

The Indian government are deciding if hydroelectric power would be a viable energy source to supply electricity to every household in the city of Mumbai during the dry season.

Some data is shown in the table below.

Population of Mumbai City	23 million
Population of Mumbai Metropolitan Area	26 million
Average number of people per household in Mumbai City and Metropolitan areas	4.77
Average electricity consumption per household per day in Mumbai City	3000 MW
Average electricity consumption per household per day outside the city	1500 MW
Duration of the dry season	December to February
Average number of daylight hours in Mumbai per day	7 hours
The cost of building one dam	790 million Indian Rupees

(c)
Using the data, calculate the number of dams that would be needed.

[3]

[3 marks]

Question 2d

(d)
Comment on the suitability for Mumbai to use hydropower as its main energy source during the dry season, and give reasons for your answer.

[2]

[2 marks]

Question 2e

Currently, 95% of the energy generated for the city of Mumbai comes from coal.

(e)
Suggest, with reasons, a cleaner and more sustainable alternative energy source for the Indian government to consider that would be more suitable for Mumbai.

[3]

[3 marks]

Question 3a

A small wind turbine with a blade length of 150 cm and an efficiency of 41% is situated in a field on the coast of Spain.

The air density at this location is 1200 g m^{-3}. For 3.5 hours, the wind speed is 39.6 km hr^{-1} and for 1.25 hours, the wind speed is 14.4 km hr^{-1}.

(a)
Calculate the power obtained from the wind turbine during this time.

[3]

[3 marks]

Question 3b

A solar panel with a surface area of 1.45×10^{-6} km^2 and 24% efficiency is also present in the field. The average intensity of sunlight received per day is 8.2 kWh m^{-2}, assuming that this location receives sunlight for an average of 8 hours per day.

(b)
Compare the power obtained by the solar panel and the wind turbine when operating for the same number of hours.

[2]

[2 marks]

Question 3c

The local council decide to install enough solar panels to power a village of 3500 houses. The average electricity consumption per household is 10.2 kWh per day.

(c)
(i)
Calculate the number of solar panels needed to power the village for one day.

[2]

(ii)
Suggest reasons the local council have chosen solar panels over wind turbines to power the village.

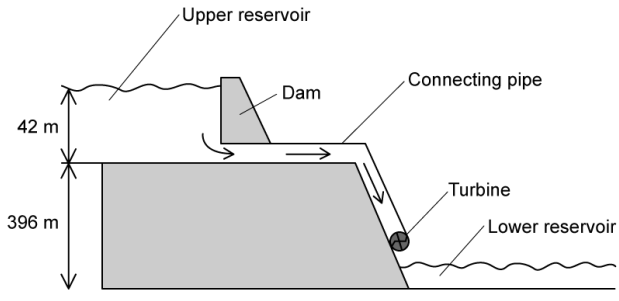
[2]

[4 marks]

Question 4a

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

Water, with a density of 1.0×10^3 kg m^{-3}, flows out of the reservoir at 1.5×10^{10} cm^3 per minute. The pumped storage system produces 0.58 GW of power and can operate continuously for 19 hours and 27 minutes before the water in the upper reservoir is depleted.

(a)
Calculate the efficiency, and hence, the total energy supplied by the system.

[3]

[3 marks]

Question 4b

(b)
Draw a Sankey diagram to represent the energy transferred by the turbine in the hydroelectric dam, indicating clearly the scale used.

[2]

[2 marks]

Question 5a

A holiday park is deliberating whether to install photovoltaic cells or solar heating panels on the roofs of their chalets.

(a)
Distinguish between a solar heating panel and a photovoltaic cell using considerations of the energy transfers involved.

[2]

[2 marks]

Question 5b

The holiday resort wishes to heat a 125–litre water tank from 10 °C to 40 °C over 2 hours to provide hot water for the chalet every 24 hours. The maximum amount of solar radiation incident upon the roof at any one time is 8.53×10^{-4} W mm^{-2}.

Water has a density of 1.1×10^{3} kg m^{-3} and a specific heat capacity of 4200 J kg °C^{-1}.

One photovoltaic cell is a rectangle of dimensions 500 mm and 300 mm. The power output of one cell is 215.36 W when radiation is at its maximum intensity.

The solar heating panel is 67% efficient.

(b)
Compare the area on the roof required by the solar heating panels and the photovoltaic panels.

[4]

[4 marks]

Question 5c

(c)
Justify the difference between the values calculated in part (b).

[2]

[2 marks]