**IB · DP · Physics**

🕐 3 hours   ❓ 15 questions

Structured Questions

8.1 Energy Sources

8.1.1 Specific Energy / 8.1.2 Sankey Diagrams / 8.1.3 Primary & Secondary Energy Sources / 8.1.4 Energy Resources / 8.1.5 Energy Generation / 8.1.6 Safety Issues in Nuclear Power

Easy (5 questions)	/67
Medium (5 questions)	/65
Hard (5 questions)	/52
Total Marks	**/184**

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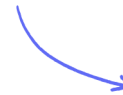
Easy Questions

1 (a) A manufacturing company is looking to revolutionise the way water can be heated in the home. Fuels can be compared using energy density and specific energy.

Match, by drawing a line, energy density and specific energy to the quantity they compare and their units.

Specific Energy
Energy Density

Mass
Volume

J m⁻³
J kg⁻¹

(4 marks)

(b) Kerosene is a clean and cost−effective energy source for heating water. The specific energy of Kerosene is 48×10^6 J kg^{-1} and the energy density is 3.3×10^{10} J m^{-3}.

$$Density = \frac{Energy\ density}{Specific\ energy}$$
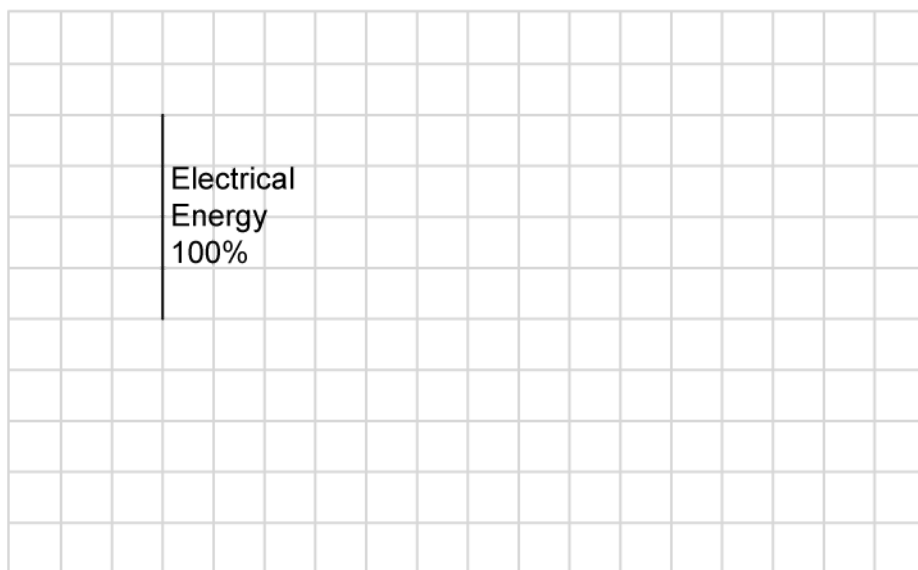
Calculate the density of Kerosene.

(3 marks)

(c) A new kettle is being developed that claims to be 75% efficient.

Sketch a Sankey diagram on the squares below to represent this situation.

Electrical
Energy
100%

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(3 marks)

(d) In a new prototype kettle, claimed to be 95% efficient, 300 000 J of energy is required to raise the temperature of the full kettle of water from room temperature to boiling point.

Calculate the amount of energy wasted by the kettle.

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(2 marks)

2 (a) An energy company is analysing their energy sources to provide cheaper and greener energy to its customers.

Define a primary energy source.

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(3 marks)

(b) The energy company are considering using more nuclear power to generate their electricity.

State whether nuclear fission is a renewable or non-renewable energy source and give a reason for your answer.

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(2 marks)

(c) The energy company is trying to improve its understanding of nuclear energy.

Identify four advantages of using nuclear power by placing a tick (✔) next to the correct statements in the table below.

	There are extensive reserves of fissionable materials
	Nuclear power is always sustainable and will never run out
	The technology to extract the fissionable material from the rocks is improving
	No greenhouse gases are produced from a nuclear reactor
	Nuclear waste is easy to dispose
	A large amount of power can be produced from a small amount of fissionable material

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<div align="right">

(4 marks)

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(d) The energy company is investigating the purpose of the control rods, the moderator and the shielding within a nuclear reactor.

Place a tick (✔) in the correct box to show the purpose of each part of the nuclear reactor.

	Control Rods	**Moderator**	**Shielding**
Absorb hazardous radiation			
Slow down neutrons			
Absorb neutrons			

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<div align="right">

(3 marks)

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3 (a) A developer looking to create a new residential complex is analysing the energy required for the construction of the project. She is investigating the differences between primary and secondary energy sources.

The following statements are about secondary energy sources. Place a tick (✔) next to the correct statement(s).

	Statement is correct
Wind power is an example of a secondary energy source	
Secondary energy sources come from the use or processing of primary energy sources	
Examples of secondary energy sources are geothermal, hydroelectric and solar power	
An example of a secondary energy source includes converting the gravitational potential energy from falling water into electricity	

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(2 marks)

(b) The developer is also trying to identify which energy resources are renewable and which are non-renewable.

Identify whether the energy resources below are renewable or non-renewable. Place a tick (✔) in the correct for each resource.

	Renewable Resources	Non-Renewable Resources
Petrol		
Solar Energy		
Wind		
Coal		
Nuclear Fission		
Tidal		
Natural Gas		
Bio-Fuel		

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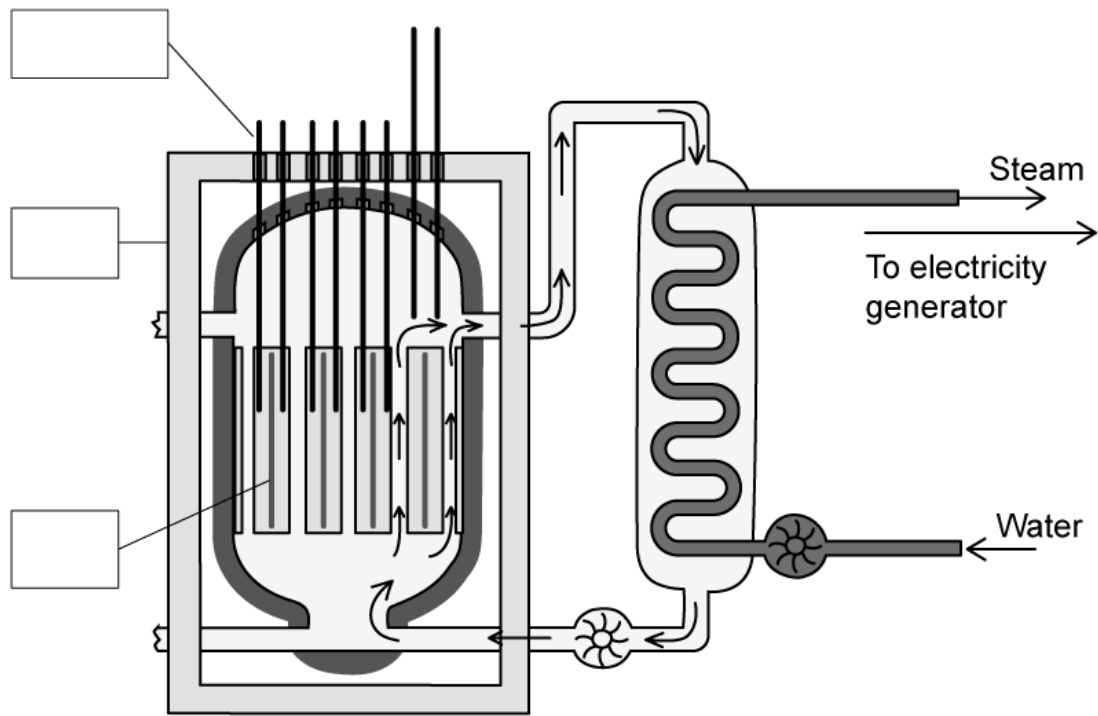
(4 marks)

(c) The developer is investigating the set-up of a nuclear power plant.

Identify the key components of the nuclear reactor by adding the following labels to the diagram:

- Control Rods
- Graphite Moderator
- Radiation Shielding

(3 marks)

(d) The developer is impressed by the amount of electricity that can be generated in a nuclear reactor with a small amount of uranium. They are concerned, however, with the safety of workers within a nuclear power plant.

With the aid of the diagram supplied below, identify three safety features designed to reduce workers' exposure to radiation.

Nuclear reactor   Control room

_____

_____

_____
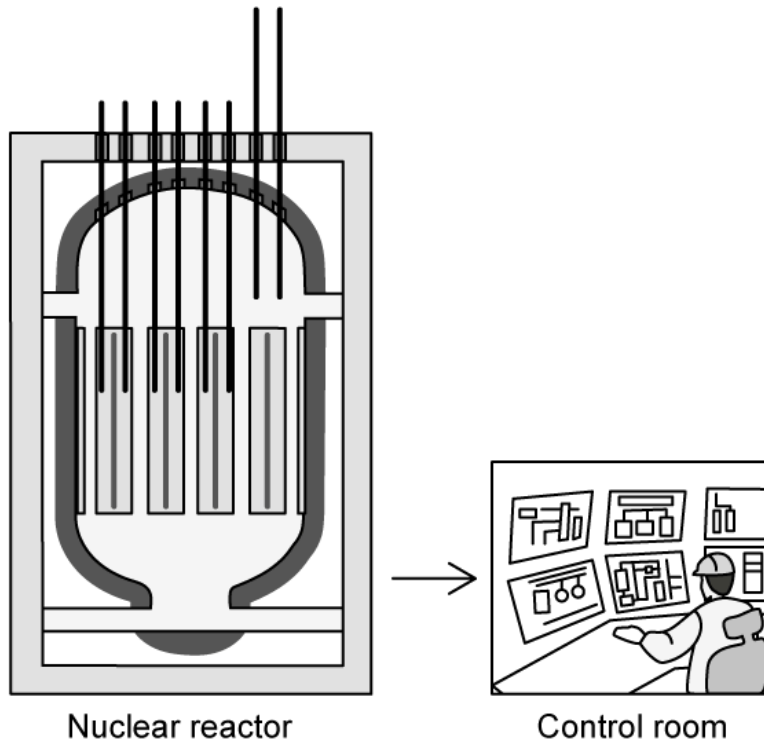
(3 marks)

4 (a) A farmer has been approached by the National Grid asking if they can install wind turbines on part of his land.

Identify the following components of the wind turbine by labelling the diagram below:

- Rotor blade
- Generator
- Gear Box

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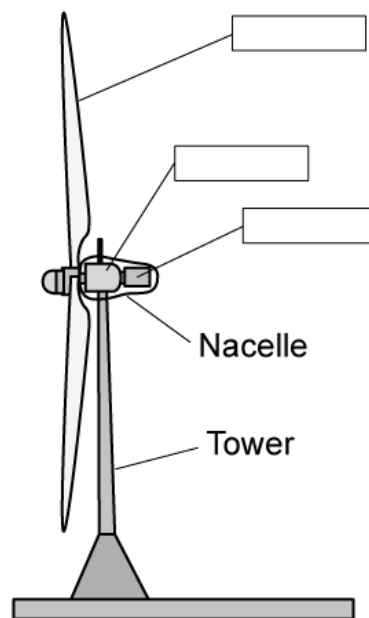
(3 marks)

(b) The National Grid are really keen to use the farmer's land for wind turbines because of the consistently high wind speed available. The density of the surrounding air is 1.32 kg m^{-3} and its velocity is 12 m s^{-1}. The cross-sectional area of the column of air that would be incident on one wind turbine is 125 000 m^2.

Calculate the maximum power possible in this situation and put your answer in standard form.

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(3 marks)

(c) The farmer would prefer not to have wind turbines on his land. He is keen to support the motion for an extension to be made to the local coal-fired power station instead.

The following statements are advantages or disadvantages of using a coal-fired power station to generate electricity. Place a tick (✔) next to the correct statement(s) to say whether they are advantages or disadvantages.

	Advantage	Disadvantage
Produces greenhouse gases		
High energy density of fuel		
Available at any time		
Non-renewable		
Produces pollution		
Long established method for generating electricity		
Extensive infrastructure already in place		

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(4 marks)

(d) The National Grid are continually assessing the main uses of energy and the types of energy resources used to generate them.

Identify the types of energy resources used for transport, electricity generation and heating by drawing lines between them.

Each energy resource may be used up to a maximum of two times.

Fossil Fuels

Water waves

Nuclear

Biofuel

Wind

Geothermal

Solar

Tidal

Hydroelectric

Transport

Electricity Generation

Heating
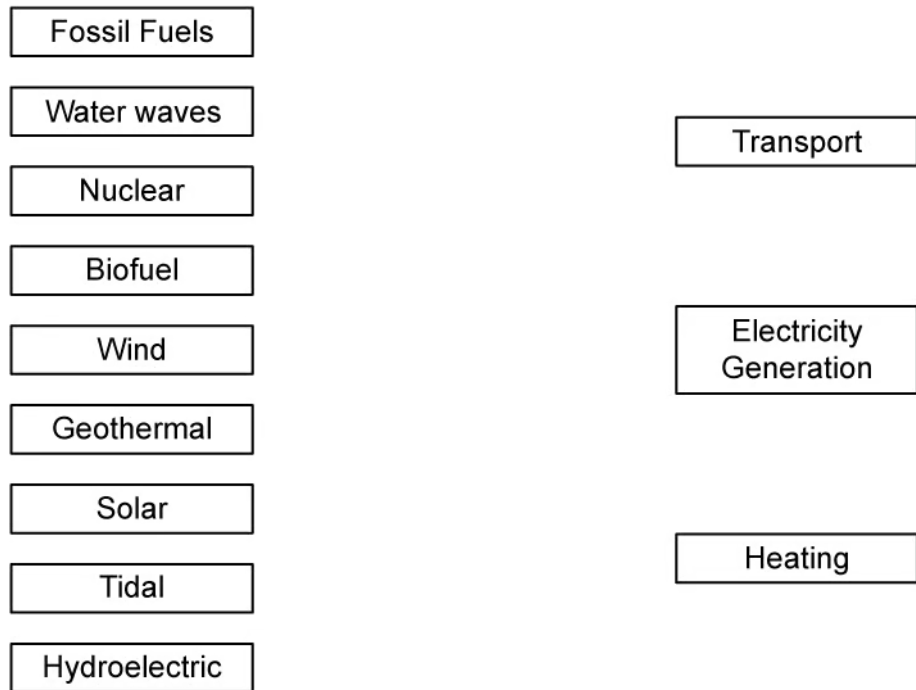
(3 marks)

5 (a) Nepal is a mountainous country, making it ideal for using hydroelectric power to generate electricity.

Use the text in the box to complete the sentences below, identifying the conditions needed for hydroelectric power.

gravitational potential energy	**depth**	**dropped**
Kinetic energy	**height**	**pumped**

    (i)   Water needs to be stored at _____.

[1]

    (ii)   _____ energy is released.

[1]

    (iii)   Water is _____ from a height to turn the turbines of a generator.

[1]

(3 marks)

(b) A location in the Annapurna region of Nepal is being analysed for its suitability as a new hydroelectric power station. The plan is to have water of density 1000 kg m^{-3} flowing at a rate of 150 × 10^{-3} m^3 s^{-1} through a turbine that then descends a distance of 380 m.

Calculate the maximum power obtained from this system.

(4 marks)

(c) Most people in cities in Nepal have solar panels on their roof to generate electricity for their household.

Identify three advantages of using solar panels in countries like Nepal where there is bright sunlight for a large portion of the day.

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(3 marks)

(d) The Nepali government are putting together a flyer to explain to people how solar panels work.

On the diagram below label the following:

- Electrode
- Reflect-proof film
- N-type semiconductor
- P-type semiconductor

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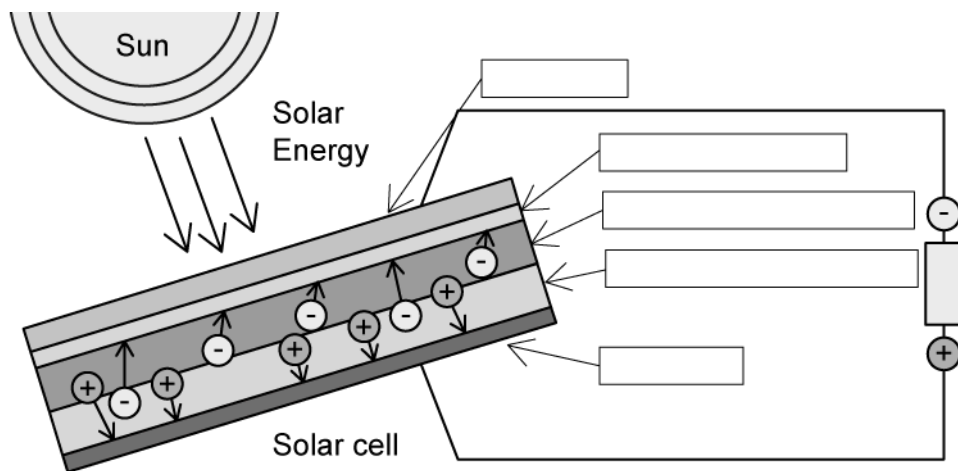
(e) On the second page of the flyer, the Nepali government wants to have a clear description of the function of each part of the solar panel.

Draw a line between the correct component of the solar panel and its function.

Electrode	Stops the incident light being reflected away from the solar panel
Reflect-Proof Film	Negative electrons move from one side of the semiconductor
N-Type Semiconductor	Incident light causes electrons to be emitted
P-Type Semiconductor	The movement of the electrons through the semiconductor generates an electrical current

(4 marks)

Medium Questions

1 (a) 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%

Calculate the mass of trapped water.

(2 marks)

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

(3 marks)

(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]

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(3 marks)

(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]

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(2 marks)

2 (a) 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.

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}.

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(4 marks)

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

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

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(3 marks)

(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]

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(5 marks)

(d) 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.

Discuss reasons why this is the case.

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(3 marks)

3 (a) 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.

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

(3 marks)

(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)

(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]

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(4 marks)

(d) 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.

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

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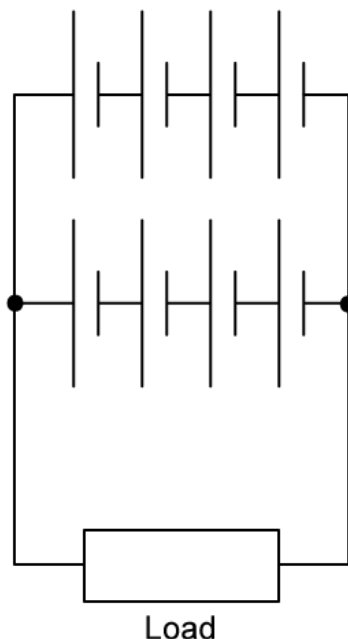
(3 marks)

4 (a) 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.

Load

For the module, calculate:

  (i)   the total emf

[1]

  (ii)   the total internal resistance.

[2]

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(3 marks)

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

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

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(3 marks)

(c) 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.
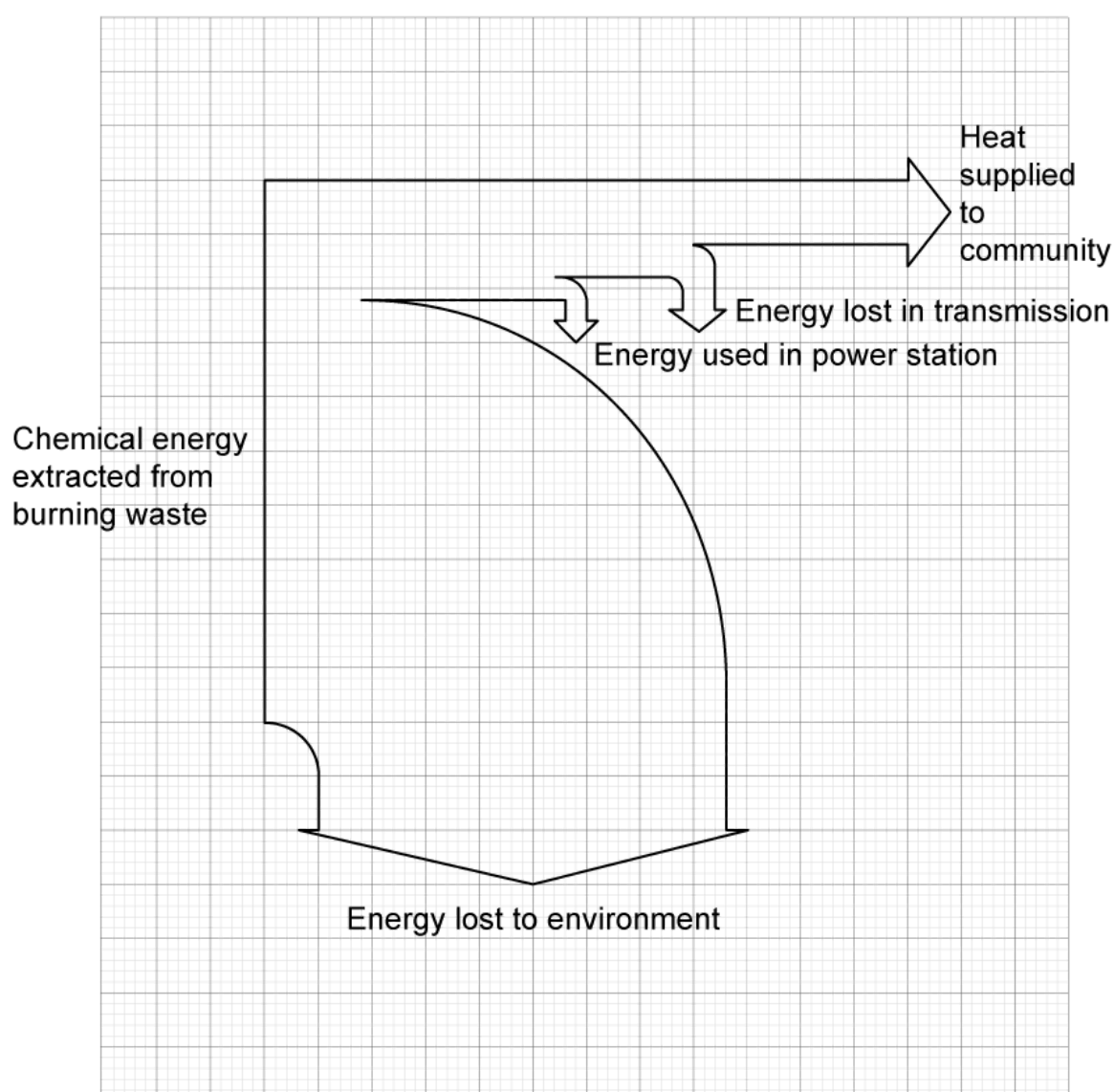
For the power station:

    (i)   determine its efficiency

[2]

    (ii)   identify the primary and secondary energy sources.

[2]

(4 marks)

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

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

(2 marks)

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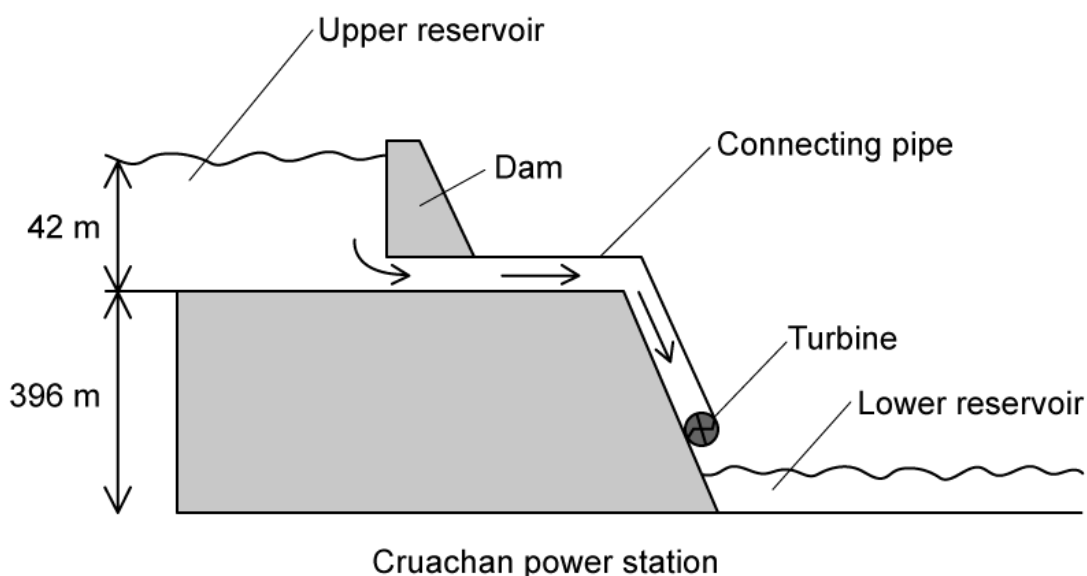
Estimate the specific energy of the water held in the reservoir.

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(3 marks)

(b) Water is made to flow out of the upper reservoir through connecting pipes at a rate of 12 000 m³ per minute. The density of water is 1.0×10^3 kg m⁻³.

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

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(4 marks)

(c) 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.

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]

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(4 marks)

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

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

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(3 marks)

Hard Questions

1 (a) 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 km hr^{-1} and the air density is 1.2×10^{-6} g mm^{-3}.

6000 cm
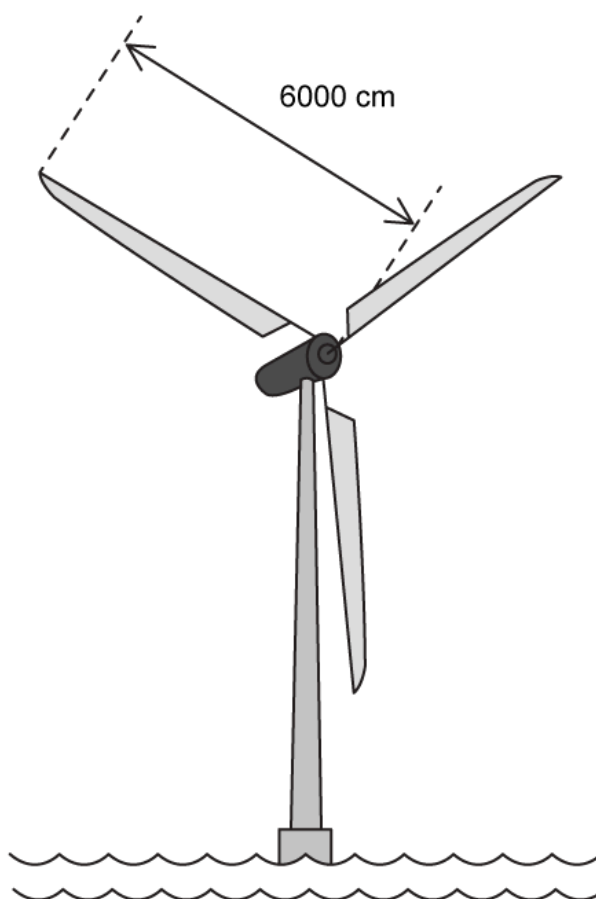
Calculate the number of wind turbines required in the wind farm to power a town of 30 million houses for 2 years.

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

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(4 marks)

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

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(4 marks)

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

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(4 marks)

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

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

Calculate the average wind speed for the actual output of the turbine.

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(2 marks)

(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.

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(3 marks)

2 (a) 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%.

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

(3 marks)

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

(2 marks)

(c) 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	833 kWh
Average electricity consumption per household per day outside the city	417 kWh
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

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

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(3 marks)

(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.

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(2 marks)

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

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

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(3 marks)

3 (a) 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}.

Calculate the energy supplied by the wind turbine during this time.

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(3 marks)

(b) A solar panel with a surface area of 1.45 × 10^{-6} km^2 and 44% 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 8.2 hours per day.

Compare the energy supplied by the solar panel and the wind turbine when operating for the same number of hours.

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(2 marks)

(c) 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.

  (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]

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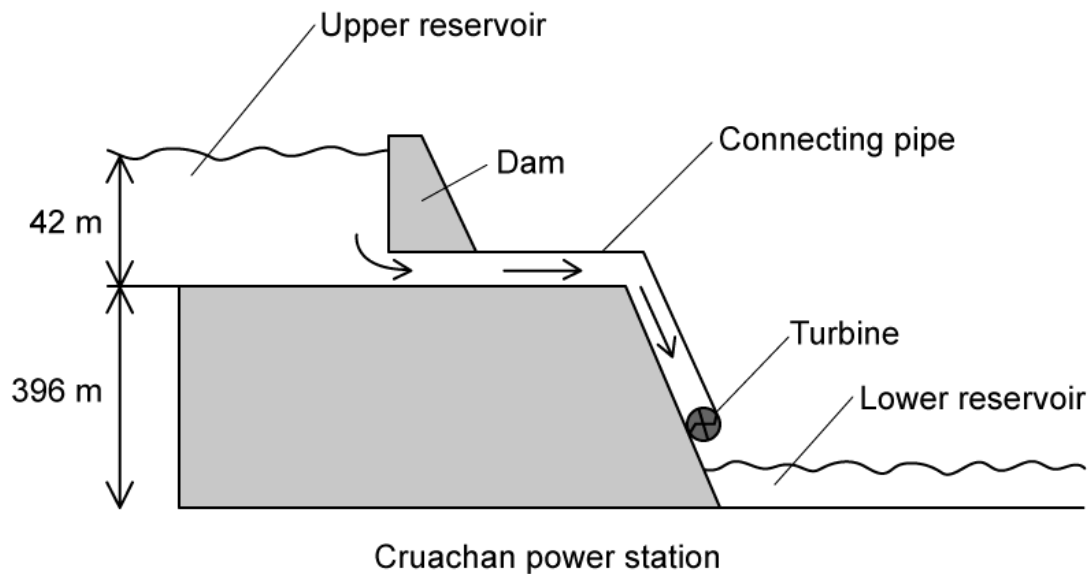
(4 marks)

4 (a) 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 $1.0 \times 10^3 \, \text{kg m}^{-3}$, flows out of the reservoir at $1.5 \times 10^{10} \, \text{cm}^3$ 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.

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

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(3 marks)

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

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

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

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(2 marks)

(b) 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 $8.53 \times 10^{-4}\,\text{W mm}^{-2}$.

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

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.

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

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(4 marks)

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

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(2 marks)