3 Thermal physics
Answers

Answers to in-text questions

1

	Temperature / K	Temperature / °C
average temperature of Earth	289	16
melting point of zinc	693	420
temperature of the visible surface of the Sun	5778	5505
average temperature of the human body	310	37
boiling point of liquid nitrogen	77	–196
freezing point of mercury	235	–38
surface temperature of dry ice (solid carbon dioxide) when it sublimes from a solid directly to a gas	194	–79

2 $p_{new}V_{new} = pV$; $2.5 \times V_{new} = 1.0 \times 0.36$; $V_{new} = 0.14\ m^3$

3 $p_{new}V_{new} = pV$; $3 \times V_{new} = 1 \times 1.56$; $V_{new} = 0.520\ L$

4 $740\ mmHg = \left(\frac{740 \times 133.322}{1000}\right)\ kPa = 98.7\ kPa$; $p_{new}V_{new} = pV$; $101.325 \times V_{new} = 98.7 \times 520$; $V_{new} = 507\ cm^3$

5 $Q = Pt = 2 \times 10^3 \times 120 = 2.4 \times 10^5$
$Q = mc\Delta\theta$; $2.4 \times 10^5 = 0.75 \times c \times (100 - 20)$; $c = 4.0 \times 10^3\ J\ kg^{-1}\ K^{-1}$

Answers to additional problems

1 a) The particles in X have a greater amplitude of vibration and greater average speed than Y.

b) Discussed on pages 74–75 of *Physics for IB Diploma Course Preparation*.

2 a) Your answer should refer to:
- Elastic collision of molecules with wall atoms
- Change of momentum of molecules at walls leading to a force acting on wall
- Total momentum of system remaining constant
- Pressure as force per unit area

b) Your answer should refer to:
- Area of walls is constant, and therefore volume of gas is also constant.
- As temperature increases, average speed of gas molecules increases;
- force per impact at wall increases **and** time of flight between walls increases;
- change of momentum of molecules at walls increases;
- pressure (as force ÷ area) must increase.

3 a) Energy is removed from a gas, the speed of the atoms/molecules decreases and bonds reform between atoms/molecules to form a liquid.

b) The atmosphere in the bathroom is warm, and laden with maximum amount of vapour; the mirror is colder than air and its temperature has a smaller maximum. Water must leave the vapour phase at the mirror surface and form as liquid on surface.

4 **a)** A narrow wall has a small area and will exert large pressure on ground (leading to subsidence); a foundation is wider (and has negligible weight) so weight of building is spread over larger area, decreasing the pressure exerting on the ground.

b) A large pressure on soft mud would allow the vehicle to get stuck; a large area reduces the pressure for the same weight and prevents the vehicle sinking.

c) Spikes have a small area; a very large pressure is produced at the spike which makes it penetrate the ground; this prevents the athlete from slipping

5 **a)** $15 \times 9.81 = 1.5 \times 10^2$ N **b)** $p = \frac{F}{A} = \frac{150}{25 \times 10^{-3} \times 18 \times 10^{-3}} = 3.3 \times 10^5$ Pa = 3.3 kPa

c) $p = \frac{F}{A} = \frac{150}{25 \times 10^{-3} \times 35 \times 10^{-3}} = 1.7 \times 10^5$ Pa = 1.7 kPa

6 $p = \rho g h$; $101325 = 1000 \times 9.81 \times h$; $h = 10.3$ m

7 Pressure inside the balloon is approximately the same as the pressure outside. As the pressure drops in the high atmosphere the gas in the balloon expands (despite the fall in temperature).

8 Atmospheric pressure is about 10 m of water so the pressure at the surface is about 10 m of water pressure. 5 m down, it is about 15 m of water pressure.
Assume beaker volume is 250 cm³, $p_{5m}V_{5m} = pV$; $15 \times V_{new} = 10 \times 250$; $V_{5m} = 170$ cm³

9 **a)** For 1 kg of water:

Energy to cool to 0°C	= 15 × 4200	= 63000 J
Energy to freeze		= 330000 J
Energy to cool ice	= 5 × 2100	= 10500 J
Total energy		= 403500 J

b) 2.5 × 403500 ≡ 1.0 MJ every 300 s; this is 3.3 kW to be removed.

10 Energy required to bring water to 100°C, $Q = mc\Delta\theta = 0.15 \times 4200 \times (100 - 18) = 5.2 \times 10^4$ J

$\frac{5.2 \times 10^4 \text{ J}}{2.3 \times 10^6 \text{ J kg}^{-1}} = 0.023$ kg of steam required; therefore minimum mass of water = 150 + 23 = 173 g

11 **a)** Energy transfered to thermometer, $Q = mc\Delta\theta = 0.100 \times 13 \times (36 - 20) = 21$ J
Calculate temperature change in water also using $Q = mc\Delta\theta$; $21 = 0.05 \times 4200 \times \Delta\theta$; $\Delta\theta = 0.1$°C

b) The larger the thermal capacity, the greater the error in the true reading of the temperature. Factors to consider include: small mass, small specific heat capacity.

12 **a)** Using $Q = mL$, and assuming that the rate of energy loss from system is constant (C):
$100 - C = 0.1 \times 10^{-3} \times L$ (1)
$180 - C = 0.2 \times 10^{-3} \times L$ (2)
Subtracting (1) from (2) gives $80 = 0.1 \times 10^{-3} \times L$; 8.0×10^5 J kg^{-1}

b) Plug L into (1); $100 - C = 0.1 \times 10^{-3} \times 8.0 \times 10^5$; $C = 20$ W