

1. What is the phenomenon that best explains why greenhouse gases absorb infrared radiation?
 A. Resonance
 B. Interference
 C. Refraction
 D. Diffraction

(Total 1 mark)

2. In which of the following places will the albedo be greatest?
 A. A forest
 B. A grassland
 C. An ocean
 D. A polar ice cap

(Total 1 mark)

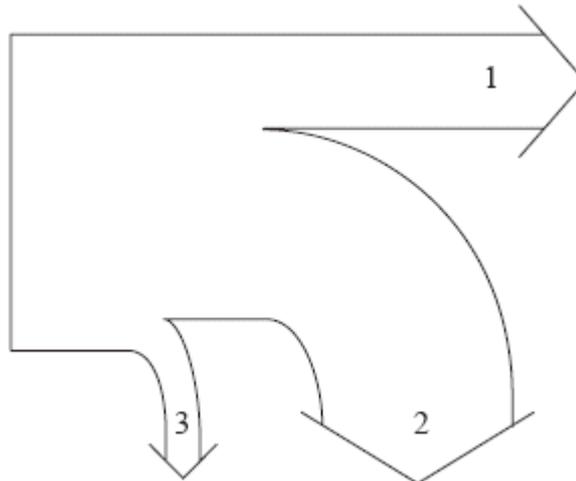
3. A wind turbine produces a power P when the wind speed is v . Assuming that the efficiency of the turbine is constant, the best estimate for the power produced when the wind speed becomes $2v$ is
 A. $2P$.
 B. $4P$.
 C. $6P$.
 D. $8P$.

(Total 1 mark)

4. The design of a nuclear power station includes an electrical generator. The function of the generator is to convert
 A. nuclear energy to kinetic energy.
 B. kinetic energy to thermal energy.
 C. thermal energy to electrical energy.
 D. kinetic energy to electrical energy.

(Total 1 mark)

5. The Sankey diagram of a fossil-fuelled power station is shown below.



Which of the following best identifies the thermal energy removed by water and the useful electrical energy output of the station?

	Thermal energy removed	Useful electrical energy output
A.	2	1
B.	2	3
C.	3	1
D.	1	2

(Total 1 mark)

6. Which of the following processes leads to the production of a nucleus of plutonium-239 from a nucleus of uranium-238?
- A. Neutron capture by uranium nucleus
 - B. Radioactive decay of uranium nucleus
 - C. Electron capture by uranium nucleus
 - D. Nuclear fission of uranium nucleus

(Total 1 mark)

7. A thermal power station is 20 % efficient and generates useful electrical power at 1000 MW. The fossil fuel used has an energy density of 50 MJ kg^{-1} . The mass of fuel in kg consumed every second is given by which of the following?
- A. 0.01
 - B. 0.25
 - C. 4
 - D. 100

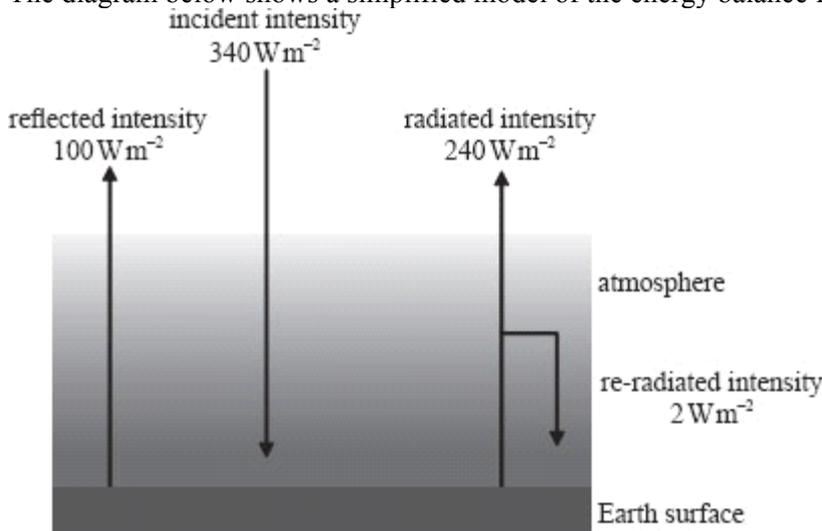
(Total 1 mark)

8. Which of the following correctly describes both the role of the moderator and of the control rods in a nuclear reactor?

	Moderator	Control rods
A.	slows down the neutrons	maintain a constant rate of fission
B.	cools down the reactor	extract thermal energy
C.	cools down the reactor	maintain a constant rate of fission
D.	slows down the neutrons	extract thermal energy

(Total 1 mark)

9. The diagram below shows a simplified model of the energy balance for Earth.

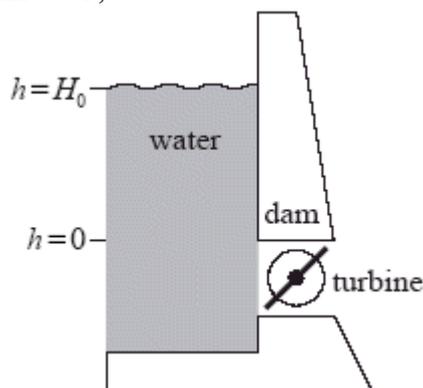


The albedo of the Earth according to this model is equal to

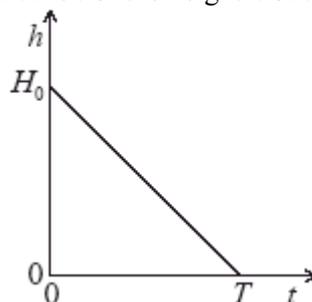
- A. $\frac{2}{340}$
- B. $\frac{100}{340}$
- C. $\frac{238}{340}$
- D. $\frac{240}{340}$

(Total 1 mark)

10. The water in a reservoir behind a dam drops from an initial height H_0 above a turbine to produce hydroelectricity. At time $t = T$, $h = 0$.



The graph shows the variation with time t of the height h of the water above the turbine.

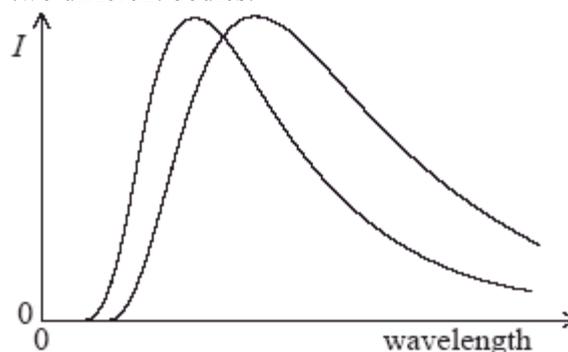


Which of the following is a measure of the maximum theoretical electric power available?

- A. H_0 and the slope of the graph
- B. T and the slope of the graph
- C. T and the area under the graph
- D. H_0 and the area under the graph

(Total 1 mark)

11. The diagram shows the variation with wavelength of the power per unit wavelength I radiated from an area of 1 m^2 of two different bodies.



Which of the following is a correct comparison of the temperature and of the emissivity of the two bodies?

	Temperature	Emissivity
A.	same	same
B.	same	different
C.	different	same
D.	different	different

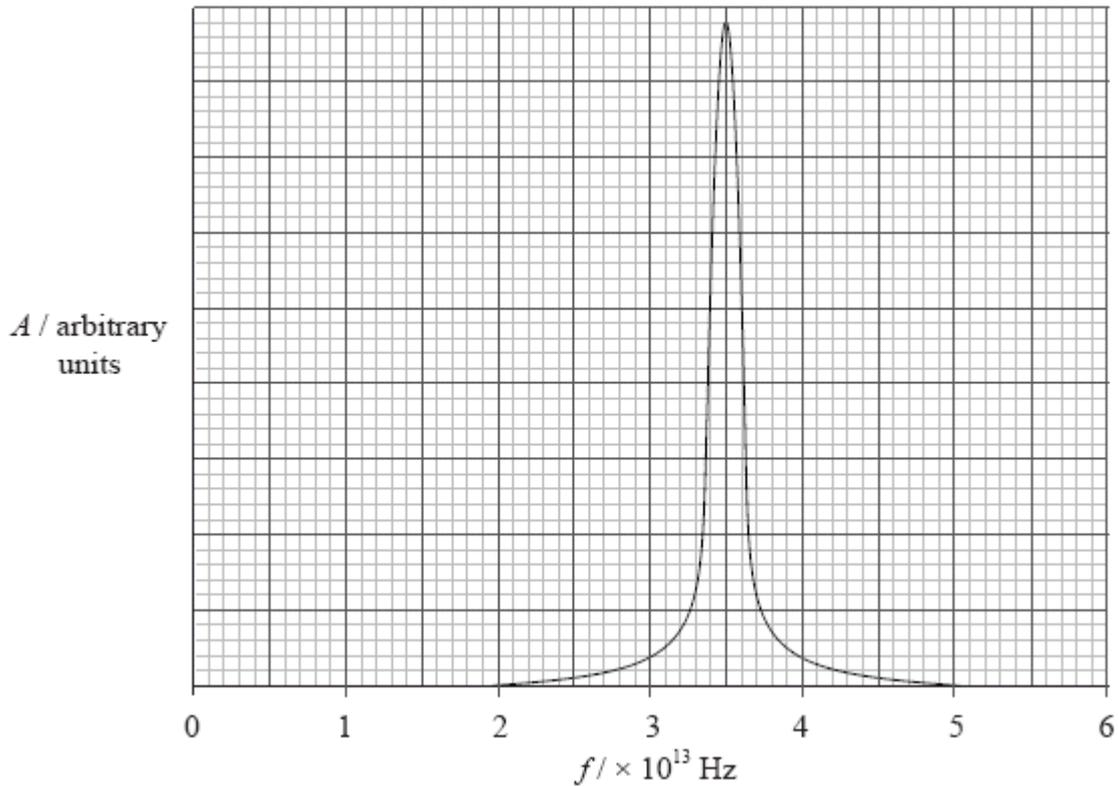
(Total 1 mark)

12. Critical mass refers to the amount of fissile material that
- A. will allow fission to be sustained.
 - B. is equivalent to 235 g of uranium.
 - C. will produce a growing chain reaction.
 - D. is the minimum mass necessary for fission to take place.

(Total 1 mark)

13. This question is about greenhouse effect

- (a) The graph shows part of the absorption spectrum of nitrogen oxide (N_2O) in which the intensity of absorbed radiation A is plotted against frequency f .



- (i) State the region of the electromagnetic spectrum to which the resonant frequency of nitrogen oxide belongs.

.....

(1)

- (ii) Using your answer to (a)(i), explain why nitrogen oxide is classified as a greenhouse gas.

.....

(2)

- (b) Define *emissivity* and *albedo*.

Emissivity:

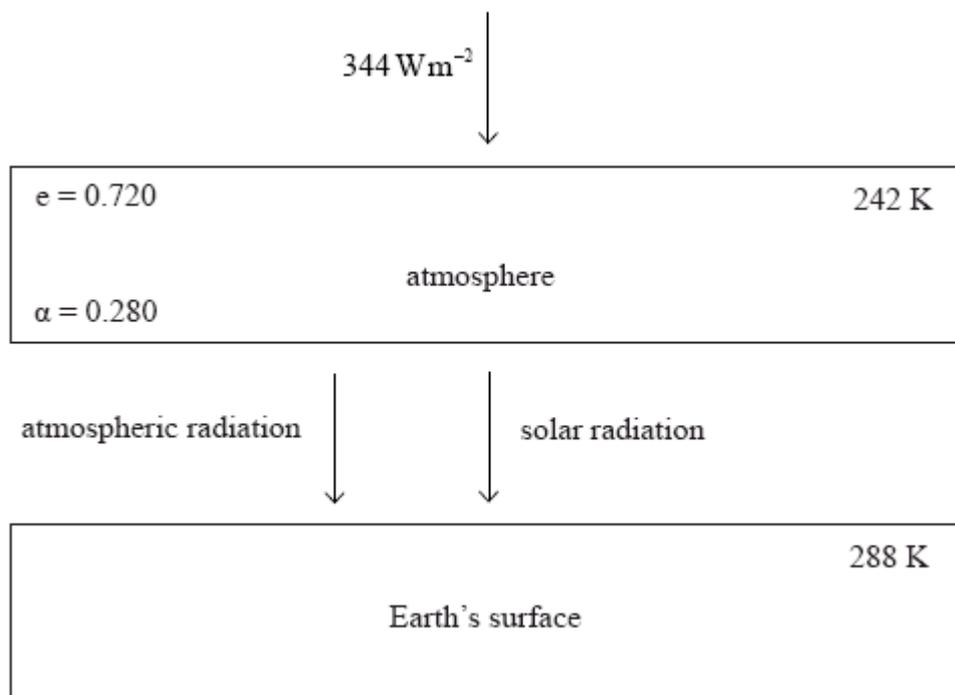
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Albedo:

.....

(3)

- (c) The diagram shows a simple energy balance climate model in which the atmosphere and the surface of Earth are two bodies each at constant temperature. The surface of the Earth receives both solar radiation and radiation emitted from the atmosphere. Assume that the Earth's surface behaves as a black body.



The following data are available for this model.

average temperature of the atmosphere of Earth	= 242 K
emissivity, e of the atmosphere of Earth	= 0.720
average albedo, α of the atmosphere of Earth	= 0.280
solar intensity at top of atmosphere	= 344 W m^{-2}
average temperature of the surface of Earth	= 288 K

Use the data to show that the

- (i) power radiated per unit area of the atmosphere is 140 W m^{-2} .

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(2)

- (ii) solar power absorbed per unit area at the surface of the Earth is 248 W m^{-2} .

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(1)

- (d) It is hypothesized that, if the production of greenhouse gases were to stay at its present level then the temperature of the Earth’s atmosphere would eventually rise by 6.0 K.

Calculate the power per unit area that would then be

- (i) radiated by the atmosphere.

.....
.....

(1)

- (ii) absorbed by the Earth’s surface.

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.....

(1)

- (e) Estimate, using your answer to (d)(ii), the increase in temperature of Earth’s surface.

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.....
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(3)

(Total 14 marks)

14. This question is about a nuclear reactor.

- (a) Uranium is used as a fuel in a small research nuclear reactor. The concentration of $^{235}_{92}\text{U}$ in a sample of uranium must be increased before it can be used as a fuel.

State the name of the process by which the concentration of $^{235}_{92}\text{U}$ is increased.

.....

(1)

- (b) The reactor produces 24 MW of power. The efficiency of the reactor is 32 %. In the fission of one uranium-235 nucleus 3.2×10^{-11} J of energy is released.

Determine the mass of uranium-235 that undergoes fission in one year in this reactor.

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(4)

- (c) Explain what would happen if the moderator of this reactor were to be removed.

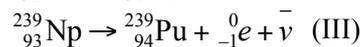
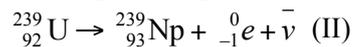
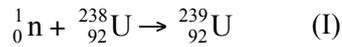
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(3)

- (d) During its normal operation, the following set of reactions takes place in the reactor.



- (i) State the name of the process represented by reaction (II).

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(1)

- (ii) Comment on the international implications of the product of these reactions.

.....

.....

.....

(2)

(Total 11 marks)

Additional Problems

15. Which of the following correctly shows a renewable and a non-renewable source of energy?

	Renewable	Non-renewable
A.	oil	geothermal
B.	wind	biofuels
C.	ocean waves	nuclear
D.	natural gas	coal

(Total 1 mark)

16. The albedo for the oceans is lower than that for glaciers. This is because, compared to ice, sea water

- A. has a greater density.
- B. has a greater specific heat capacity.
- C. has a greater coefficient of volume expansion.
- D. absorbs a greater amount of radiative power.

(Total 1 mark)

17. Degraded energy is energy that is

- A. stored in the Earth's atmosphere.
- B. available from non-renewable energy sources.
- C. converted into work in a cyclical process.
- D. no longer available for the performance of useful work.

(Total 1 mark)

18. Greenhouse gases

- A. reflect infrared radiation but absorb ultraviolet radiation.
- B. reflect ultraviolet radiation but absorb infrared radiation.
- C. transmit infrared radiation but absorb ultraviolet radiation.
- D. transmit ultraviolet radiation but absorb infrared radiation.

(Total 1 mark)

19. This question is about fossil fuels and the greenhouse effect.

(a) State **two** reasons why most of the world’s energy consumption is provided by fossil fuels.

- 1.
- 2.

(2)

(b) A power station has an output power of 500 MW and an overall efficiency of 27 %. It uses natural gas as a fuel that has an energy density of 56 MJ kg⁻¹.

(i) Define *energy density*.

.....

(1)

(ii) Determine the rate of consumption of natural gas in the power station.

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.....
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(3)

(c) Outline why the enhanced greenhouse effect may result in an increase in the temperature of the Earth’s surface.

.....
.....
.....

(3)

(d) (i) The solar intensity at the position of the Earth is 1380 W m⁻². The average albedo of Earth is 0.300. State why an average value of albedo is quoted.

.....

(1)

(ii) Show that the average reflected intensity from the Earth is about 100 W m⁻².

.....
.....
.....

(4)

- (e) One of the expected results of global warming is an increased sea level. The increase in volume ΔV for a temperature increase ΔT is given by $\Delta V = \gamma V \Delta T$. Show, using the following data, that the resulting rise in sea level is about 0.5 m.

Temperature increase = 2.0 °C
 Surface area of oceans on Earth = $3.6 \times 10^8 \text{ km}^2$
 Average ocean depth = 3.0 km
 $\gamma = 8.8 \times 10^{-5} \text{ K}^{-1}$

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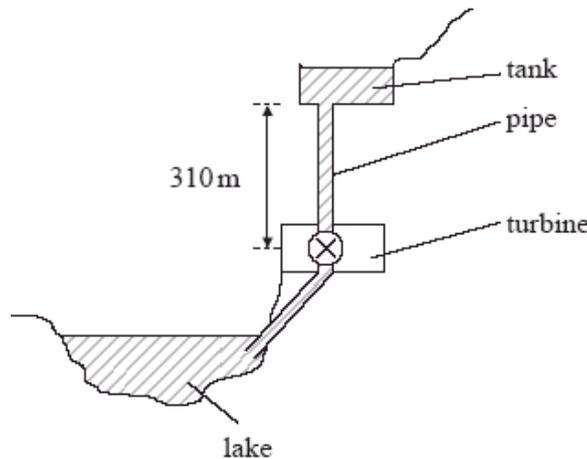
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(2)
(Total 16 marks)

20. This question is about a pumped-storage power station.

- (a) The diagram, not to scale, shows a pumped-storage power station used for the generation of electrical energy.



Water stored in the tank is allowed to fall through a pipe to a lake via a turbine. The turbine is connected to an electrical generator. The pumped-storage ac generator system is reversible so that water can be pumped from the lake to the tank.

The tank is 50 m deep and has a uniform area of $5.0 \times 10^4 \text{ m}^2$. The height from the bottom of the tank to the turbine is 310 m. The density of water is $1.0 \times 10^3 \text{ kg m}^{-3}$.

- (i) Show that the maximum energy that can be delivered to the turbine by the falling water is about $8 \times 10^{12} \text{ J}$.

.....

.....

(3)

- (ii) The flow rate of water in the pipe is $400 \text{ m}^3 \text{ s}^{-1}$. Calculate the power delivered by the falling water.

.....

.....

(2)

(b) The energy losses in the power station are shown in the following table.

Source of energy loss	Percentage loss of energy
friction and turbulence of water in pipe	27
friction in turbine and ac generator	15
electrical heating losses	5

(i) Calculate the overall efficiency of the conversion of the gravitational potential energy of water in the tank into electrical energy.

.....

(1)

(ii) Sketch a Sankey diagram to represent the energy conversion in the power station.

(2)

(c) The electrical power produced at the power station is transmitted by cables to the consumer.

(i) Outline how the energy losses in transmission are minimized.

.....

(3)

(ii) State **one** advantage and **one** disadvantage that a pumped-storage system has compared to a tidal water storage system.

Advantage:

.....

Disadvantage:

.....

(2)

(Total 13 marks)

Mark Scheme

1. A 3. D 5. A 7. D 9. B 11. D
2. D 4. D 6. A 8. A 10. A 12. A
13. (a) (i) infrared; 1
- (ii) nitrogen dioxide in the atmosphere will readily absorb infrared radiation radiated from the surface of Earth / *OWTTE*; and re-radiate the energy in random directions (so preventing the energy radiated from Earth escaping into space); 2
- (b) *emissivity*:
the ratio of energy/power emitted (per unit area) of a body; to the energy/power emitted (per unit area) of a black body of the same dimensions at the same temperature;
- or*
- ratio of power emitted by a body; to the power emitted if it were a black body;
- albedo*:
the fraction of energy/power incident in a surface that is reflected / *OWTTE*;
Allow answers that define in terms of the albedo of Earth. 3
- (c) (i) power per unit area = $e\sigma T^4$;
= $0.720 \times 5.67 \times 10^{-8} \times 242^4$;
= 140 W m^{-2} 2
- (ii) = 0.720×344 ;
= 248 W m^{-2} 1
- (d) (i) new power radiated by atmosphere = $[0.720 \times 5.67 \times 10^{-8} \times 248^4]$
= 154 W m^{-2} ; 1
- (ii) new power absorbed by Earth = $(154 + 248) = 402 \text{ W m}^{-2}$; 1
- (e) $402 = 5.67 \times 10^{-8} \times T^4$;
 $T = 290\text{K}$;
to give $\Delta T = 2\text{K}$; 3
- [14]**

14. (a) enrichment; 1
- (b) power produced $\left(\frac{24}{0.32}\right) = 75 \text{ MW}$;
 energy produced in a year $(75 \times 10^6 \times 365 \times 24 \times 60 \times 60 =) 2.37 \times 10^{15} \text{ J}$;
 number of reactions required in one year $\left(\frac{2.37 \times 10^{15}}{3.2 \times 10^{-11}}\right) = 7.39 \times 10^{25}$;
 mass used $(7.39 \times 10^{25} \times 235 \times 1.66 \times 10^{-27}) \approx 29 \text{ kg}$ 4
- or*
- mass used $\left(\frac{7.39 \times 10^{25}}{6.02 \times 10^{23}} \times 235 \times 10^{-3}\right) = 29 \text{ kg}$;
- (c) the neutrons would not be slowed down;
 therefore they would not be/have less chance of being captured/induce fission;
 so (much) less/no power would be produced; 3
- (d) (i) beta decay; 1
- (ii) the reactions end up producing plutonium (from uranium 238);
 (this isotope of) plutonium may be used to manufacture nuclear
 weapons / can be used as fuel in other reactors / plutonium
 is extremely toxic;
- or*
- the products of the reactions are radioactive for long periods
 of time / *OWTTE*;
 therefore posing storage/safety problems; 2
 [11]
- Additional problems**
15. C [1]
16. D [1]
17. D [1]
18. D [1]
19. (a) wide availability / a great deal available;
 ease of transportation;
 power stations can be built close to the source;
 high energy density; 2 max

- (b) (i) the energy that can be liberated per kg/stored per kg;

1

(ii) $Eff = \frac{500}{P_{in}};$

$$P_{in} = \left[\frac{500}{0.27} \right] = 1900 \text{ (MW)};$$

$$\text{rate} = \left[\frac{1900}{56} \right] = 33 \text{ kg s}^{-1} \text{ or } 34 \text{ kg s}^{-1};$$

3

Award [3] for correct answer if the first marking point is omitted.

- (c) (because of increased greenhouse gases) atmosphere absorbs more (IR) energy and heats up;
-
- atmosphere radiates in all directions;
-
- Earth's surface absorbs some of this extra (IR) radiation hence temperature increases;

3

Award [2 max] if no indication made to re-radiation in all directions either by "all directions" in second marking point or by "some" in third marking point.

- (d) (i) different surfaces absorb/reflect different intensities;

1

- (ii) radiation intercepted by cross section of Earth
- $\pi r^2 \times 1380$
- ;
-
- this is distributed over surface of Earth
- $4\pi r^2$
- ;

$$\text{therefore, radiation incident} = \frac{\pi r^2}{4\pi r^2} 1380 = 345 \text{ W m}^{-2};$$

$$\text{intensity of reflected radiation} = 0.300 \times 345;$$
$$= 104 \text{ (100) W m}^{-2}$$

4

Award [1] for the use of 0.300×1380 .

- (e)
- $\Delta V = \gamma V \Delta T = 8.8 \times 10^{-5} \times 3.6 \times 10^{14} \times 3.0 \times 10^3 \times 2.0$
- ;

$$h = \frac{1.9 \times 10^{14}}{3.6 \times 10^{14}};$$

$$= 0.53 \text{ (0.5) m}$$

2

[16]

- 20.**
- (a) (i) mass =
- $50 \times 5.0 \times 10^4 \times 10^3$
- ;
-
- loss in gpe =
- $50 \times 5.0 \times 10^4 \times 10^3 \times 310 \times 9.81$
- ;
-
- Accept use of 335 m (including centre of mass of tank water)*
-
- accept $g = 10$.*

$$7.6 \times 10^{12} \text{ (J)};$$

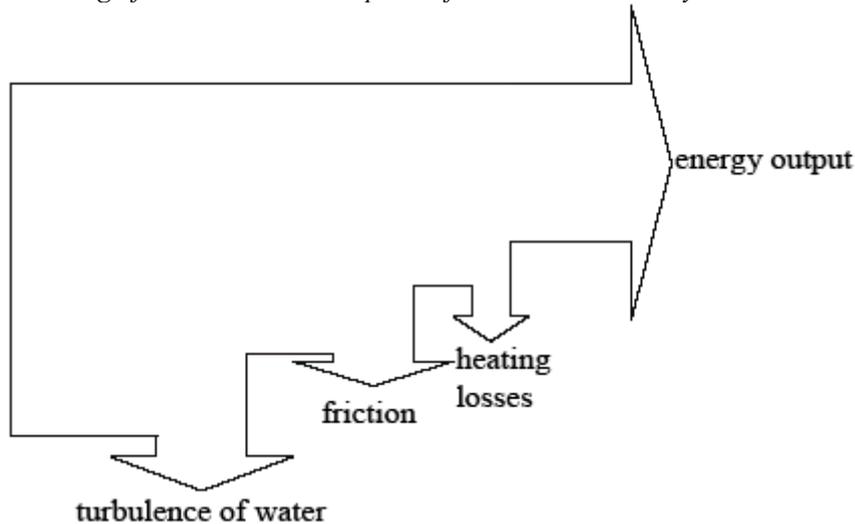
$$\approx 8 \times 10^{12} \text{ (J)}$$

3

Do not penalize if the first marking point is incorporated into the second marking point.

- (ii) flows for 6250 s;
 $1.2 \times 10^9 \text{ W}$ *or* $1.3 \times 10^9 \text{ W}$;
Accept solution from (a)(i) or from flow rate.

- (b) (i) 53%; 1
- (ii) losses in correct order and approximately correct ratio of size;
 arrows correctly labelled with source of loss; 2
Labelling of width in % is acceptable for correct ratio only.



(diagram not to scale)

- (c) (i) transmit at high/increased potential difference/voltage;
 use (step-up) transformer to (increase potential difference/voltage and) reduce current;
 lower current means I^2R /resistive losses reduced;
 large cable cross-section/good conductor used for cables
 so resistive losses reduced; 3 max
Do not accept discussion of reduction of station distance from consumer.

- (ii) *advantage*: pumped storage on demand;
disadvantage: but needs to be re-stored before re-use;
Answer must focus on comparison between tidal and pumped storage.
Do not accept arguments based on unreliability of tide or installation costs. 2
[13]

[14]