Markscheme-Topic 3: Thermal Physics

1. C
2. D
3. C
4. C
5. B
6. B
7. B
8. B
9. D
10. A
11. D
12. B
13. D
14. D
15. B
16. D
17. B
18. D
19. A
20. A
21. A
22. B
23. D
24. C
25. C
26. A
27. A
28. B
29. A
30. B
31. C
32. B

Short answer questions

1. (a) (165, 0);
   (b) *Look for these points:*
   to change phase, the separation of the molecules must increase;
   *Some recognition that the ice is changing phase is needed.*
   so all the energy input goes to increasing the PE of the molecules;
   *Accept something like “breaking the molecular bonds”.*
KE of the molecules remains constant, hence temperature remains constant; 

*If KE mentioned but not temperature then assume they know that temperature is a measure of KE.*

(c) 
(i) time for water to go from 0 to 15°C = 30 s; 
energy required = \( ms\Delta \theta \) = \( 0.25 \times 15 \times 4 \times 200 \) = 15750 J; 

\[
\text{power} = \frac{\text{energy}}{\text{time}} = 525 \text{ W} \sim 530 \text{ W};
\]

(ii) ice takes 15 s to go from –20°C to 0; 
energy supplied = \( 15 \times 530 \) J; 
sp ht = \( \frac{530 \times 15}{20 \times 0.25} = 1590 = 1600 \text{ Jkg}^{-1} \text{ K}^{-1};
\]

(iii) time to melt ice = 150 s; 

\[
L = \frac{(150 \times 530)}{0.25} = 320 \text{ kJ kg}^{-1};
\]

2. Gases and liquids

(a) 
forces between gas molecules (except during collisions) are much smaller than between liquid molecules; 
speed of gas molecules much greater than speed of liquid molecules; 
motion / movement of gas molecules is less restricted than that for liquid molecules; 
average separation of molecules much greater in a gas than in a liquid;  

(b) 
the molecules do not have the same speed / the molecules have different speeds; 
the speed of the molecules change each time they collide / the speed of individual molecules is always changing / OWTTE; 
Accept use of words “kinetic energy” in place of speed.

(c) 
the energy / heat required to raise / change the temperature of a substance of 1 kg by 1K / °C; 

(d) 
(i) the water is changing phase / boiling / KE of molecules is constant, (PE is changing); 

(ii) time = 420(s); 
energy supplied = \( 300 \times 420 \); 
\[
= 4.2 \times 10^3 \times 0.40 \times \Delta \theta;
\]
to give \( \Delta \theta = 75; \) 
therefore, boiling temperature \( \theta = 95 \text{°C}; \)

(e) \( 300 \times 3.0 \times 10^3 = 0.40 \times L; \)
to give \( L = 2.3 \times 10^6 \text{ Jkg}^{-1}; \)

3. (a) 
[If for each appropriate and valid point eg 
thermal energy is the KE of the component particles of an object; 
thus measured in joules; 
the temperature of an object is a measure how hot something is 
(it can be used to work out the direction of the natural flow of thermal energy between two objects in thermal contact) / measure of the average KE of molecules; 
it is measured on a defined scale (Celsius, Kelvin etc);  

(b) 
(i) correct substitution: energy = power \times \text{time};
\[
= 1200 \text{ W} \times (30 \times 60) \text{ s};
\]
\[
= 2.2 \times 10^6 \text{ J};
\]
(ii) use of $E = mc \Delta \theta$ to get

\[
\Delta \theta = \frac{2.2 \times 10^6}{(4200 \times 70)} \text{ K};
\]

= 7.5 K; 3 max

(c) [H] naming each process up to [3 max].

convection;
conduction;
radiation;

[H] for an appropriate (matching) piece of information / outline for each process up to [3 max].

eg convection is the transfer of thermal energy via bulk movement of a gas due to a change of density;
conduction is transfer of thermal energy via intermolecular collisions;
radiation is the transfer of thermal energy via electromagnetic waves (IR part of the electromagnetic spectrum in this situation) / OWTTE; 6 max

(d) (i) [H] for each valid and relevant point eg

in evaporation the faster moving molecules escape;
this means the average KE of the sample left has fallen;
a fall in average KE is the same as a fall in temperature; 3 max

(ii) energy lost by evaporation = 50% \times 2.2 \times 10^6 J;

= 1.1 \times 10^6 J;

correct substitution into $E = ml$
to give mass lost

= 1.1 \times 10^6 J / 2.26 \times 10^6 J kg^{-1}

= 0.487 kg

= 487 g; 3 max

(iii) [H] for any valid and relevant factors [2 max] eg

area of skin exposed;
presence or absence of wind;
temperature of air;
humidity of air etc;

[H] for appropriate and matching explanations [2 max] eg

increased area means greater total evaporation rate;
presence of wind means greater total evaporation rate;
evaporation rate depends on temperature difference;
increased humidity decreases total evaporation rate etc; 4 max

4. (a) (i) $P \propto \frac{1}{V}$ or $V \propto \frac{1}{P}$ or $PV = \text{constant}$ or pressure inversely proportional to volume, etc; 1

(ii) $V \propto T$, etc; 1

(b) (i) $\frac{P_1}{T_1} = \frac{P_2}{T'}$ or $P_1T' = P_2T_1$; 1

(ii) $\frac{V_1}{T'} = \frac{V_2}{T_2}$ or $V_1T_2 = V_2T'$; 1

(c) from (i) $T' = \frac{P_2T_1}{P_1}$;

from (ii) $T' = \frac{V_1T_2}{V_2}$;
equate to get \( \frac{PV_1}{T_1} = \frac{PV_2}{T_2} \);

so that \( \frac{PV}{T} = \) constant or \( PV = KT \);

5. (a) gas that obeys the equation \( pV = nRT \) / no forces between molecules;
at all pressures, volumes and temperatures / any other postulate;

(b) (i) \( pV = nRT \)
\[ 20 \times 10^6 \times 2 \times 10^{-2} = n \times 8.3 \times 290; \]
\( n = 170 \) (166); 2 max

(ii) number = \( n \times N_A \);
\[ \text{number} = 166 \times 6.02 \times 10^{23} = 1.0 \times 10^{26}; \]

(c) (i) average volume = \( 2.0 \times 10^{-28} \) m\(^3\);

(ii) average separation = \( \sqrt[3]{(2.0 \times 10^{-28})} \);
\[ = 5.8 \times 10^{-10} \text{ m}; \]

Allow solution based on sphere.

6. (a) internal energy: (random translational) kinetic energy of atoms / molecules;

(b) (i) 546 K;

(ii) temperature doubled but pressure remains constant;
hence volume doubled to 44.0m\(^3\);

or
\[ V \propto T; \]
therefore, volume doubled to 44.0m\(^3\);

(c) (i) \( W = 0; \)

(ii) \( \Delta W = p_A (V_C - V_A) \)
\[ = 1.01 \times 10^5 \times 22.0; \]
\[ = 22.2 \times 10^5 \text{ J}; \]

Note the ecf from (b)(ii).

(iii) work done on the gas;
because the volume is decreasing;
Award [0] for a bald statement without any attempt at reasoning.

(iv) total work done by gas in cycle is\( \Delta W = 0 + 31.5 \times 10^5 - 22.2 \times 10^5; \)
work output = \( 9.3 \times 10^5 \) J; 2
7.

(a) Molecules strike the face and rebound. Explanations of force arising during the collision can be in terms of momentum change, or, acceleration, change of velocity, etc.; Many collisions leads to average force and average pressure; 

(b) If they strike the bottom they rebound; Their average velocities are high compared to any speed they would gain downward due to gravity, between collisions; (Thus effect of gravity on their motion is negligible). Look for explanations along the lines of rebounding and comparative effect of gravity.

(c) Average KE of molecules is the same; since temperature is the same;

(d)

The molecules are more spread out, but have similar representative velocity vectors since the temperature is the same as before;

(e) There are fewer collisions of molecules with the piston face per unit time, because the molecules have further to go before returning or any reasonable expression of the basic ideas, e.g. molecules are further apart, so strike the walls less often;

(f) 

\[ P_1 V_1 = P_2 V_2; \]

\[ P_2 = \frac{P_1 V_1}{V_2} - 300 \times \frac{1}{2} \text{ kPa}; \]

(g) Yes work is done; It is done by the gas;