Mark scheme for Topic 8

1 Power is proportional to the cube of speed, so $2^3 = 8$, hence **D**.

2 **C**

3 Most of the reflection is from the clouds, **B**.

4 The correct definition is **B**.

5 **a** **i** $P = IA = 740 \times 0.016 = 11.84 \approx 12\ \text{W}$ **[1]**

ii $P = VI = 24 \times 0.32 = 7.68 \approx 7.7\ \text{W}$ **[1]**

iii $e = \dfrac{7.68}{11.84} = 0.649 \approx 0.65$ **[1]**

iv Power available to lift water is $0.30 \times 7.68 \approx 2.3\ \text{W}$

$$P = \frac{\Delta m}{\Delta t} gh$$

$$2.3 = \frac{\Delta m}{\Delta t} \times 9.8 \times 8.0$$

$$\frac{\Delta m}{\Delta t} = 0.029\ \text{kg}\,\text{s}^{-1}.$$ **[4]**

b For most practical uses, No,

since the rate is so small. **[2]**

6 **a** Mass of air stopped by windmill in time Δt is $\rho A v \Delta t$.

The kinetic energy of this mass of air is thus $\frac{1}{2}(\rho A v \Delta t)v^2 = \frac{1}{2}\rho A \Delta t v^3$.

Therefore to get the power we divide by Δt

to get the answer $P = \frac{1}{2}\rho A v^3$. **[3]**

b **i** Power from one generator is $P = \frac{1}{2}\rho A v^3 = \frac{1}{2} \times 1.2 \times \pi (5.2)^2 (6.5)^3$.

$P = 13997 \approx 14\ \text{kW}$

Number needed is $\frac{120}{13.997} = 8.57 \approx 6$. **[3]**

ii Power calculated is theoretical maximum without taking losses into account.

It is unlikely that the wind speed will always be at this value. **[2]**

c Power increases with increasing density.

In the morning the temperature is lower and so the density of air is larger than at midday when the warm air expands. **[2]**

7 **a** The power radiated from a unit area of a body is proportional to the fourth power of the surface's absolute temperature.

Emissivity is the ratio of the power radiated per unit area by a body to the power radiated per unit area by a black body at the same temperature. **[2]**

b **i** From left to right

σT_1^4

$(1-e)\sigma T_1^4$

$e\sigma T_2^4$ **[3]**

ii Net intensity loss is intensity in minus intensity out.

This is

$$\sigma T_1^4 - (1-e)\sigma T_1^4 - e\sigma T_2^4$$
$$= e\sigma (T_1^4 - T_2^4)$$ **[2]**

iii If $I_{net} = 0$, $T_1 = T_2$ so ratio is 1. **[1]**

8 **a** The power radiated from a unit area of a body is proportional to the fourth power of the surface's absolute temperature. **[1]**

b $I = \dfrac{P}{4\pi d^2}$

$I = \dfrac{3.9\times10^{26}}{4\pi\times(1.5\times10^{11})^2}$ **[2]**

$= 1400\ \mathrm{W\,m^{-2}}$

c **i** Albedo is the ratio of the reflected to the incident intensity on a body.

Emissivity is the ratio of the power radiated per unit area by a body to the power radiated per unit area by a black body at the same temperature. **[2]**

ii **[2max]** from:

The quantity/type of vegetation of the surface.

The cloud cover in the region.

The nature of the soil.

The amount of ice. **[2]**

iii The power of the radiation that is received on Earth travels through a disc of area πR^2 and so equals $S\pi R^2$ but when distributed over the entire surface area of $4\pi R^2$ the intensity is $\dfrac{S\pi R^2}{4\pi R^2} = \dfrac{S}{4}$ **[2]**

Exam tip: there is hardly an exam question that does not use this.

iv Intensity radiated by surface = Intensity received by surface. **[1]**

Exam tip: you must understand this condition of equilibrium.

Intensity received by surface is $\dfrac{(1-\alpha)S}{4}$ since $\dfrac{\alpha S}{4}$ is reflected.

Hence $\sigma T^4 = \dfrac{(1-\alpha)S}{4}$

and so $T = \sqrt[4]{\dfrac{(1-\alpha)S}{4\sigma}}$ **[2]**

v

$$T = \sqrt[4]{\frac{(1-0.30)1400}{4\times 5.67\times 10^{-8}}} = 256.4\text{ K}$$
≈ 256 K **[1]**

d **i** Because the Earth is taken to be a black body. **[1]**

ii The atmosphere radiates as a grey body with emissivity *e*. **[1]**

iii The part of the intensity radiated by the Earth that is absorbed by the atmosphere is $e\sigma T_E^4$.

and so the part that is transmitted through is $\sigma T_E^4 - e\sigma T_E^4$

$(1-e)\sigma T_E^4$ **[2]**

e **i** Net intensity into atmosphere is $e\sigma T_E^4$.

Net intensity out of atmosphere is $e\sigma T_A^4 + e\sigma T_A^4$.

Equating gives the result. **[2]**

ii Net intensity into surface is $\frac{(1-\alpha)S}{4} + e\sigma T_A^4$.

Net intensity out of surface is σT_E^4.

Equating and using the result in e(i) gives
$\sigma T_E^4 = \frac{(1-\alpha)S}{4} + e\sigma T_A^4 = \frac{(1-\alpha)S}{4} + \frac{e\sigma T_E^4}{2}$.

Solving for the Earth temperature gives the required answer

$$T_E = \sqrt[4]{\frac{(1-\alpha)S}{2\sigma(2-e)}}$$
[3]

iii

$$T_E = \sqrt[4]{\frac{(1-0.30)\times 1400}{2\times 5.67\times 10^{-8}\times(2-0.65)}} = 282.9 \approx 283\text{ K}$$

$$T_A = \frac{282.9}{\sqrt[4]{2}} = 237.8 \approx 238\text{ K}$$
[2]

f The model has neglected to take into account the part of the Earth's radiated intensity that is reflected by the atmosphere back down to Earth. **[1]**

g **i** The Earth radiates in the infrared region of electromagnetic waves.

The greenhouse gases in the atmosphere have energy levels that differ in energy by amounts comparable to infrared photon energies,

and so some of the radiation is absorbed by greenhouse gas molecules as they make transitions into higher energy levels. **[3]**

Exam tip: it is essential that you mention the first marking point.

ii The incoming radiation is mainly ultraviolet and visible.

And so the corresponding photon energies are too high to excite the molecules of the greenhouse gases. **[2]**

9 **a** **i** The intensity at the top of the Martian atmosphere is less than that at Earth by the factor $1.5^2 = 2.25$, i.e. is only $\frac{350}{2.25} = 155.6 \approx 155\ \text{W m}^{-2}$.

Of this $0.15 \times 155.6 = 23.3\ \text{W m}^{-2}$ is reflected, leaving $155.6 - 23.3 = 132.3 \approx 132\ \text{W m}^{-2}$ to reach the surface. **[1]**

ii Intensity radiated by surface = Intensity received by surface.

Exam tip: you must understand this condition of equilibrium.

Hence $\sigma T^4 = 132.3$

$$T = \sqrt[4]{\frac{132.3}{5.67 \times 10^{-8}}}$$

$$T = 219.8\ \text{K}$$

$$\approx 220\ \text{K}$$

[4]

b The answer obtained above ignores the greenhouse effect and gives a temperature very close to /higher than the actual temperature.

So the greenhouse effect is not dominant on Mars/the greenhouse effect on Mars is negligible. **[2]**

10 **a** Both effects have to do with infrared radiation from the Earth's surface that is absorbed by greenhouse gases in the atmosphere and is then reradiated, partly, towards the Earth again.

In the case of the ordinary greenhouse effect the greenhouse gases are naturally present and in the case of the enhanced greenhouse effect, human activities have tended to increase the concentrations of these gases. **[2]**

b **i** $\gamma = \dfrac{\frac{\Delta V}{V}}{\Delta\theta}$,

i.e. the fractional increase in volume per unit temperature increase. **[1]**

ii The volume will increase by $\Delta V = \gamma A d \Delta\theta = 2.0\times10^{-4}\times A\times3.5\times10^{3}\times2.5 = 1.75A$

The increase in depth is therefore $\dfrac{\Delta V}{A}$

i.e. $\dfrac{1.75A}{A} = 1.75\text{ m.}$ **[3]**

c That all the water down to a depth of 3.5 km is warmed.

That all the water down to a depth of 3.5 km initially had the same temperature.

That all the new volume is still based on the same area *A*. **[3]**

Exam tip: in this topic in particular you must be prepared to list approximations made in reaching simple quantitative results.

d Increased levels of carbon dioxide will increase the absorption of infrared radiation from the Earth's surface.

The carbon dioxide molecules will then reradiate this energy in all directions, including back down to the Earth surface. **[2]**

e Examination of very old ice samples from Antarctica and Greenland.

Shows peaks in high average temperatures coinciding with peaks in high concentrations of carbon dioxide. **[2]**