WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 3

PHYSICS



EXAM QUESTION PACK

OPTION D: ENERGY AND THE ENVIRONMENT

SCORE	PERCENTAGE
/80	%

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#1

14. *(a)* (i) Solar energy resources are considered to be renewable resources. State what is meant by a *renewable energy resource*. [1]

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(ii) The proton-proton chain is a set of reactions that take place in our Sun and can be summarised in the following equation.

$$4\,{}^{1}_{1}\mathrm{H} + 2\,{}^{0}_{-1}\mathrm{e} \longrightarrow {}^{4}_{2}\mathrm{He} + 2\nu_e$$

Use data to show that the percentage mass loss is approximately 0.7%. [2]

Mass of ${}^{1}_{1}\mathrm{H}$ = 1.007 28 u

Mass of ${}^{4}_{2}\mathrm{He}$ = 4.001 51 u

Mass of ${}^{0}_{-1}\mathrm{e}$ = 0.000 55 u

Mass of ν_e = 0.000 00 u

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(iii) The Sun can be assumed to have come to the end of its life when it has lost 0.7 % of its mass to radiated energy. Estimate the lifetime of the Sun in years. Take the mass of the Sun to be 2.0×10^{30} kg and assume it to have a constant power output of 3.8×10^{26} W. [2]

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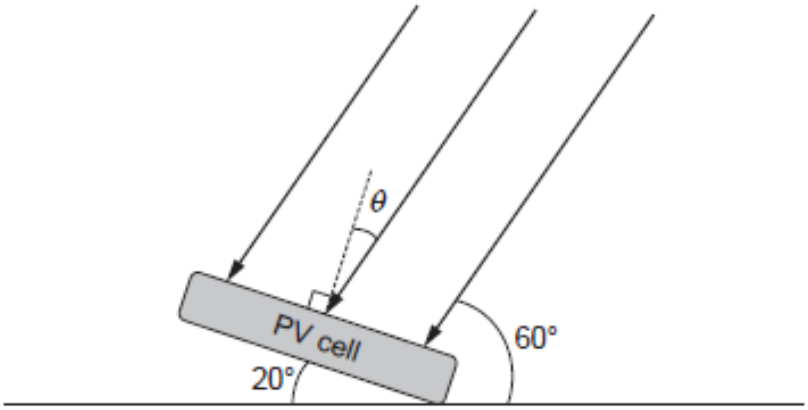
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(b) The power output, P, from a photovoltaic (PV) cell of surface area, A, can be calculated using the equation:

$$P = \mu A I \cos\theta$$

where μ is the conversion efficiency of the cell, I is the intensity of solar radiation and θ is the angle between the normal and the incident sunlight.

Diagram not to scale



A factory decides to install rooftop PV cells at an angle of 20° to the horizontal. At midday when the Sun's elevation is 60° the solar radiation incident upon the surface of the Earth has an intensity of 600 W m^{-2}. An individual PV cell has a conversion efficiency of 20% and is found to produce a power output of 150 W.

(i) Show that the area of the PV cell is approximately 1.3 m^2. [2]

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(ii) The factory roof covers an area of 3.6×10^4 m^2 and the factory owner plans for the installation to produce a mean power output of 4.0 MW. It is suggested that the company should install 27 500 of these PV cells. Discuss whether or not you believe this to be suitable. [3]

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(c) (i) Describe what is meant by the *enrichment* of uranium and explain why it is necessary. [2]

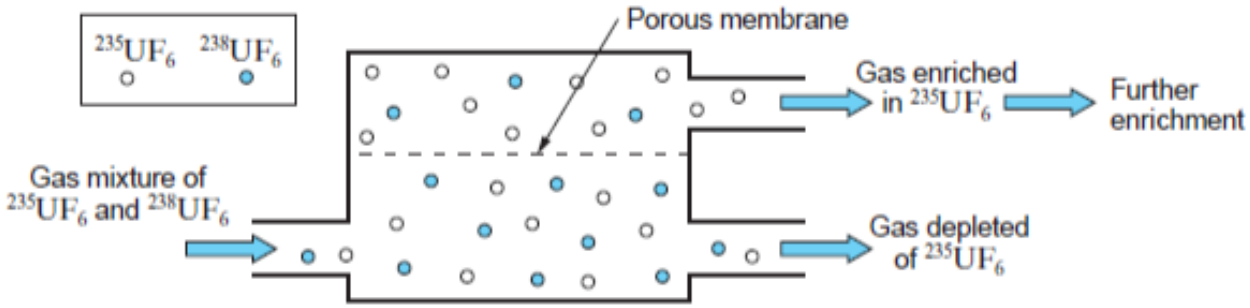
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(ii) Gaseous diffusion was one of the original methods used to enrich uranium fuel. Uranium hexafluoride gas composing of $^{235}UF_6$ and $^{238}UF_6$ moves from a region of high pressure to a region of low pressure through a porous membrane. The lighter and faster $^{235}UF_6$ molecules diffuse through the membrane at a greater rate.

The first stage of the enrichment process is shown below.



During this stage, the mixture is enriched by a factor that can be calculated using:

$$\text{enrichment factor} = \sqrt{\frac{\text{molar mass of } ^{238}UF_6}{\text{molar mass of } ^{235}UF_6}}$$

Use the equation and data below to show that the uranium hexafluoride gas would need to complete more than 450 stages if it is to increase the concentration of uranium-235 from 0.7% to 5%. [3]

Molar mass of $^{235}UF_6$ = 349g mol^{-1}

Molar mass of $^{238}UF_6$ = 352g mol^{-1}

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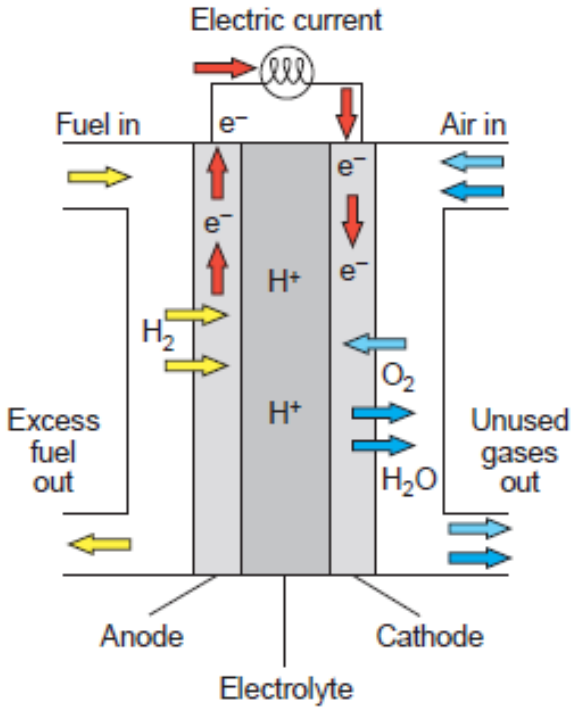
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(iii) State an alternative method for the enrichment of uranium. [1]

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(d) A method of reducing CO_2 emissions involves the use of fuel cells to power cars. The basic layout for a *proton exchange membrane fuel cell* is shown in the diagram below.



(i) Describe the purpose of the electrolyte and state the waste product from the reaction. [2]

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(ii) In order for the fuel cell to be considered to have no CO_2 emissions, the sourcing of the hydrogen fuel must be considered. Two possible sources are:

- Electrolysis of water – where electrical energy is used to split water molecules to create hydrogen and oxygen;
- Reforming fossil fuels – where steam at high temperature is reacted with a fossil fuel to separate the hydrogen from the carbon in a hydrocarbon.

Discuss their likely impact on CO_2 emissions. [2]

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Question taken from Eduqas examination paper 842103, June 2019

#2

14. *(a)* (i) State the principle of Archimedes. [1]

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(ii) The Greenland ice sheet is estimated to have an area of 1.5×10^6 km^2 and a mean thickness of 2.1 km.

I. Show that the mass of the Greenland ice sheet is approximately 3×10^{18} kg.
[Density of ice = 920 kg m^{-3}] [2]

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II. Scientists predict that sea levels would rise by about 8 metres if all the Greenland ice sheet were to melt. Use the following information to justify their prediction. [2]
[Density of water = 1000 kg m^{-3};
Surface area of ocean on Earth = 3.6×10^8 km^2]

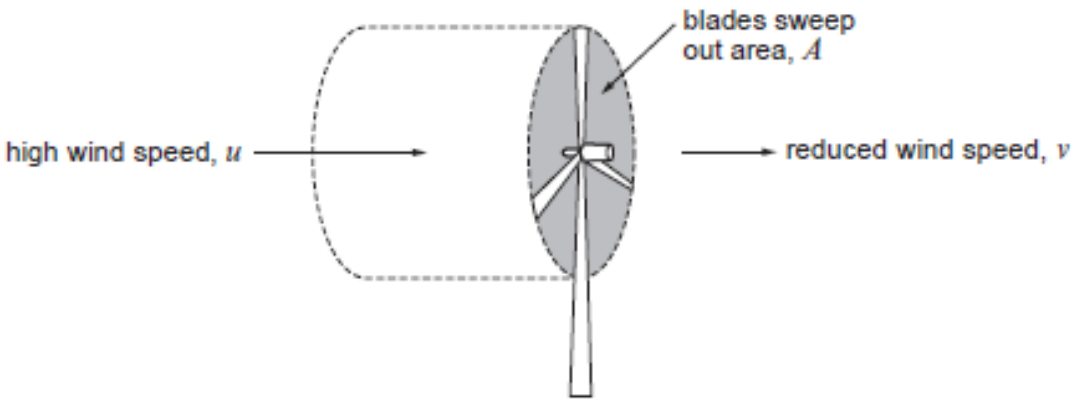
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(b) Wind turbines convert as much as possible of the kinetic energy of the air that moves through the area swept out by the blades into electrical energy.



(i) Show that the kinetic energy per second (the power, P) arriving at the blades per second can be given by:

$$P = \frac{1}{2} A \rho u^3$$

where ρ is the density of the air. [2]

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(ii) Use the above equation to determine whether doubling the length of the blades or doubling the wind speed would have the greater effect on the power available to be converted into electrical energy. [2]

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(iii) A wind turbine has blades of length 30 m. Wind of speed $8.0\,m\,s^{-1}$ arrives at the blades, which is reduced to $5.0\,m\,s^{-1}$ after passing through the blades. Calculate the maximum possible efficiency of this wind turbine. [Density of air = $1.2\,kg\,m^{-3}$]. [3]

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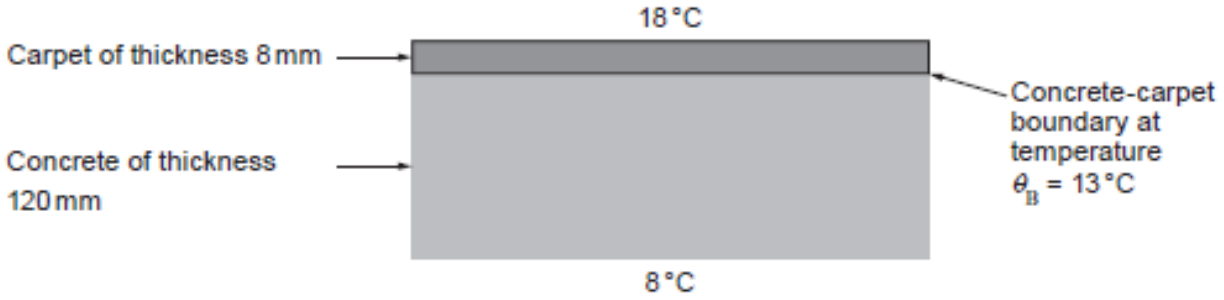
(iv) Explain why the actual efficiency of the turbine is less than your answer to *(b)*(iii). [1]

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(c) (i) Use an appropriate equation to show that the unit of the coefficient of thermal conductivity, K, is $\mathrm{W\,m^{-1}\,K^{-1}}$. [2]

(ii) One room in a house has a floor made of concrete of thickness 120 mm covered by a carpet of thickness 8 mm. The temperature at the upper surface of the carpet is 18 °C and that of the lower surface of the concrete is 8 °C. Show that, under these conditions, the temperature (θ_B), at the concrete-carpet boundary is 13 °C.
[Assume $K_{concrete} = 0.9\,\mathrm{W\,m^{-1}\,K^{-1}}$ and $K_{carpet} = 0.06\,\mathrm{W\,m^{-1}\,K^{-1}}$]. [3]



(iii) Without the carpet, thermal energy is conducted through the concrete floor (of dimensions 6 m × 8 m) at a rate of 3.6 kW. The carpet manufacturer claims that fitting the carpet would reduce the rate at which energy is transferred by about 50%. Use the above conditions to test their claim. [2]

Question taken from Eduqas examination paper 842103, June 2018

#3

(a) (i) The total power emitted by the Sun is 3.8×10^{26} W. Calculate the intensity of radiation received at the upper atmosphere of planet Earth and state the name given to this value. The distance between the Earth and the Sun is 1.5×10^{11} m. [2]

(ii) A student models the energy balance of planet Earth without its atmosphere. He calculates the theoretical power absorbed by the Earth to be 1.2×10^{17} W. Assuming the Earth to be in thermal equilibrium and to behave as a black body, show that the temperature of the Earth for this model is approximately 250 K. The radius of the Earth is 6.4×10^{6} m. [3]

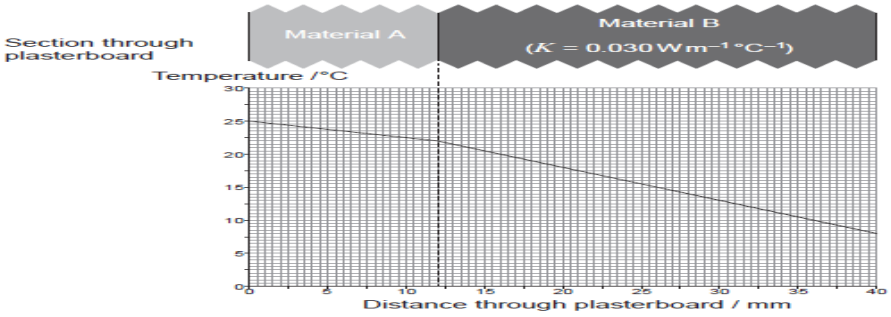
(iii) The actual mean surface temperature of the Earth is 287 K. Without calculation, account for this difference in temperature and explain how human activity has further contributed to this. [3]

(b) (i) State and explain the three conditions that are simultaneously required to produce a sustainable fusion reaction. [3]

(ii) A fusion test reactor requires a triple product greater than 3.5×10^{28} s K m^{-3}. The plasma has a volume of 70 m^3 and contains 2.4×10^{22} particles. If a confinement time of 0.9 seconds is achieved, determine the minimum temperature necessary for this reaction. [2]

(c) (i) A company manufactures thermal plasterboards using a composite of two different materials. One of the materials is known to have a *thermal conductivity value of* $0.030\,W m^{-1}\,°C^{-1}$. Explain what the statement in italics means. [2]

(ii) Jack investigates the thermal properties of a sample of thermal plasterboard. He produces a graph of temperature against distance as shown below.



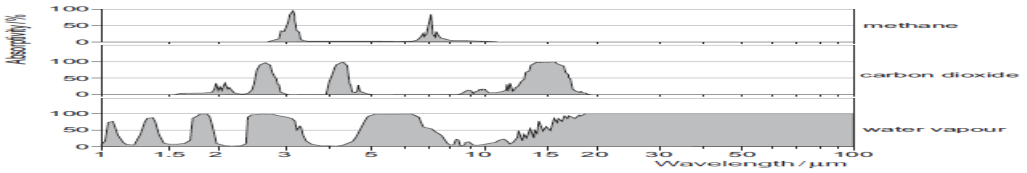
Jack suggests that material **B** has twice the thermal conductivity value of material **A** and that the U-value of the plasterboard is approximately 0.90 W m^{-2} °C^{-1}. Evaluate whether or not Jack's suggestions are correct. [5]

Question taken from Eduqas examination paper 842103, November 2020

#4

(a) (i) Assuming that the Earth emits radiation as a black body at a temperature of 288 K, confirm that the peak wavelength of the radiation emitted by the Earth is in the infra-red part of the electromagnetic spectrum. [2]

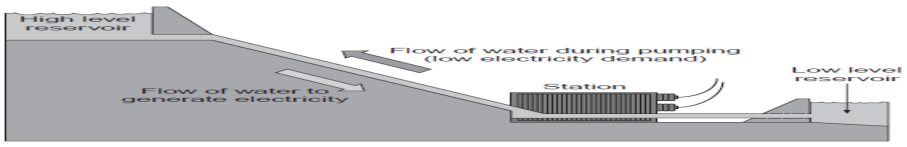
(ii) The graphs below show greenhouse gas absorption spectra for methane (CH_4), carbon dioxide and water vapour as a function of the wavelength of the radiation incident on the gas. An absorptivity of zero % means no radiation is absorbed, whilst an absorptivity of 100 % means that all the incident radiation is absorbed.



I. Make three observations from these graphs regarding absorption of infra-red by these gases. [3]

II. Studies show that the concentration levels of these gases in the atmosphere continue to increase. Choose two of these gases and give one reason as to why the concentration level is increasing for each of your choices. [2]

(b) The diagram shows a pumped storage hydroelectric power station. The station has a power output of 1200 MW and the height difference between the high level reservoir and the turbine units is 420 m.

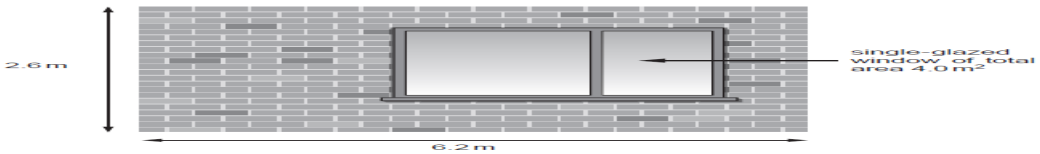


(i) Assuming the generating process is 85 % efficient, calculate the mass of water passing through the turbines per second. [3]

(ii) The power station has a mean **annual** output of 240 GWh of electrical energy. Calculate the mean time during which the power station is in use per day. Give your answer in hours. [2]

(iii) Without considering energy losses, give one reason why this power station would not be able to produce significantly more than 240 GWh of energy per year. [1]

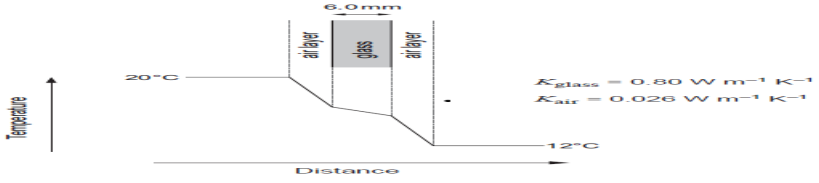
(c) The interior of a house is maintained at a constant temperature of 20 °C. A room in the house has one exterior wall of dimensions 2.6 m × 6.2 m and a window of area 4.0 m^2 as shown.



(i) The rate of heat transfer through the window is 154 W. Calculate the total rate of heat loss from the room when the external temperature on a windless day is 12 °C. [2]

[U_{wall} = 1.6 W m^{-2} K^{-1}]

(ii) The heat loss through the window is kept low by a thin layer of stationary air in contact with the inside and outside of the window. These layers provide insulation. The temperature variation across the region of the window is shown below. The thickness of the window pane is 6.0 mm.



I. Use the rate of heat loss through the window to show that the temperature difference across the glass is approximately 0.3 °C. [2]

II. Calculate the thickness of each of the layers of air. You should assume that the two layers of air have equal thickness. [2]

III. Without calculation, explain how the rate of heat loss through the window would be different if it were a breezy day. [1]

Question taken from Eduqas examination paper 842103, June 2017

Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
14	(a)	(i)	An energy resource that can be replenished in a relatively short space of time e.g. human life time or equivalent OR An energy resource that can be used for a long period of time (1)	1			1		
		(ii)	Mass of LHS $4 \times 1.00728\text{u} + 2 \times 0.00055\text{u} = 4.03022$ $\Delta m = 4.03022 - 4.00151 = 0.02871$ [u] (1) $\frac{0.02871}{4.03022} \times 100 = [0.71\,\%]$ (1)		2		2	2	
		(iii)	Use of $E = mc^2$ i.e. $2 \times 10^{30} \times \frac{0.7}{100} \times (3 \times 10^8)^2 = 1.26 \times 10^{45}$ [J] (1) $t = \frac{E}{P} = \frac{1.26 \times 10^{45}}{3.8 \times 10^{26}} = 3.3 \times 10^{18}$ [s] $= 1 \times 10^{11}$ [years] (1)		2		2	2	
	(b)	(i)	θ used as 10° (1) Manipulation $\rightarrow A = \frac{P}{\mu I \cos\theta} = \frac{150}{0.2 \times 600 \times \cos 10°}$ $= 1.27$ [m²] (1)		2		2	2	
		(ii)	**Award (1) mark for calculation and (1) mark for 'suitable' supporting comment** $\frac{3.6 \times 10^4}{1.27} = 28\,000$ cells ∴ roof has large enough area for recommended no. of cells OR $\frac{4 \times 10^6}{150} = 27000$ cells ∴ power output would be large enough with recommended no. of cells OR $\frac{4 \times 10^6}{27\,500} = 145$ W ∴ power output of each cell (150 W) would be large enough with recommended no. of cells. N.B. Accept alternative suitable calculations **Award (1) mark for 'unsuitable' comment referencing power output affected by other factors** e.g. variable cloud cover / daily change in sun's position / seasonal change in sun's position / etc			3	3	1	
	(c)	(i)	Increase concentration of U-235 (relative to U-238) (1) U-235 is fissile whereas U-238 is not [and absorbs neutrons] (1)	2			2		
		(ii)	$\sqrt{\frac{352}{349}} = 1.004$ (1) $0.7\,\%] \times 1.004^n = 5$ [%] (1) Taking logs to find n to be 492 or 459 if $\sqrt{\frac{352}{349}}$ used (1) [If $0.7\% + 1.004^n = 5\%$ used to give an answer of 365 or 340 award 2 marks out of 3]		3		3	3	
		(iii)	[Gas] centrifuge Accept alternative e.g. Laser isotope/liquid thermal diffusion	1			1		
	(d)	(i)	Allows only positive H ions through it to the cathode meaning negative electrons must travel along external circuit producing power (1) Waste product: Water (1)	2			2		
		(ii)	Electrolysis of water argument dependent on how electrical energy is produced e.g. gas fired power contributes to CO_2 emissions whereas PV cells do not (1) Reforming fossil fuels releases carbon which could in turn be released into atmosphere as CO_2 or comment regarding carbon capture (1)			2	2		
			Question 14 total	**6**	**9**	**5**	**20**	**10**	**0**

#2

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14	*(a)*	(i)		Object totally or partially immersed in a fluid (accept liquid or gas) is buoyed (accept lifted, upward force, upthrust) by a force equal to the weight of the displaced fluid	1			1		
		(ii)	(I)	Volume = $1.5 \times 10^6 \times 2.1 = 3.15 \times 10^6$ km^3 and correct conversion of units seen (e.g 3.15×10^{15} m^3) (1) Mass = $920 \times 3.15 \times 10^{15} = 2.9 \times 10^{18}$ kg seen (1)		2		2	2	
			(II)	Volume of water produced = $\frac{2.9 \times 10^{18}}{10^3}$ (= 2.9×10^{15} m^3) (1) (accept 3.0×10^{15} m^3 if value given used) Sea level rise = $\frac{2.9 \times 10^{15}}{3.6 \times 10^{14}}$ = 8.05 (m) (seen) (or 8.3 if 3.0×10^{18} kg used) (1)			2	2	2	
	(b)	(i)		Mass of air (per second) = $\rho A u$ (1) Convincing substitution into ½ mu^2 (1)	2			2		
		(ii)		Doubling blade length will increase power by a factor of 4 (accept 2^2) (1) Doubling speed will increase power by a factor 8 (accept 2^3) (1)		2		2		
		(iii)		**Either** Correct substitution and power calculated for either input or output power: i.e. input P = 0.87 MW, Output P = 0.21 MW Or $P_{IN} = \frac{1}{2}\pi \times 30^2 \times 1.2 \times (8^3 - 5^3)$ (1) P_{IN} calculated (0.87 – 0.21 = 0.66) (1) (ecf for either or both powers]. % efficiency = $(\frac{0.66}{0.87}) \times 100$ = 75.9% [accept 76%, 0.759 or 0.76](1)		3		3	2	
		(iv)		Friction between moving parts (in the turbine). Don't accept 'heat', 'sound'.			1	1		
	(c)	(i)		All units correctly identified: $\frac{\Delta Q}{\Delta t}$: J s^{-1}; A: m^2 ;$\frac{\Delta \theta}{\Delta x}$: K m^{-1} (1) Correct substitution and convincing algebra (1)	2			2		
		(ii)		Understanding shown that heat flow through both materials is the same (even if substitution below incorrect) (1) **Either** $\frac{0.06 \times A \times (18 - \theta_B}{8} \frac{0.9 \times}{120} \times (\theta_B - 8$ (1) Convincing algebra to show θ_B = 13 °C (1) Or With 13 °C: Carpet heat flow/m^2 = 37.5 W m^{-2} or Concrete heat flow / m^2 = 37.5 W m^{-2} (1) Other heat flow shown to be the same, thus confirming (1)	1	1 1		3	2	
		(iii)		Either carpet: $\frac{\Delta Q}{\Delta t} = \frac{0.06 \times 48 \times 5}{0.008}$ [or 48 × 37.5] or concrete: $\frac{\Delta Q}{\Delta t} = \frac{0.9 \times 48 \times 5}{0.12}$ [or 48 × 37.5] (1) = 1.8 kW = 50% ∴ claim verified (1)			2	2	2	
				Question 14 total	**6**	**9**	**5**	**20**	**10**	**0**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	$I = \frac{P}{A} = \frac{3.8\times10^{26}}{4\pi(1.5\times10^{11})^2} = 1\,344$ [W m^{-2}] (1) Solar constant (1)	1	1		2	1	
		(ii)	Use of $P = \sigma AT^4$ (1) Manip and sub to give $T = \sqrt[4]{\frac{P}{\sigma A}} = \sqrt[4]{\frac{1.2\times10^{17}}{5.67\times10^{-8}\times4\pi\times(6.4\times10^6)^2}}$ (1) 253 [K] (answer seen) (1)		3		3	3	
		(iii)	Atmosphere and the greenhouse effect (1) Burning fossils fuels/increased livestock farming increase CO_2/methane (1) More IR absorbed (1)		3		3		
	(b)	(i)	High enough temperatures to overcome coulomb repulsion (1) High enough particle density to allow high enough collision rate (1) Long enough confinement time [for more output/reactions] (1)	3			3		
		(ii)	$3.5 \times 10^{28} = \frac{2.4\times10^{22}}{70} \times T \times 0.9$ (1) $T = 1.13 \times 10^8$ [K] (1)		2		2	2	
	(c)	(i)	[Rate of flow of heat is] 0.030 J s^{-1} (or W) through an area of 1 m^2 (1) when the temperature gradient is 1 K m^{-1}(1) **Alternative:** (Rate of heat flow is) 0.030 J s^{-1} (or W) per unit cross-sectional area (1) per unit temperature gradient (1)	2			2		
		(ii)	Gradients calculated: A = [-]0.25 and B = [-]0.5 [°C/mm] (1) Heat flow per unit area same through both materials so temperature gradient $\alpha \frac{1}{K}$ or K × temp gradient = constant (1) Material A has 2× thermal conductivity of material B ∴ suggestion is incorrect (1) Use of B's gradient to find $\frac{P}{A} = 0.030 \times 0.5 \times 10^3 = 15$ W m^{-2} and $U = \frac{P}{A\Delta\theta} = \frac{15}{17}$ or use of thermal resistance (1) = 0.88 W m^{-2} K^{-1} ∴ suggestion is correct or too high as there is no consideration of stationary air layers (1)			5	5	4	
			Question total	**6**	**9**	**5**	**20**	**10**	**0**

#4

Question				Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)		Use of Wien' law or correct substitution [$\lambda = \frac{0.0029}{288}$] (1) λ = 10.1 μ[m] and confirmation statement (1)			2	2	1	
		(ii)		**Any 3 ×(1) from:** • All gases absorb in IR region (or between 1 μm at 20 μm) • Methane absorbs strongly at 3 μm and 8 μm / has two peaks • CO_2 - Isolated peaks at 2 / 2.5 / 4 and 15 μm • CO_2 - Complete 'blockout' between 5 and 8 μm • H_2O - Numerous peaks between 1 and 10 μm **General comparison with no numerical data award max of 1 mark**			3	3		
		(iii)		**Any 2 ×(1) from:** CO_2 – Burning fossil fuels or deforestation (answer must imply increase as consequence of human activity e.g. more cars etc) CH_4 – Increased agriculture or melting permafrost H_2O – Melting ice caps (or global warming – more evaporation)	2			2		
	(b)	(i)		Correct attempt (without efficiency) at $mg\Delta h = 120 \times 10^6$ (1) Correct use of efficiency e.g. $m = \frac{120 \times 10^6}{0.85 \times 9.81 \times 420}$ (1) $m = 3.4 \times 10^4$ [kg s^{-1}] (1)	1	1 1		3	3	
		(ii)		$t = \frac{E}{P}$ i.e. $\frac{240 \times 10^9}{365 \times 120 \times 10^6}$ or t = 2000 hrs /yr seen (1) t = 5.5 hrs per day (1)	1	1		2	1	
		(iii)		Limited by amount of water available in upper lake / time taken to pump water up	1			1		
	(c)	(i)		$\frac{Q}{t}$ = 1.6 × (16.12 – 4) × 8 + 154 (1) $\frac{Q}{t}$ = 309.14 [W] (1)		2		2	2	
		(ii)	I	$154 = \frac{(0.8 \times 4 \times \Delta\theta)}{6 \times 10^{-3}}$ (1) $\Delta\theta$ = 0.29 [°C] seen (1)		2		2	2	
			II	Inside air/glass boundary temp calculated to be = 16.15 °C **or** outside glass/air boundary temp to be 15.85 °C **or** $\Delta\theta$ for air = 3.85 °C (1) Correct use of thermal conduction equation to show thickness of air = 2.6 [mm] e.g. $154 = \frac{(4 \times 0.026 \times (20 - 16.5))}{x}$ (1) **Alternative:** $\Delta\theta$ across total air layers = (20 – 8 – 0.3) °C [= 7.7 °C] (1) Correct use of thermal conduction equation e.g. $154 = \frac{(4 \times 0.026 \times 7.7)}{2x}$ (1)		2		2	1	
			III	Rate of heat loss would increase due to removal of insulating (air) layer(s) (or $\Delta\theta$ for glass greater without air layers / greater temperature gradient). Accept appropriate calculation.	1			1		
				Question total	**6**	**9**	**5**	**20**	**10**	**0**