Name

Date

Quiz - Energy, Power, Climate Change

1. It is hypothesized that global warming may lead to significant changes in the average sea-level. This hypothesis assumes that:

   A. average rainfall will increase.

   B. icebergs will melt.

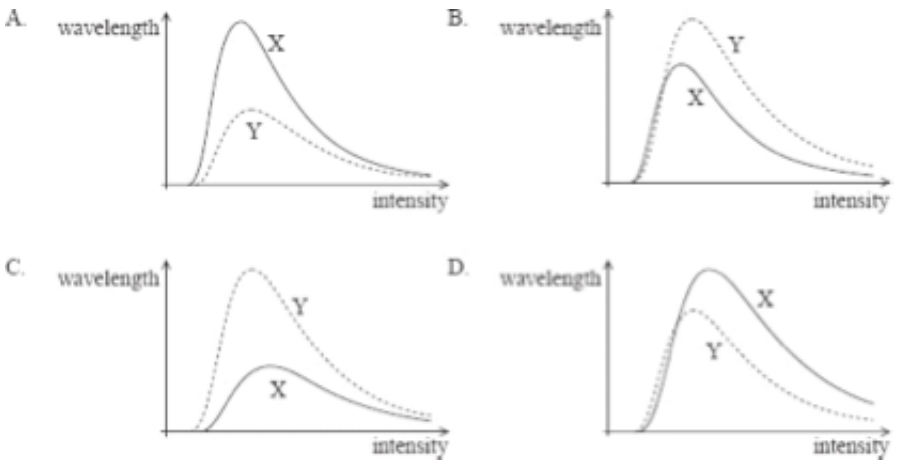
   C. glaciers will melt.

   D. the rate of evaporation of seawater will increase.

   [1]

   Solution:C

2. Two black bodies X and Y are at different temperatures. The temperature of body Y is higher than that of body X. Which of the following shows the black body spectra for the two bodies?



   [1]

   Solution:C

3. This question is about solar power.

   A. Distinguish, in terms of energy conversion, the difference between a photovoltaic cell and an active solar heater.

   Photovoltaic Cell: .....

   Active Solar Heater: .....

   [2]

   B. An outside tank, open to the air, contains 4.0×10^3 kg of water. During daylight hours, the average temperature of the water decreases at a rate of $0.38\ K \cdot h^{-1}$. In order to maintain a constant temperature during daylight hours, it is proposed to heat the water using an active solar heater. The average solar power density during the day is $7.2 \times 10^2 W \cdot m^2$ and the specific heat capacity of water is $4.2 \times 10^3 J \cdot kg^1 K^1$.

   Estimate the minimum effective area of the solar heater needed in order to keep the temperature of the water constant.

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[3]

Solution:(a) *photovoltaic cell:* converts light energy into electric energy;
active solar heater: converts light energy into thermal energy;

$$\text{(b) energy lost per second by the water } = 4.0 \times 10^3 \times 4200 \times \frac{0.38}{3600}$$

$$= 1.8 \times 10^3 W;$$

$$\text{area needed} = \left(\frac{1.8 \times 10^3}{720}\right) = 2.5 m^2$$

4. This question is about wind power.

The maximum theoretical wind power P for air of speed v moving normally through area A where ρ is the density of air is given by:

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

A. i. Air of density $1.3\,kg \cdot m^{-3}$ and speed of 9.0 $\text{m}\cdot\text{s}^{-1}$ is incident on a wind turbine having blades of diameter 15 m. Calculate the maximum wind power incident on the turbine.

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[2]

ii. State why it is impossible in practice to extract all of the power P in (i) from the air.

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[1]

iii. State two reasons why wind turbines are not placed close to one another.

1. .....

2. .....

[2]

B. A nuclear power station has an output power of 200 MW. It is proposed to replace the power station with a series of wind turbines each with an energy output of 750 kW. State and discuss one advantage and one disadvantage such a change might bring if this proposal was to take place.

Advantage: .....

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Disadvantage: .....

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[4]

Solution:

$$P = \frac{\rho \pi r^2 v^3}{2} = \frac{1.3 \times \pi \times 7.5^2 \times 9.0^3}{2}$$

$$P = 8.4 \times 10^4 W$$

(ii) the speed of air (mass) cannot drop to zero / OWTTE;
(iii) 1. idea of less KE available for the next turbine;
2. idea of turbulence;

(b) advantage:
statement: wind is a renewable source of energy / clean source of energy;
comment: any relevant comment re statement;

disadvantage:
statement: number of turbines required is very large (about 270) / noise / ugly site / ecological impact;
comment: any relevant comment re statement;
Award [1] for each statement and [1] for each comment re statement.
N.B. some aspect(s) might be considered to be an advantage or disadvantage (eg ugliness / beauty of site), accept both.

5. This question is about solar power.

A. Describe, in terms of energy transformations, the difference between a photovoltaic cell and an active solar heater.

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[2]

B. A photovoltaic cell of area 6.5 x 10^{-4} m^2 is situated on the roof of a house. The cell has an efficiency of 8%. At a time when the power of the solar radiation incident on the photovoltaic cell is a maximum, the cell delivers a power of 47 mW to the external circuit.

i. Deduce that the maximum value of the power of the solar radiation incident on the cell is approximately 0.90 $kW \cdot m^{-2}$.

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[2]

ii. State one reason why the power of solar radiation at any particular region does not have a constant value.

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[1]

C. A power of 3.0 kW is required to produce adequate hot water for the house.

i. Use the data from (b) to determine the minimum area of the photovoltaic cells required to generate this power.

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[2]

ii. The efficiency of energy conversion in an active solar heater is 24%. Calculate the minimum area of this solar heater required to generate this power.

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[1]

iii. State and explain whether it is more practical to use photovoltaic cells or an active solar heater to provide hot water for the house.

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[2]

Solution:(a) photovoltaic cell: light energy / energy from the Sun is converted into electrical energy; active solar heater: light energy / energy from the Sun is converted into thermal energy / heat;

(b) (i) if x is the power incident on the photovoltaic cell

$$x = \frac{47 \times 10^{-3} \times 100}{8}$$

$$x = 590mW$$

$$\text{therefore, power incident per square metre} = \frac{590 \times 10^{-3}}{6.5 \times 10^{-4}}$$

$$= 0.90kW \cdot m^{-2}$$

(ii) the amount of sunlight varies with season / time of day / OWTTE

(c) (i)

$$\text{minimum number of cells required} = \frac{3 \times 10^3}{47x10^{-3}} = 6.4x10^4$$

$$\text{total area} = 6.4 \times 10^4 \times 6.5 \times 10^{-4} = 42m^2$$

(ii) $\text{area} = \frac{3.0}{0.9 \times 0.24} = 14m^2$

(iii)active solar heater;

requires less area / any other relevant reason eg cost / storage problems;
Award [0] if no reason is given or if reason is incorrect.

6. Simple harmonic motion and the greenhouse effect.

A. A body is displaced from equilibrium. State the two conditions necessary for the body to execute simple harmonic motion

i. .....

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ii. .....

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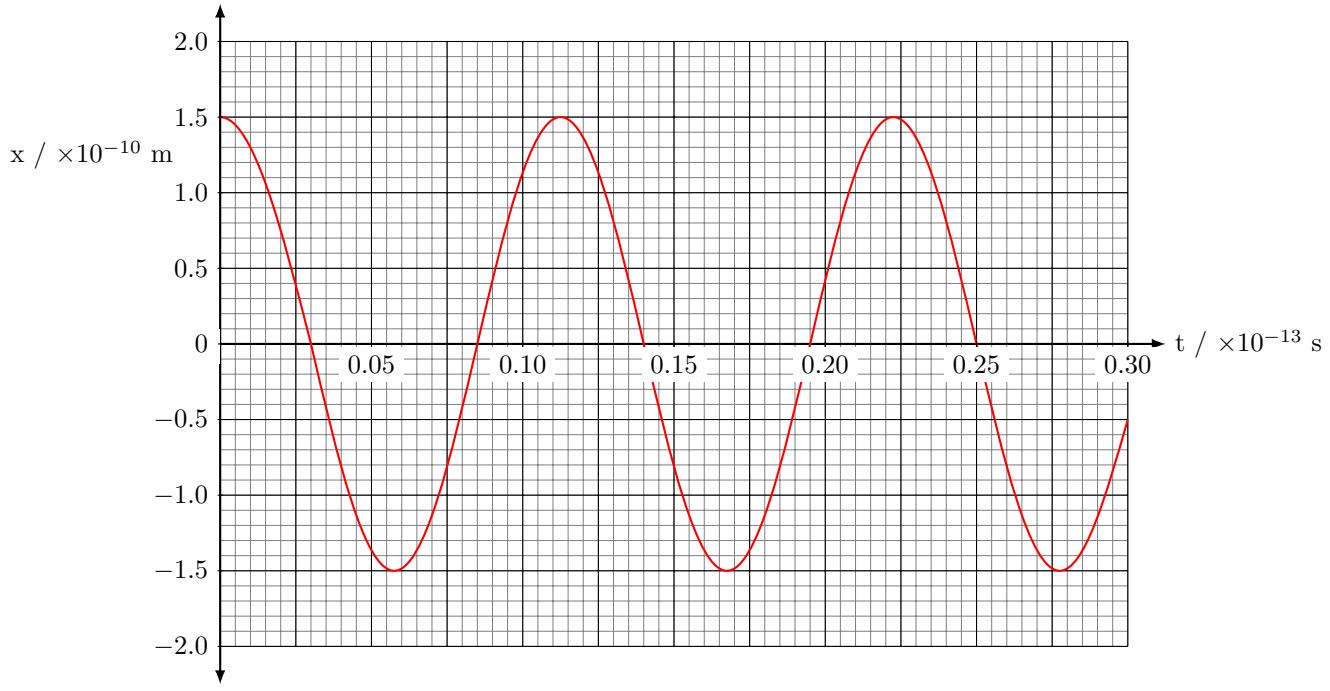
[2]

B. In a simple model of a methane molecule, a hydrogen atom and the carbon atom can be regarded as two masses attached by a spring. A hydrogen atom is much less massive than the carbon atom such that any displacement of the carbon atom may be ignored.

The graph below shows the variation with time t of the displacement x from its equilibrium position of a hydrogen atom in a molecule of methane.



The mass of hydrogen atom is 1.7 x 10^{-27} kg. Use data from the graph above

i. to determine its amplitude of oscillation.

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[1]

ii. to show that the frequency of its oscillation is 9.1 x 10^{13} Hz.

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[2]

iii. to show that the maximum kinetic energy of the hydrogen atom is 6.2 x 10^{-18} J.

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[2]

C. Assuming that the motion of the hydrogen atom is simple harmonic, its frequency of oscillation f is given by the expression:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m_p}}$$

where k is the force per unit displacement between a hydrogen atom and the carbon atom and mp is the mass of a proton.

i. Show that the value of k is approximately 560 N·m^{-1}.

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[1]

ii. Estimate, using your answer to (c)(i), the maximum acceleration of the hydrogen atom.

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[2]

D. Methane is classified as a greenhouse gas.

i. Describe what is meant by a greenhouse gas.

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[2]

ii. Electromagnetic radiation of frequency 9.1 x 10^{13} Hz is in the infrared region of the electromagnetic spectrum. Suggest, based on the information given in (b)(ii), why methane is classified as a greenhouse gas.

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[2]

Solution:

A. the force acting / accelerating (on the body) is directed towards equilibrium (position);
and is proportional to its / the bodies displacement from equilibrium;

B. i. 1.5 x 10^{-10} m;

ii.

$$T = 1.1 \times 10^{-12} s;$$

$$f = \left(\frac{1}{1.1 \times 10^{-12}}\right);$$

$$= 9.1 \times 10^{13} \text{ Hz}$$

iii.

$$\omega = (2\pi f) = 5.7x10^{14}(rad \cdot s^{-1});$$

$$E_{max} = \left(\frac{1}{2} m\omega^2 x_o^2\right)$$

$$= \frac{1}{2} \times 1.7 \times 10^{-27} \times (5.7)^2 \times 10^{28};$$

$$= 6.2 \times 10^{-18} \text{ J}$$

C. i.

$$k = (4\pi^2 f^2 m_p) = 40 \times 83 \times 10^{26} \times 1.7 \times 10^{?27};$$

$$\approx 560\, N \cdot m^{-1}$$

ii. use of F = kx and F = ma;

to give a = $\frac{560 \times 1.5 \times 10^{-10}}{1.7 \times 10^{-27}}$ = 5.0 x 10^{19} m·s^{-2} ;

D. i. infrared radiation radiated from Earth will be absorbed by greenhouse gases;
and so increase the temperature of the atmosphere / Earth;

ii. the natural frequency of oscillation (of a methane molecule) is equal to 9.1 x 10^{13} Hz;
because of resonance the molecule will readily absorb radiation of this frequency;