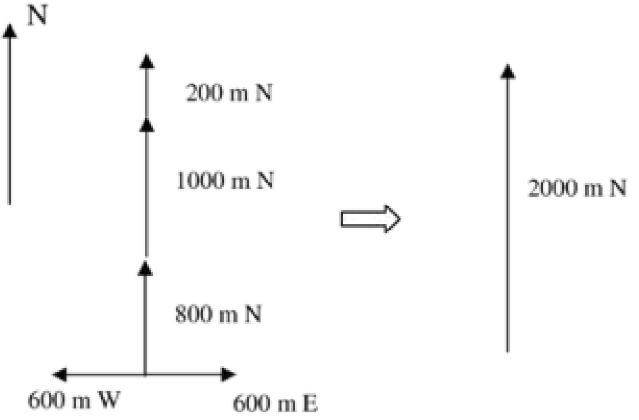
Motion & Forces

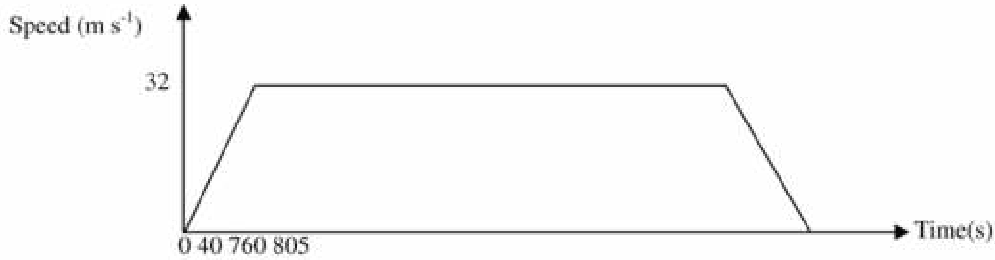
Set 1: Uniform Motion

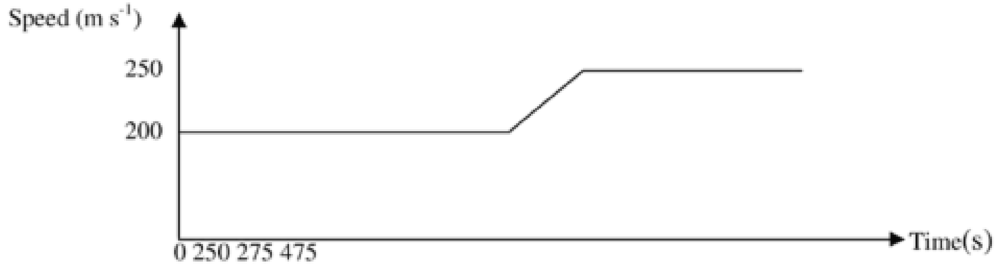
1.1	(a)	$v_{av} = \frac{s}{t} = \frac{20.1\text{ m}}{0.75\text{ s}} = 26.8\text{ m s}^{-1}$
	(b)	$\frac{26.8 \times 3600}{1000} = 96.5\text{ km h}^{-1}$
1.2	(a)	$v_{av} = \frac{165\text{ km}}{1.5\text{ h}} = 110\text{ km h}^{-1}$
	(b)	The **distance** between two points > **displacement** unless the path is absolutely straight.
1.3		$s = v_{av}t = 850\text{ km h}^{-1} \times 3.5\text{ h} = 3000\text{ km}$
1.4	(a)	$s = x_f - x_i = 270\text{ km E} - 255\text{ km E} = 15\text{ km E}$
	(b)	$v = \frac{s}{t} = \frac{15\text{ km E}}{0.5\text{ h}} = 30\text{ km h}^{-1}\text{ E}$
1.5		15 min = 0.25 h $v_{av} = \frac{s}{t} = \frac{1.0\text{ km W}}{0.25\text{ h}} = 4.0\text{ km h}^{-1}\text{ W}$ $s = v_{av}t = 4.0\text{ km h}^{-1}\text{ W} \times 1.25\text{ h} = 5.0\text{ km W}$
1.6		$3.84 \times 10^5\text{ km} = (3.84 \times 10^5 \times 1000)\text{ m} = 3.84 \times 10^8\text{ m}$ $v_{av} = \frac{s}{t}$ $t = \frac{s}{v_{av}} = \frac{3.84 \times 10^8\text{ m}}{6.40 \times 10^3\text{ m s}^{-1}} = 6.00 \times 10^4\text{ s}$
1.7		$280\text{ km} = (280 \times 1000)\text{ m} = 2.8 \times 10^5\text{ m}$ $v_{av} = \frac{s}{t}$ $t = \frac{s}{v_{av}} = \frac{2.8 \times 10^5\text{ m SE}}{8.2\text{ m s}^{-1}\text{ SE}} = 3.42 \times 10^4\text{ s}$
1.8		Have timers standing at 10 m intervals who then record Rebecca's time as she passes them during one of her sprints. Time differences can then be calculated for each 10 m interval and hence her speed during each interval can be determined.
1.9		Have a passenger time how long it takes you to travel a known distance while your speedometer indicates a constant steady speed. Calculate your actual speed (distance ÷ time) and compare this to your speedometer reading.

1.10	(a)	Total distance = 800 m + 600 m + 1000 m + 600 m + 200 m = 3200 m
	(b)	$v_{av} = \frac{s}{t} = \frac{3200\text{ m}}{(20 \times 60)\text{ s}} = \frac{3200\text{ m}}{1200\text{ s}} = 2.67\text{ m s}^{-1}$
	(c)	
	(d)	$v_{av} = \frac{s}{t} = \frac{2000\text{ m N}}{(20)(60)\text{ s}} = \frac{2000\text{ m N}}{1200\text{ s}} = 1.67\text{ m s}^{-1}\text{ N}$
1.11		Distance travelled = 26 708 km – 26 455 km = 253 km at 92 km h^{-1} travelling time must have been $t = \frac{s}{v_{av}} = \frac{253\text{ km}}{92\text{ km h}^{-1}} = 2.75\text{ h}$ total time = 3 h $\therefore$ lunch time = $(3 - 2.75)\text{ h} = 0.25\text{ h}$ (or 15 mins)
1.12	(a)	$v_{av} = \frac{s}{t} = \frac{800\text{ m}}{(20 \times 60)\text{s}} = \frac{800\text{ m}}{1200\text{ s}} = 0.67\text{ m s}^{-1}$
	(b)	Stream speed must be $v_s = (4 - 0.67)\text{ m s}^{-1} = 3.33\text{ m s}^{-1}$
	(c)	$v_{av} = \frac{s}{t}$ $t = \frac{s}{v_{av}} = \frac{10\ 000\text{ m}}{0.67\text{ m s}^{-1}} = 15\ 000\text{ s or }4.17\text{ h}$
	(d)	Speed downstream must be $v_s = (4 + 3.33)\text{ m s}^{-1} = 7.33\text{ m s}^{-1}$ $v_{av} = \frac{s}{t}$ $t = \frac{s}{v_{av}} = \frac{10000\text{ m}}{7.33\text{ m s}^{-1}} = 1364\text{ s or }0.38\text{ h or }23\text{ mins}$
1.13	(a)	Greatest speed is when the gradient is steepest, ie between D and E.
	(b)	Speed was zero when the gradient was zero ie between B and C.

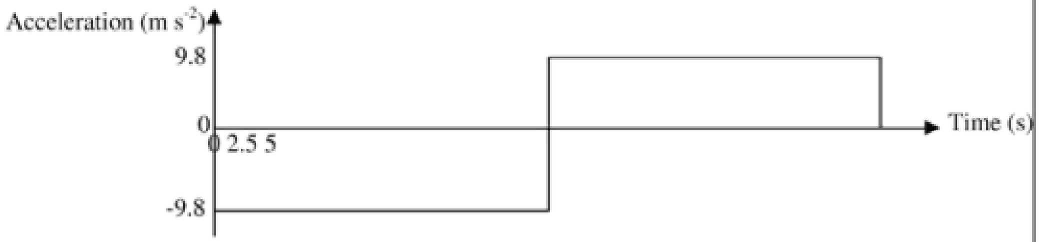
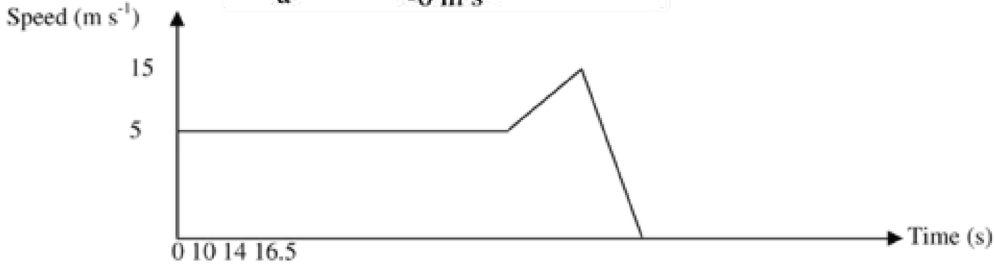
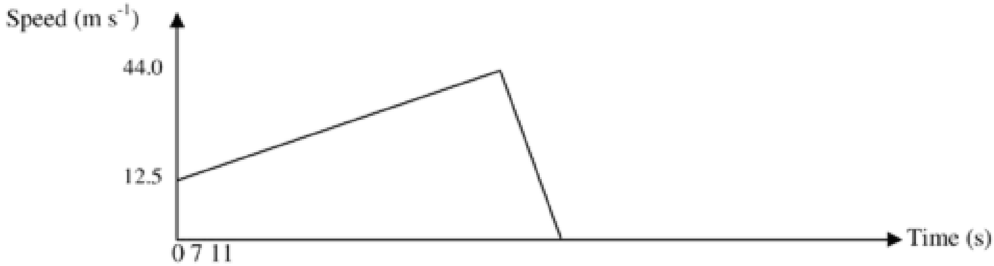
	(c)	She turned back when the gradient became negative, ie at D.
	(d)	Total distance was 15 km out and 15 km back = 30 km.
	(e)	$v_{av} = \frac{s}{t} = \frac{30\text{ km}}{0.8\text{ h}} = 37.5\text{ km h}^{-1}$
	(f)	The direction of travel.
1.14	(a)	$v_{av} = \frac{s}{t} = \frac{600\text{ m upstream}}{1200\text{ s}} = 0.50\text{ m s}^{-1}\text{ upstream}$ Stream speed must be $v_s = (2.0 - 0.50)\text{ m s}^{-1} = 1.5\text{ m s}^{-1}$
	(b)	Downstream speed must be $v_d = (2.0 + 0.50)\text{ m s}^{-1}\text{ downstream} = 2.5\text{ m s}^{-1}\text{ downstream}$ $v_{av} = \frac{s}{t}$ $t = \frac{s}{v_{av}} = \frac{8400\text{ m}}{2.50\text{ m s}^{-1}} = 3360\text{ s or } 0.93\text{ h}$

Set 2: Accelerated Motion

2.1	(a)	$v = u + at = 0 + (0.8\ \text{m s}^{-2})(40\ \text{s}) = 32\ \text{m s}^{-1}$ 
	(b)	Distance travelled = area below the graph = $[(0.5)(40)(32)] + [(720)(32)] + [(0.5)(45)(32)]$ = 24,400 m = 24.4 km
	(c)	$32\ \text{m s}^{-1} = \left(\dfrac{32 \times 3600}{1000}\right)\ \text{km h}^{-1} = 115\ \text{km h}^{-1}$
	(d)	$v_{av} = \dfrac{s}{t} = \dfrac{24\ 400\ \text{m}}{8.5\ \text{s}} = 30.3\ \text{m s}^{-1}$
2.2		Time how long it takes a stone to hit the bottom of the well (stopping the watch on hearing the sound of the stone's impact at the bottom of the well). Then, use the equation **$s = ut + ½at^2$** to calculate the distance travelled by the stone and hence the depth of the well, taking u = zero and a = 9.8 m s^{-2}. This is only an estimate as the time taken for the sound of the stone's impact to travel back to the top of the well will not be taken into consideration (i.e. the measured time will be greater than the real time).
2.3	(a)	$a = \dfrac{v-u}{t} = \dfrac{11.13\ \text{m s}^{-1} - 0}{3.15\ \text{s}} = 3.53\ \text{m s}^{-2}$
	(b)	$45\ \text{km h}^{-1} = \left(\dfrac{45 \times 1000}{3600}\right)\ \text{m s}^{-1} = 12.5\ \text{m s}^{-1}$ $a = \dfrac{v-u}{t} = \dfrac{12.5\ \text{m s}^{-1} - 0}{2.65\ \text{s}} = 4.72\ \text{m s}^{-2}$
2.4	(a)	Change in velocity, $\Delta v = at = 21.3\ \text{m s}^{-2} \times 5.35\ \text{s} = 114\ \text{m s}^{-1}$ upwards
	(b)	The initial velocity would be required
2.5	(a)	$t = \dfrac{d}{v_{av}} = \dfrac{5000\ \text{m}}{200\ \text{m s}^{-1}} = 250\ \text{s}$

	(b)	$t = \frac{v - u}{a} = \frac{250\ m\ s^{-1}\ -\ 200\ m\ s^{-1}}{2\ m\ s^{-2}} = 25\ s$
	(c)	$t = \frac{d}{v_{av}} = \frac{50\,000\ m}{250\ m\ s^{-1}} = 200\ s$
	(d)	
	(e)	Distance travelled during the acceleration phase = the relevant area below the graph (between 250s and 275s), so distance = area of the trapezium = 0.5 x (250 + 200) x 25 = 5625 m
2.6		$s = \frac{v^2 - u^2}{2a} = \frac{(7\ m\ s^{-1})^2 - 0}{2\ x\ 0.77\ m\ s^{-2}} = 31.8\ m$
2.7	(a)	$21.8\ km\ h^{-1} = \left(\frac{21.8\ x\ 1000}{3600}\right) m\ s^{-1} = 6.1\ m\ s^{-1}$ $28.6\ km\ h^{-1} = \left(\frac{28.6\ x\ 1000}{3600}\right) m\ s^{-1} = 7.9\ m\ s^{-1}$ $a = \frac{v - u}{t} = \frac{(7.9\ m\ s^{-1}\ -\ 6.1\ m\ s^{-1})}{1.7\ s} = 1.1\ m\ s^{-2}$
	(b)	$62.6\ km\ h^{-1} = \left(\frac{62.6\ x\ 1000}{3600}\right) m\ s^{-1} = 17.4\ m\ s^{-1}$ $t = \frac{v - u}{a} = \frac{17.4\ m\ s^{-1}\ -\ 7.9\ m\ s^{-1}}{1.1\ m\ s^{-2}} = 8.6\ s$
2.8		Since a golf ball is a compact mass then air resistance would be negligible, so in the absence of any forces other than gravity, all golf balls would accelerate at the same rate (9.8 m s^{-2}).
2.9	(a)	$v = \sqrt{u^2\ +\ 2as} = \sqrt{(8\ m\ s^{-1})^2\ +\ (2\ x\ 9.8\ m\ s^{-2}\ x\ 72\ m)} = 38.4\ m\ s^{-1}$
	(b)	$t_{ball} = \frac{v - u}{a} = \frac{(38.4 - 8)\ m\ s^{-1}}{9.8\ m\ s^{-2}} = 3.1\ s$ $t_{skydiver} = \frac{d}{v_{av}} = \frac{72\ m}{8\ m\ s^{-1}} = 9\ s$ time difference = $t_{skydiver} - t_{ball}$ = (9 – 3.1) s = 5.9 s

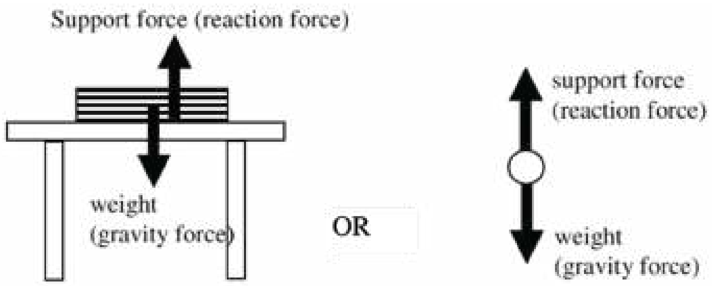
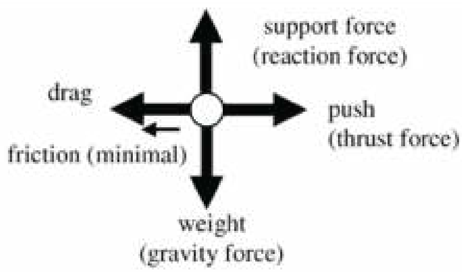
2.10	(a)	$60 \text{ km h}^{-1} = \left(\frac{60 \times 1000}{3600}\right) \text{m s}^{-1} = 16.7 \text{ m s}^{-1}$
	(b)	$d = v_{av} \times t = 16.7 \text{ m s}^{-1} \times 0.5 \text{ s} = 8.35 \text{ m}$ (his thinking distance)
	(c)	$a = \frac{v-u}{t} = \frac{(0-16.7) \text{ m s}^{-1}}{4.5 \text{ s}} = -3.7 \text{ m s}^{-2}$
	(d)	$s = \frac{v^2-u^2}{2a} = \frac{(0)-(16.7^2)}{(2)(-3.7)} \text{m} = 37.7 \text{ m}$ (his braking distance)
	(e)	Total stopping distance = thinking distance + braking distance = 8.35 + 37.7 = 46 m
	(f)	$55 \text{ km h}^{-1} = \left(\frac{55 \times 1000}{3600}\right) \text{m s}^{-1} = 15.3 \text{ m s}^{-1}$ $d = v_{av} \times t = 15.3 \text{ m s}^{-1} \times 0.5 \text{ s} = 7.65 \text{ m}$ (his thinking distance) $s = \frac{v^2-u^2}{2a} = \frac{(0)-(15.3^2)}{(2)(-3.7)} \text{m} = 31.6 \text{ m}$ (his braking distance) time to brake, $t = \frac{v-u}{a} = \frac{(0-15.3) \text{ m s}^{-1}}{-3.7 \text{ m s}^{-2}} = 4.1 \text{ s}$ So, the total stopping time = reaction time + braking time = 0.5 s + 4.1 s = 4.6 s and the total stopping distance = thinking distance + braking distance = 7.65 + 31.6 = 39.3 m
	(g)	After 4.1 s, the first car would still be travelling at a speed of v, given by: $v = u + at = 16.7 \text{ m s}^{-1} + (-3.7 \text{ m s}^{-2} \times 4.1 \text{ s}) = 1.5 \text{ m s}^{-1}$
	(h)	Braking at 60 km h^{-1} compared to 55 km h^{-1} adds almost 7 metres to the stopping distance so it is very good advice.
2.11		Braking at 50 km h^{-1} compared to 40 km h^{-1} adds significantly to the stopping distance of a motor vehicle so around schools where a child may well suddenly dash out into the road, the reduction in drivers' speeds could literally save lives.
2.12	(a)	$a = \frac{v-u}{t} = \frac{(50-0) \text{ m s}^{-1}}{5 \text{ s}} = 10 \text{ m s}^{-2}$
	(b)	$v_{av} = \frac{u+v}{2} = \frac{(0 + 50) \text{ m s}^{-1}}{2} = 25 \text{ m s}^{-1}$
	(c)	The initial velocity is zero, i.e. the rock was released from a rest position
2.13	(a)	$t_{up} = 2.5 \text{ s}$ $u = v - gt = 0 - (-9.8 \text{ m s}^{-2})(2.5 \text{ s}) = 24.5 \text{ m s}^{-1}$ upwards
	(b)	$t_{down} = 2.5\text{s}$ $v = u + gt = 0 + (9.8 \text{ m s}^{-2})(2.5 \text{ s}) = 24.5 \text{ m s}^{-1}$ downwards

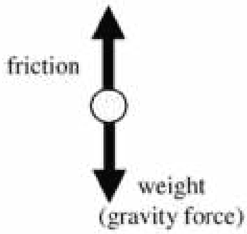
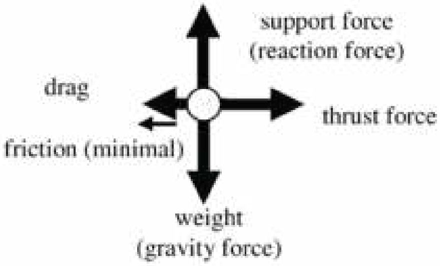
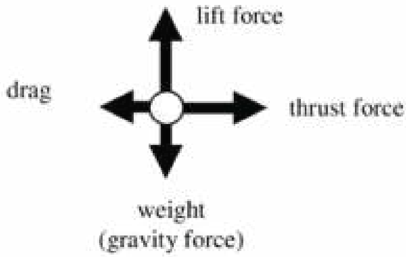
	(c)	
2.14	(a)	$v = u + at = 5\ m\ s^{-1} + (2.5\ m\ s^{-2})(4\ s) = 15\ m\ s^{-1}$
	(b)	Time to come to rest, $t = \frac{\Delta v}{a} = \frac{(0\ m\ s^{-1}\ -\ 15\ m\ s^{-1})}{-6\ m\ s^{-2}} = 2.5\ s$ 
	(c)	Distance travelled = area below the graph = [(10)(5)] + [(0.5)(5 + 15)(4)] + [(0.5)(2.5)(15)] = 108.75 m
2.15	(a)	 maximum velocity, $v = u + at = 12.5\ m\ s^{-1}\ +\ (4.5\ m\ s^{-2}\ x\ 7\ s) = 44.0\ m\ s^{-1}$ time to stop, $t = \frac{\Delta v}{a} = \frac{(0\ m\ s^{-1}\ -\ 44\ m\ s^{-1})}{-11\ m\ s^{-2}} = 4.0\ s$
	(b)	Distance travelled = area below the graph = [(0.5)(12.5 + 44)(7)] + [(0.5)(4)(44)] = 285.75 m
2.16		Acceleration time $t_a = \frac{\Delta v}{a} = \frac{(1.7\ m\ s^{-1}\ -\ 0\ m\ s^{-1})}{0.11\ m\ s^{-2}} = 15.5\ s$ Constant speed time $t_c = \frac{d}{v_{av}} = \frac{30\,m}{1.7\,m\,s^{-1}} = 17.6\,s$ total time of trip = 15.5 s + 17.6 s = 33.1 s
2.17	(a)	$a = g \sin \theta = (9.8\ m\ s^{-2})(\sin 10^{o}) = 1.7\ m\ s^{-2}$ down the slope

	(b)	$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \text{ x } 129 \text{ m}}{1.7 \text{ m s}^{-2}}} = 12.3 \text{ s}$
	(c)	$v = u + at = 0 + (1.7 \text{ m s}^{-2})(12.3 \text{ s}) = 20.9 \text{ m s}^{-1}$

Motion & Forces

Set 3: Force and Newton's Laws

3.1	(a)	$g = \frac{F_w}{m} = \frac{525\ \text{N}}{70\ \text{kg}} = 7.5\ \text{N kg}^{-1}$ (or $7.5\ \text{m s}^{-2}$)
3.2	(a)	The mass is the same on both planets
	(b)	Since weight is directly proportional to the acceleration due to gravity, then $\frac{g_{Earth}}{g_{Mars}} = \frac{9.8\ \text{m s}^{-2}}{3.72\ \text{m s}^{-2}} = 2.63$ therefore the astronaut weighs 2.63 times as much on Earth compared to Mars
	(c)	Since resultant force is directly proportional to the acceleration of the astronaut, then it would require the same force to produce the same acceleration anywhere, provided the mass remains constant. The force on both planets, $F = m\,a = (40\ \text{kg})(2\ \text{m s}^{-2}) = 80\ \text{N}$
	(d)	since g is less on Mars, then she will be able to jump higher than she could on Earth.
3.3	(a)	
	(b)	

	(c)	
	(d)	
	(e)	
3.4		Consider the gardener and the barrow as a single system.  It is true that the forces between the gardener and the barrow are equal and opposite where they are in contact on the handles but the force of the ground on the feet of the gardener is greater than force of the ground on the wheel of the barrow in the opposite direction so they move forward.
3.5	(a)	The water lowers the frictional force between the floor and your feet so the chances of sliding or not stopping is increased so this is an application of Newton's third law.
	(b)	The clumps of dirt experience the equal but opposite reaction to that of the rear drive wheels spinning quickly, as stated in Newton's third law.
	(c)	Running on grass provides a slightly more elastic surface than concrete or bitumen so the time it takes your feet to stop moving after every stride is slightly increased. This in turn will reduce the force acting on your feet (since impulse, F x t must be constant) and hence the force experienced by your joints and muscles is reduced - Newton's second law.

	(d)	The gravel or water lower the frictional forces between the tyres and the ground so the chances of sliding, not stopping or failing to turn is increased so this is an application of Newton's third law.
	(e)	Newton's first law states that a moving body will keep moving unless an external force restrains it. A dog or person in the back of a utility has no such restraining force, since if the vehicle suddenly stops the dog or person would continue moving in the original direction of the truck.
3.6	(a)	$\Delta v = v - u = -1.9\ m\ s^{-1} - 3.2\ m\ s^{-1} = -5.1\ m\ s^{-1}$ (negative shows the direction is upwards)
	(b)	$a = \frac{\Delta v}{t} = \frac{-5.1\ m\ s^{-1}}{0.15\ s} = -34.0\ \ m\ s^{-2}$ (negative shows the direction is upwards)
	(c)	$F_{av} = m\ a = (0.5\ kg)(-34.0\ m\ s^{-2}) = -17.0\ N$ (upwards)
3.7		$F_{av} = \frac{m\Delta v}{t} = \frac{m(v-u)}{t}$ $= \frac{(13\ kg)\ (0\ m\ s^{-1}\ -\ 6.5\ m\ s^{-1})}{1.3\ s} = -67.5\ N$ (negative shows opposite direction to origina
3.8		$Ft = m\Delta v$ $\therefore \Delta v = \frac{Ft}{m} = \frac{(-2100\ N)(2.5\ s)}{750\ kg} = -7.0\ m\ s^{-1}$ but $\Delta v\ = v - u$ $\therefore v = \Delta v + u = (-7.0\ m\ s^{-1}\ +\ 16.5\ m\ s^{-1})\ =\ 9.5\ m\ s^{-1}$ (east)
3.9	(a)	Both trucks experience the same magnitude of force as each other, but in opposite directions – this is an example of Newton's third law.
	(b)	Since the force on each vehicle is the same, and since F = m a, then the lighter vehicle (the car) will experience a much greater acceleration.
3.10	(a)	i). accelerating upwards or decelerating downwards at a rate of $0.98\ m\ s^{-2}$ (i.e. $\frac{g}{10}$, since Wilma is 5 kg heavier, which is an additional one tenth of her mass). ii). travelling at constant velocity or stationary since her mass is unchanged iii). accelerating downwards or decelerating upwards at a rate of $0.49\ m\ s^{-2}$ (i.e. $\frac{g}{20}$, since Wilma is 2.5 kg lighter, which is a reduction of one twentieth in her mass).
	(b)	i). $1.6\ m\ s^{-2}$ is 0.16g ($\frac{1.6}{9.8}$) so she will be 0.16 times heavier = (0.16)(50 kg) = 8.2 kg, so her new mass will be 50 kg + 8.2 kg = 58.2 kg ii). acceleration = 0, so her mass remains 50 kg iii).$1.3\ m\ s^{-2}$ is 0.13g ($\frac{1.3}{9.8}$) so she will be 0.13 times lighter = (0.13)(50 kg) = 6.6 kg, so her new mass will be 50kg – 6.6kg = 43.4 kg

		iv). this is effectively the same as part i). so her new mass = 58.2 kg
3.11	(a)	F_{cable} = weight $F_w = m\,g = (160\text{ kg} + 15\text{ kg})(9.8\text{ m s}^{-2}) = 1715\text{ N}$ upwards
	(b)	$F = m\,a = F_{cable} - F_w$ so $F_{cable} = (ma) + (mg) = [(175\text{ kg})(1.5\text{ m s}^{-2})] + 1715 = 1978\text{ N}$ upwards
	(c)	acceleration = 0, so the tension in the cable remains the same as the load = 1715 N, but upwards
	(d)	$F = m\,a = F_w - F_{cable}$ so $F_{cable} = F_w - (ma) = 1715\text{N} - (175\text{kg})(3.0\text{ m s}^{-2}) = 1190\text{ N}$ upwards
3.12	(a)	Maria will recoil (move backwards) at the same speed with which she pushes Chris away.
	(b)	Maria would still recoil but at a slower speed than Chris.
3.13	(a)	$F_{friction} = \dfrac{F_w}{12} = \dfrac{([525+385]\text{ kg})\,(9.8\text{ m s}^{-2})}{12} = 743\text{ N}$
	(b)	$F_{net} = F_{pull} - F_{friction} = 965\text{ N} - 743\text{ N} = 222\text{ N}$
	(c)	$a = \dfrac{F_{net}}{m} = \dfrac{222\text{ N}}{(525+385)\text{ kg}} = 0.244\text{ m s}^{-2}$
	(d)	tension in tow bar between first and second trolley: $T_2 = m_2\,a = (385\text{ kg})(0.244\text{ m s}^{-2}) = 93.9\text{ N}$
	(e)	$F_{friction} = \dfrac{F_w}{12} = \dfrac{(525\text{ kg})(9.8\text{ m s}^{-2})}{12} = 429\text{ N}$ $F_{net} = F_{pull} - F_{friction} = 965\text{ N} - 429\text{ N} = 536\text{ N}$ $a = \dfrac{F_{net}}{m} = \dfrac{536\text{ N}}{525\text{ kg}} = 1.02\text{ m s}^{-2}$
3.14		Since the limestone and granite stone are compact masses then air resistance would be negligible, so in the absence of any forces other than gravity, both stones would fall at the same rate (9.8 m s^{-2}) and hit the ground at the same time. The feather is not a compact mass and air resistance will have a significant impact as it falls, greatly reducing the resultant force acting upon it. It falls much slower.
3.15		tension in rope between truck and first car: $T_1 = (m_1 + m_2)\,a = (1200\text{ kg} + 1200\text{ kg})(1.45\text{ m s}^{-2}) = 3480\text{ N}$ tension in rope between first and second car: $T_2 = m_2\,a = (1200\text{ kg})(1.45\text{ m s}^{-2}) = 1740\text{ N}$

Set 4: Momentum and Impulse

4.1		$p = m v = (64 \text{ kg})(9.5 \text{ m s}^{-1}) = 608 \text{ kg m s}^{-1}$ North (or 608 N s North)
4.2		$36 \text{ km h}^{-1} = \frac{(36)(1000)}{3600} = 10 \text{ m s}^{-1}$ $p = m v = (2100 \text{ kg} + 55 \text{ kg} + 45 \text{ kg})(10 \text{ m s}^{-1}) = 22\,000 \text{ kg m s}^{-1}$ West (or 22,000 N s West)
4.3	(a)	$v = \frac{p}{m} = \frac{8 \text{ kg m s}^{-1} \text{ south}}{75 \text{ kg}} = 0.107 \text{ m s}^{-1}$ south
	(b)	$v = \frac{p}{m} = \frac{8 \text{ kg m s}^{-1} \text{ south}}{0.5 \text{ kg}} = 16 \text{ m s}^{-1}$ south
4.4	(a)	Impulse = F t = (63 N)(0.1 s) = 6.3 N s in the direction of the bat's velocity
	(b)	Let "toward the cushion" be positive Then $p_{initial} = mu = (0.2 \text{ kg})(1.25 \text{ m s}^{-1}) = 0.25 \text{ kg m s}^{-1}$ $P_{final} = mv = (0.2 \text{ kg})(-1.25 \text{ m s}^{-1}) = -0.25 \text{ kg m s}^{-1}$ Impulse = $\Delta p = -0.25 \text{ kg m s}^{-1} - 0.25 \text{ kg m s}^{-1} = -0.50 \text{ kg m s}^{-1}$ (away from the cushion)
	(c)	$80 \text{ km h}^{-1} = \frac{(80)(1000)}{3600} = 22.2 \text{ m s}^{-1}$ $p_{initial} = m u = (18\,500 + 4250) \text{ kg} \times 22.2 \text{ m s}^{-1} = 5.05 \times 10^5 \text{ kg m s}^{-1}$ $p_{final} = 0$ Impulse = $\Delta p = -0 \text{ kg m s}^{-1} - 5.05 \times 10^5 \text{ kg m s}^{-1}$ $= -5.05 \times 10^5 \text{ kg m s}^{-1}$ (negative means opposite to original direction of travel)
	(d)	Impulse = F t = (150 N)(4 s) = 600 N s east
4.5		$F = \frac{\text{impulse}}{\text{time}} = \frac{195 \text{ N s}}{13 \text{ s}} = 15.0 \text{ N}$
4.6		$\Delta v = \frac{Ft}{m} = \frac{(-810 \text{ N})(2.5 \text{ s})}{250 \text{ kg}} = -8.1 \text{ m s}^{-1}$ $\Delta v = v - u$ so $v = \Delta v + u = -8.1 \text{ m s}^{-1} + 16.5 \text{ m s}^{-1} = 8.4 \text{ m s}^{-1}$ (positive means in the original direction)
4.7	(a)	$p_{initial} = m v = (0.15 \text{ kg})(7 \text{ m s}^{-1}) = 1.05 \text{ kg m s}^{-1}$ towards Sam
	(b)	$p_{final} = 0$ Impulse = $\Delta p = -0 \text{ kg m s}^{-1} - 1.05 \text{ kg m s}^{-1} = -1.05 \text{ kg m s}^{-1}$ towards Max
4.8	(a)	$m_1u_1 + m_2u_2 = (m_1 + m_2)v$ since $u_2 = 0$, then $v = \frac{m_1u_1}{(m_1 + m_2)} = \frac{(0.12 \text{ kg})(30 \text{ m s}^{-1})}{(0.12 \text{ kg} + 0.1 \text{ kg})} = 16.4 \text{ m s}^{-1}$ (in the original direction)

	(b)	$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ since $u_2 = 0$, then $v_2 = \frac{(m_1u_1)-(m_1v_1)}{m_2} = \frac{(0.12\ kg)(30\ m\ s^{-1}) - (0.12\ kg)(15\ m\ s^{-1})}{0.1\ kg} = 18\ m\ s^{-1}$ (in the original dir
4.9	(a)	Impulse – momentum equation states that $F = \frac{m(v-u)}{t}$ So, if the time taken to stop is short, the force is larger, hence a greater impact on joints and muscles.
	(b)	$m_{club}u_{club} + m_{ball}u_{ball} = m_{club}vclub_1 + m_{ball}v_{ball}$ since $u_{ball} = 0$ and you cannot control speed of golf club after impact, then the following can be used to influence the ball speed: .Speed of golf club head (length of club), u_{club} .Mass of golf club head, m_{club} Increasing both factors will increase the final speed of the golf ball. Also, since $F = \frac{m(v-u)}{t}$, then following through with your swing lengthens the time, t with which the ball is in contact with club which will also produce a greater change in velocity.
	(c)	Same explanation as part (b).
	(d)	Tightly strung racquets have less elasticity than others so on impact with the tennis ball, the stopping time for the ball (before it is sent in the opposite direction) will be reduced. Since $F = \frac{m(v-u)}{t}$, then the racquet itself will impose a greater force on the ball, making the ball move faster.
	(e)	Since $F = \frac{m(v-u)}{t}$, then if the time is longer (gradual stop) the force on his hands will be reduced.
	(f)	As part (e); however, now time is important so extending the "catching" time may mean missing an opportunity. Also, all the catchers have special gloves, and a baseball is softer than a cricket ball.
4.10	(a)	Newton's first law states that a moving body will keep moving unless an external force accelerates it. A person in a car needs a restraining force, such as that provided by a seatbelt, in the event that a vehicle suddenly stops. Otherwise, the person would continue moving in the original direction of the vehicle, then suffer injury when accelerated rapidly by the windscreen or some other very solid object.
	(b)	Since $F = \frac{m(v-u)}{t}$, then if the time is longer (gradual stop) the force on a human torso will be reduced – a collapsible steering wheel provides such a gradual stop.
	(c)	Same explanation as part (b).
	(d)	Same explanation as part (a).
	(e)	Same explanation as part (b).

4.11	(a)	Impulse = F t = (48 N)(0.002 s) = 0.096 N s $F = \frac{\text{impulse}}{\text{time}} = \frac{0.096\ \text{N s}}{0.080\ \text{s}} = 1.2\ \text{N}$
	(b)	Since $F = \frac{m(v-u)}{t}$, then if the time is longer (gradual stop) the force on a human torso and head will be reduced – an air bag provides such a gradual stop.
4.12	(a)	$v = \sqrt{2gs} = \sqrt{(2)(9.8\ \text{m s}^{-2})(20\ \text{m})} = 19.8\ \text{m s}^{-1}$
	(b)	$a = \frac{v^2 - u^2}{2s} = \frac{0-(19.8\ \text{m s}^{-1})^2}{(2)(0.03\ \text{m})} = -6530\ \text{m s}^{-2}$
	(c)	F = ma = (1.5 kg) (-6530 m s^{-2}) = -9800 N
	(d)	$t = \frac{v-u}{a} = \frac{0-19.8\ \text{m s}^{-1}}{-6530\ \text{m s}^{-2}} = 3.03 \times 10^3\ \text{s (or 3.30 ms)}$
	(e)	Impulse = F t = (9800 N) (0.00303 s) = 29.7 N s
	(f)	Impulse = Δp, so the change in momentum = 29.7 kg m s^{-1} (or 29.7 N s)
4.13		Since $F = \frac{m(v-u)}{t}$, then in an accident when a car and driver may be instantly brought to rest (hence a very short time, t) the force of impact on the belt could be huge. It does not just depend on the person's mass (or their weight).
4.14		initially, $p_x = m_x u_x \sin\theta$ = (0.02 kg)(500 m s^{-1})(sin 45°) = 7.07 kg m s^{-1} and $p_y = m\ u \cos\theta$ = (0.02 kg)(500 m s^{-1})(cos 45°) = 7.07 kg m s^{-1} finally, $p_x = m\ v \sin\theta$ = (0.02 kg)(500 m s^{-1})(sin 45°) = 7.07 kg m s^{-1} and $p_y = m\ u \cos\theta$ = (0.02 kg)(-500 m s^{-1})(cos 45°) = -7.07 kg m s^{-1} Δp_x = 7.07 kg m s^{-1} - 7.07 kg m s^{-1} = 0 Δp_y = -7.07 kg m s^{-1} - 7.07 kg m s^{-1} = -14.14 kg m s^{-1}
4.15		105 km h^{-1} $= \frac{(105\ \text{km h}^{-1})(1000\ \text{m km}^{-1})}{3600\ \text{s h}^{-1}}$ = 29.2 m s^{-1} 85 km h^{-1} $= \frac{(85\ \text{km h}^{-1})(1000\ \text{m km}^{-1})}{3600\ \text{s h}^{-1}}$ = 23.6 m s^{-1} $p_{initial}$ = m u = (0.145 kg)(29.2 m s^{-1}) = 4.23 kg m s^{-1} (South) p_{final} = m v = (0.145 kg)(23.6 m s^{-1}) = 3.42 kg m s^{-1} (West) $\Delta P = \sqrt{(P_{final}^2 + P_{initial}^2)} = \sqrt{(4.23\ \text{kg m s}^{-1})^2 + (3.42\ \text{kg m s}^{-1})^2} = 5.44\ \text{kg m s}^{-1}$ direction, θ will be given by tan θ = $P_{finall} \div P_{initial}$ so $\theta = \tan^{-1}\left(\frac{3.42\ \text{m s}^{-1}}{4.23\ \text{m s}^{-1}}\right)$ = North 39° West

4.16		$m\,u = m_1 v_1 + m_2 v_2$ so $v_2 = \dfrac{(m)(u)-(m_1 v_2)}{m_2} = \dfrac{(800\text{ kg})(500\text{ m s}^{-1})-(240)(-120\text{ m s}^{-1})}{560\text{ kg}}$ = 766 m s^{-1} (in the spacecraft's original direction)
4.17	(a)	$p_{shell} = m\,v = (10\text{ kg})(75\text{ ms}^{-1}) = 750\text{ kg m s}^{-1}$ forward
	(b)	zero
	(c)	zero
	(d)	$p_{shell} + p_{cannon} = 0$ so $750\text{ kg m s}^{-1} = -(m\,v)$ $v = \dfrac{-750\text{ kg m s}^{-1}}{5000\text{ kg}} = -0.15\text{ m s}^{-1}$ (backwards)
4.18		$m_1 u_1 + m_2 u_2 = (m_1 + m_2)\,v$ since u_2 = zero, then $u_1 = \dfrac{(m_1+m_2)(v)-(m_1 v_2)}{m_1}$ She can determine m_1 and m_2 using a balance and she can calculate v by timing how long it takes (t) a block of wood with the embedded bullet to travel a specified distance (s) after impact, then $v = \dfrac{s}{t}$
4.19		$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$ since u_2 = zero, then $v_2 = \dfrac{(m_1 u_1)-(m_1 v_1)}{m_2} = \dfrac{(4\text{ kg})(2.5\text{ m s}^{-1})-(4\text{ kg})(1.4\text{ m s}^{-1})}{0.5\text{ kg}}$ = 8.8 m s^{-1} (in the original direction)
4.20		$(m_1 + m_2)\,u_1 + (m_3 u_2) = (m_1 + m_2 + m_3)\,v$ then $v = \dfrac{(m_1+m_2)(u_1)+(m_3 v_2)}{(m_1+m_2+m_3)} = \dfrac{(40\text{ kg}+50\text{ kg})(2.0\text{ m s}^{-1})+(45\text{ kg})(5.0\text{ m s}^{-1})}{(40+50+45)\text{ kg}}$ = 3.0 m s^{-1} West
4.21		$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$ $(4200\text{ kg})(2\text{ m s}^{-1}) + (2500\text{ kg})(1.5\text{ m s}^{-1}) = (4200\text{ kg})(v_1) + (2500\text{ kg})(3\text{ m s}^{-1})$ gives $v_1 = 1.11\text{ m s}^{-1}$ in the original direction
4.22	(a)	$m_1 u_1 + m_2 u_2 = m_1 v + m_2 (2v)$ $(0.08\text{ kg})(12\text{ m s}^{-1}) - (0.06\text{ kg})(14\text{ m s}^{-1}) = (0.08\text{ kg})(v) + (0.06\text{ kg})(2\,v)$ gives v = 0.60 m s^{-1} in the original direction of Walter's ball (ball 1) so Walter's ball moves at 0.60 m s^{-1} in its original direction and Linda's ball moves at 1.20 m s^{-1} in the opposite direction to its original motion

	(b)	$m_1 u_1 + m_2 u_2 = m_1 v + m_2 (2v)$ $(0.08\ kg)(12\ m\ s^{-1}) - (0.06\ kg)(14\ m\ s^{-1}) = -(0.08\ kg)(v) + (0.06\ kg)(2\ v)$ gives $v = 3.0\ m\ s^{-1}$ in the original direction of Walter's ball (ball 1) so Walter's ball moves at $3.0\ m\ s^{-1}$ in the opposite direction to its original motion and Linda's ball moves at $6.0\ m\ s^{-1}$ in the opposite direction to its original motion
4.23		$F\ t = m\ \Delta v$ for first carriage, m_1 : $F\ t = (m_1)\ (4\ m\ s^{-1})$ and for second carriage, m_2 : $F\ t = (m_2)\ (6\ m\ s^{-1})$ so $4\ m_1 = 6\ m_2$ (i.e. m_1 is 1.5 times heavier than m_2) or $m_1 = 1.5\ m_2$ Now, $m_1 u_1 + m_2 u_2 = (m_1 + m_2)\ v$ so $(4\ m_1) + (6\ m_2) = (m_1 + m_2)\ v$ and incorporating the relationship that $m_1 = 1.5\ m_2$ then $(4)(1.5)(m_2) + (6\ m_2) = (1.5)(m_2 + m_2)\ v$ (m_2 will now cancel), leaving $v = \frac{12}{2.5} = 4.8\ m\ s^{-1}$

Set 5: Energy, Work and Power

5.1		$E_k = ½ m v^2$ $= ½ (42 \text{ kg})(3.7 \text{ m s}^{-1})^2 = 287 \text{ J}$
5.2		$E_p = m g h$ $= (1000 \text{ kg})(9.8 \text{ m s}^{-2})(3.0 \text{ m}) = 29\,400 \text{ J}$ (or 29.4 kJ)
5.3	(a)	$E_k = ½ m v^2$ $= ½ (0.5 \text{ kg})(8 \text{ m s}^{-1})^2 = 16 \text{ J}$
	(b)	gain in KE = loss in PE = $m g h = (0.5 \text{ kg})(9.8 \text{ m s}^{-2})(45.0 \text{ m}) = 221 \text{ J}$ new KE = 16 J + 221 J = 237 J
5.4	(a)	$W = P t = (25 \text{ W})(24 \text{ h})(3600 \text{ s h}^{-1}) = 2.16 \times 10^6 \text{ J}$ (or 2.16 MJ)
	(b)	Not all of the electrical energy supplied by the pump will be transferred usefully – some will be lost as heat and sound energy.
5.5	(a)	$E_k = ½ m v^2$ $= ½ (2000 \text{ kg})(18 \text{ m s}^{-1})^2 = 3.24 \times 10^5 \text{ J}$ (or 324 kJ)
	(b)	$F = \frac{W}{s} = \frac{3.24 \times 10^5 \text{ J}}{48 \text{ m}}$ = 6750 N (in the opposite direction to the van's original motion)
5.6	(a)	$W = F s = (8 \text{ N})(2 \text{ m}) = 16 \text{ J}$
	(b)	$W = F s = (12 \text{ N})(0.55 \text{ m}) = 6.6 \text{ J}$
	(c)	$W = F s = (25 \text{ N})(1.8 \text{ m}) = 45 \text{ J}$
	(d)	$W = F s = (1015 \text{ kg})(9.8 \text{ m s}^{-2})(310 \text{ m}) = 3.08 \times 10^6 \text{ J}$ (or 3.08 MJ)
	(e)	since a = zero, $F = F_{friction}$, then $W = F s = (42 \text{ N})(10 \text{ m}) = 420 \text{ J}$
5.7		$v^2 = u^2 + 2gs$ $E_k = ½mv^2$ so, $E_k = ½m(u^2 + 2gs)$ $= ½(0.2 \text{ kg})((10 \text{ m s}^{-1})^2 + (2)(9.8 \text{ m s}^{-2})(12 \text{ m}))$ $= 33.5 \text{ J}$
5.8	(a)	$W = F s = (12 \text{ N})(18 \text{ m}) = 216 \text{ J}$

	(b)	$F = \frac{W}{s} = \frac{100\ J}{0.8\ m}$ = 125 N upwards
	(c)	$s = \frac{W}{F} = \frac{1200\ J}{30\ N}$ = 40.0 m
5.9		$s = \frac{W}{F} = \frac{100\ J}{125\ N}$ = 0.80 m
5.10		$F_{av} = \frac{W}{s} = \frac{3000\ J}{25\ m}$ = 120 N
5.11		W = F s = (2000 kg)(9.8 m s^{-2})(50 m) = 9.8 x 10^5 J (or 980 kJ)
5.12	(a)	$P = \frac{W}{t} = \frac{5000\ J}{12\ s}$ = 417 W
	(b)	$P = \frac{W}{t} = \frac{mgh}{t} = \frac{(2.2\ kg)(9.8\ m\ s^{-2})(2.3\ m)}{0.8\ s}$ = 62.0 W
	(c)	$E_k = ½\ m\ v^2$ $= ½\ (0.355\ kg)(20\ m\ s^{-1})^2 = 71\ J$ $P = \frac{W}{t} = \frac{71\ J}{1.2\ s}$ = 59.2 W
	(d)	$P = \frac{W}{t} = \frac{Fs}{t} = \frac{(35\ N)(15\ m)}{3.5\ s}$ = 150 W
5.13	(a)	On contact with the soft sand the athlete's feet take longer to come to rest and they move further into the surface so they have to work harder to raise them and get them moving again. So they use more of the chemical energy they have acquired from their food and their muscles have to expend more of their stored elastic potential energy. In one hour, their body would generate more power.
	(b)	Raising your centre of gravity means hurdlers have to use some of their chemical and elastic potential energy to overcome the gravitational force, meaning they have less energy to transfer into kinetic energy and therefore will not run as quickly.
	(c)	Rollers skates effectively make contact with the ground at a point rather than over a larger surface area which is the situation with the soles of your feet, therefore they work against a much smaller frictional force. This means that your legs can apply a much smaller push force to move, using less energy.
	(d)	Crouching offers a much smaller surface area therefore a reduced drag or air resistance force at the start of a sprint. This means that more of the sprinter's chemical and elastic potential energy can be used to generate a greater initial acceleration burst, producing an increase in speed more quickly.
	(e)	When walking up hill, you have to overcome an additional gravitational force, meaning you have less energy to transfer into kinetic energy and therefore you will have to work harder to cover the same distance.
	(f)	The more kinetic energy a long jumper has on take off the more gravitational potential energy

		they will acquire while in the air. This means they should be able to gain additional height and stay in the air longer, thereby producing a longer jump.
	(g)	The Fosbury Flop technique does not involve the high jumper's centre of gravity rising as high above the ground as the Scissor Kick technique. See part b). for further explanation.
	(h)	When high jumpers push their arms forward, they are using Newton's third law (equal and opposite reaction) to gain an additional push from the ground in order that they jump with a greater force.
5.14	(a)	Since $F = \frac{m(v-u)}{t}$: in a pile driver, a large mass m is (almost) instantly brought to rest. Hence the time, t is very short; so the force of impact F on the pile is huge.
	(b)	To make the pile driver more effective you could: • use a heavier weight (increase m) • create a greater swing before the weight makes contact with the pile (increase ΔV) • have the lower end of the pile shaped like a point, the smaller surface area thereby creating greater pressure as it drives into the ground
5.15	(a)	loss in E_k = gain in E_p $E_k = ½\ m\ v^2 = m\ g\ h$ (note that the mass, m is the same on both sides and thus cancels) $v_{min} = \sqrt{2\ g\ h} = \sqrt{2\ (9.8\ m\ s^{-2})(2.5\ m)} = 7.0\ m\ s^{-1}$
	(b)	The initial E_k has to overcome a frictional force as it climbs up the slope and so it will lose some energy as heat and sound energy. So it needs a greater amount of E_k to begin with in order that it can acquire the necessary E_p to reach the top of the slope.
5.16	(a)	$P = \frac{W}{t} = \frac{(F\ x\ s)}{t} = F\ x\ (\text{gradient of graph}) = (256\ kg\ x\ 9.8\ m\ s^{-2}) x \frac{14m}{8s} = 4390\ W$
	(b)	$P = \frac{W}{t} = \frac{(F\ x\ s)}{t} = F\ x\ (v_{av})$ speed of hoist $v_{av} = \frac{P}{F} = \frac{4390\ W}{(2750\ kg)(9.8\ m\ s^{-2})} = 0.163\ m\ s^{-1}$
5.17		Initially, $E_k = ½\ x\ m\ x\ v^2$ $= ½\ x\ 3.6\ kg\ x\ (130\ m\ s^{-1})^2 = 3.04\ x\ 10^4\ J$ (or 30.4 kJ) Finally, $E_k = ½\ x\ m\ x\ v^2$ $= ½\ x\ 3.6\ kg\ x\ (65\ m\ s^{-1})^2 = 7.6\ x\ 10^3\ J$ (or 7.6 kJ) W = loss in KE = 30.4kJ - 7.6kJ = 22.8 kJ
5.18	(a)	theoretical gain in E_k = loss in E_p = m x g x h $= 64kg\ x\ 9.8\ m\ s^{-2}\ x\ 250m = 157{,}000\ J$ (or 157 kJ)
	(b)	real gain in E_k = 20% of 157kJ = 31.4 kJ
	(c)	$v = \sqrt{\frac{2\ x\ E_k}{m}} = \sqrt{\frac{2\ x\ 31400\ J}{64\ kg}} = 31.3\ m\ s^{-1}$

5.19	(a)	after 2s, E_k = 600 J $P = \frac{W}{t} = \frac{600\ J}{2\ s} = 300\ W$
	(b)	$P = \frac{W}{t} = \frac{3000\ J - 1500\ J}{20\ s - 10\ s} = 150\ W$
	(c)	$P = \frac{W}{t} = \frac{4000\ J - 3000\ J}{40\ s - 25\ s} = 66.7\ W$
	(d)	Chris is changing gears on his bike so there is no increase in speed, therefore no increase in E_k.
5.20		change in E_p = m x g x h = 2.5×10^{11} kg x 9.8 m s^{-2} x 1.75 m = 4.29×10^{12} J The station can only transfer 20% of this energy usefully, so energy supplied = 8.58×10^{11} J
5.21	(a)	vertical height, h = s x sinθ = 12 m x sin 15^o = 3.1 m E_p = m x g x h = 5 kg x 9.8 m s^{-2} x 3.1 m = 152 J
	(b)	E_k = ½ x m x v^2 = ½ x 5 kg x (6 m $s^{-1})^2$ = 90 J
	(c)	$W_{friction}$ = loss in energy = 152 J – 90 J = 62 J
	(d)	$F_{av} = \frac{W_{friction}}{s} = \frac{62\ J}{12\ m} = 5.2$ N up the ramp
5.22	(a)	$F_{friction}$ = 0.1 x (213 x 9.8 m s^{-2}) = 209 N $W_{friction}$ = F x s = 209 N x 25.3 m = 5290 J vertical height moved through, h = s x sin θ = 25.3 m x sin 30^o = 12.7 m E_p = m x g x h = 213 kg x 9.8 m s^{-2} x 12.7 m = 26510 J (this is the work done overcoming gravity) So the bike must expend a total energy = 5290 J + 26510 J = 31,800 J (or 31.8 kJ)
	(b)	time up slope: $t = \frac{d}{v_{av}} = \frac{25.3\ m}{12\ m\ s^{-1}} = 2.11\ s$ $P = \frac{W}{t} = \frac{31800\ J}{2.11\ s} = 15070$ W (or 15.1 kW)
5.23		W = F x s x cos θ = 20 N x 54 m x cos 45^o = 764 J

Set 6: Nuclei and Radiation

6.1	(a)	8 protons and (17 - 8) = 9 neutrons oxygen-17
	(b)	19 protons and (40 - 19) = 21 neutrons potassium-40
	(c)	92 protons and (234 - 92) = 142 neutrons uranium-234
	(d)	95 protons and (241 - 95) = 146 neutrons americium-241
6.2	(a)	${}^{27-26=1}_{13-12=1}\mathrm{H}$ or ${}^{1}_{1}\mathrm{p}$ - it could be hydrogen-1 or a proton
	(b)	${}^{239-0=239}_{93-(-1)=94}\mathrm{Pu}$ - it is plutonium-239
	(c)	${}^{22-22=0}_{11-10=1}\mathrm{e}$ - it is a positron
	(d)	${}^{131+0=131}_{53=0=53}\mathrm{I}$ - it is iodine-131
	(e)	${}^{(7+1)\div 2=4}_{(3+1)\div 2=2}\mathrm{He}$ or ${}^{4}_{2}\alpha$ - it could be helium-4 or an alpha particle
6.3	(a)	${}^{10}_{5}\mathrm{B}+{}^{1}_{0}\mathrm{n}\rightarrow{}^{11-4=7}_{5-2=3}\mathrm{Li}+{}^{4}_{2}\mathrm{He}$
	(b)	lithium
6.4		${}^{234}_{92}\mathrm{U}\rightarrow{}^{234-4=230}_{92-2=90}\mathrm{Th}+{}^{4}_{2}\mathrm{He}$
6.5		${}^{42}_{19}\mathrm{K}\rightarrow{}^{42-0=42}_{19-(-1)=20}\mathrm{Ca}+{}^{0}_{-1}\mathrm{e}$ - the product formed is calcium-42
6.6		${}^{141}_{56}\mathrm{Ba}\rightarrow{}^{141}_{55}\mathrm{Cs}+{}^{0}_{1}\mathrm{e}$ - a positron is also produced in the decay
6.7		${}^{151}_{53}\mathrm{I}\rightarrow{}^{151-0=42}_{53-(-1)=54}\mathrm{Xe}+{}^{0}_{-1}\mathrm{e}$ - the product formed is xenon-131
6.8		${}^{99}_{42}\mathrm{Mo}\rightarrow{}^{99}_{42-(-1)=43}\mathrm{Tc}+{}^{0}_{-1}\mathrm{e}$ - an electron or beta particle is also produced
6.9		${}^{222}_{86}\mathrm{Rn}\rightarrow{}^{222-4=218}_{86-2=84}\mathrm{Po}+{}^{4}_{2}\mathrm{He}$ - the product formed is polonium-218
6.10	(a)	${}^{2}_{1}\mathrm{H}+{}^{3}_{1}\mathrm{H}\rightarrow{}^{4}_{2}\mathrm{He}+{}^{1}_{0}\mathrm{n}$
	(b)	It has to be a particle with an atomic number = 0, so it must be a neutron
6.11		${}^{14}_{7}\mathrm{N}+{}^{1}_{0}\mathrm{n}\rightarrow{}^{14}_{6}\mathrm{C}+{}^{1}_{1}\mathrm{p}$ It has to be a particle with an atomic number = 0, so it must be a neutron
6.12		${}^{239}_{94}\mathrm{Pu}\rightarrow{}^{239-4=235}_{94-2=92}\mathrm{U}+{}^{4}_{2}\mathrm{He}$ ${}^{235}_{92}\mathrm{U}\rightarrow{}^{235-4=231}_{92-2=90}\mathrm{Th}+{}^{4}_{2}\mathrm{He}$

		${}^{231}_{90}\text{Th} \rightarrow {}^{231-0=231}_{90-(-1)=91}\text{Pa} + {}^{0}_{-1}\text{e}$
6.13		${}^{232}_{90}\text{Th} \rightarrow {}^{232-4=228}_{90-2=88}\text{Ra} + {}^{4}_{2}\text{He}$ ${}^{228}_{88}\text{Ra} \rightarrow {}^{228-0=228}_{88-(-1)=89}\text{Ac} + {}^{0}_{-1}\text{e}$ ${}^{228}_{89}\text{Ac} \rightarrow {}^{228-0=228}_{89-(-1)=90}\text{Th} + {}^{0}_{-1}\text{e}$ ${}^{228}_{90}\text{Th} \rightarrow {}^{228-4=224}_{90-2=88}\text{Ra} + {}^{4}_{2}\text{He}$ ${}^{224}_{88}\text{Ra} \rightarrow {}^{224-4=220}_{88-2=86}\text{Rn} + {}^{4}_{2}\text{He}$
6.14		${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 3{}^{1}_{0}\text{n}$ since the atomic number has to be zero, the other product formed has to be a neutron and in order that the mass numbers balance, there must be three of them.
6.15	(a)	${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{134}_{51}\text{Sb} + {}^{95}_{39}\text{Y} + 3{}^{1}_{0}\text{n} + {}^{235+1-(134+95+3)=4}_{92-(51+39)=2}\text{He}$
	(b)	The additional particle formed is an alpha particle
6.16		${}^{238}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{239}_{92}\text{U}$ ${}^{239}_{92}\text{U} \rightarrow {}^{239-0=239}_{92-(-1)=93}\text{Np} + {}^{0}_{-1}\text{e}$ ${}^{239}_{93}\text{Np} \rightarrow {}^{239-0=239}_{93-(-1)=94}\text{Pu} + {}^{0}_{-1}\text{e}$
6.17		${}^{11}_{5}\text{B} + {}^{4}_{2}\text{He} \rightarrow {}^{14}_{7}\text{N} + {}^{11+4-14=1}_{5+2-7=0}\text{n}$ It has to be a particle with an atomic number = 0, so it must be a neutron

Set 7: Half Life

7.1	(a)	22 hours
	(b)	since ½ have decayed, then there will be ½ unchanged
	(c)	44 hours is two half lives and in this time ¾ of the atoms will have decayed
7.2	(a)	half life is the time taken for 500 MBq to become 250 MBq = 6 hours
	(b)	after each half life: 500 → 250 → 125 → 62.5 → 31.1 → 15.65 → 7.83 → 3.9 → 1.95 (approximately 2) This is eight half lives = 8 x 6 hrs = 48 hours
7.3		The sample becomes a sixteenth of its original value after four half lives = 4 x 30 yrs = 120 years
7.4		number of half lives elapsed $= \frac{42.9 \text{ days}}{14.3 \text{ days}} = 3$ half lives after three half lives there will be(2^{-3}) = ⅛ of the original sample remaining and therefore ⅛ the original activity, so the new activity = ⅛ x 2.4 MBq = 0.3 MBq (or 300 kBq)
7.5	(a)	after each half life: 2048 → 1024 → 512 → 256 → 128 = four half lives 4 x $t_{½}$ = 150 mins, then half life, $t_{½} = \frac{150 \text{ minutes}}{4} = 3.75$ minutes
	(b)	Each half life, a half of the original number of atoms decay into other products by emitting either alpha particles, beta particles or gamma rays (or a combination of them). This occurs because the original atoms are unstable and randomly and spontaneously decay in an attempt to become more stable.
7.6	(a)	After 24 hrs, it has gone through two half lives and therefore decayed into ¼ of its original amount. Therefore, in order for a sample with an activity of 800 kBq to be injected, the technician would need to prepare a sample with an activity 4 x 800 kBq = 3200 kBq (or 3.2 MBq)
	(b)	24 hrs after injection, it has gone through two half lives and therefore decayed into ¼ of its original amount. So the new activity = ¼ x 800 kBq = 200 kBq
7.7	(a)	A half will decay in one half life so atoms decaying = ½ x 1 x 10^{24} = 5.0 x 10^{23}
	(b)	Activity, A = λ x N $\lambda = \frac{\ln(2)}{t_{½}} = \frac{0.693}{2.41 \times 10^4 \text{ y}} = 2.88 \times 10^{-5} \text{ y}^{-1}$ so $A = 2.88 \times 10^{-5} \text{ y}^{-1} \times 1 \times 10^{24} = 2.9 \times 10^{-19}$ Bq
	(c)	${}^{239}_{94}\text{Pu} \rightarrow {}^{239-4=235}_{94-2=92}\text{U} + {}^{4}_{2}\text{He}$
7.8	(a)	$\frac{A}{A_0} = 0.5^n$

		where n is the number of half lives which have elapsed = $\left(\frac{t}{t_{½}}\right)$ and A_o is the original activity so the new activity, $A = 0.5^{\left(\frac{26\text{ y}}{5.3\text{ y}}\right)} \text{x } 800 \text{ GBq} = 26.8 \text{ GBq}$
	(b)	to reduce to $\frac{1}{1000}$ of original value requires n half-lives such that $(0.5)^n = \frac{1}{1000}$ as $2^{10} = 1024$ then n is approximately equal to 10 10 half-lives is 10 x 5.3 = 53 years "safe" in approximately (2008 + 53) = 2061 (or 6th decade of 21st century)
7.9		At the point where they have the same number of undecayed atoms X is decaying faster (half will have decayed in 8 seconds) and has the higher activity. (Activity is measured as the number of disintegrations per second.)
7.10	(a)	$\frac{A}{A_0} = 0.5^n$ so the new activity, $A = 0.5^{\left(\frac{7\text{ d}}{2.7\text{ d}}\right)} \text{x } 8 \text{ MBq} = 1.33 \text{ MBq}$
	(b)	${}^{198}_{79}\text{Au} \rightarrow {}^{228-0=198}_{79-(-1)=80}\text{Hg} + {}^{0}_{-1}\text{e}$
7.11		The fact that the ratio of carbon-12 to carbon-14 is the same in the atmosphere and in the new bone is an indication that the living animal is continuously absorbing carbon from the atmosphere. When the bone is dead, no interchange occurs and because carbon-14 is radioactive, the amount of it slowly declines (due to decay).
7.12		12.5% is $\frac{1}{8}$of the original sample which accounts for three half lives. So, three half lives = 3 x 5730 y = 17 190 years
7.13	(a)	The value of the half life will vary depending on the graph plot, but take at least three readings from the graph to estimate an average value. It should be about 20±2 minutes.
	(b)	It must be a beta particle since aluminium would absorb virtually all alpha particles and gamma rays would pass through the foil almost unaffected. Sine some particles emerge and there is a noticeable change, only beta particles are possible.
7.14	(a)	${}^{24}_{12}\text{Mg} + {}^{1}_{0}\text{n} \rightarrow {}^{24}_{11}\text{Na} + {}^{24+1-24=1}_{12-11=1}\text{p}$ or ${}^{1}_{1}\text{H}$ ${}^{24}_{11}\text{Na} \rightarrow {}^{24-0=24}_{11-(-1)=12}\text{Mg} + {}^{0}_{-1}\text{e} + {}^{0}_{0}\gamma$
	(b)	if 90% has decayed, then 10% remains, so $\frac{A}{A_0} = 0.5^n = 0.10$ then $n = \frac{\ln(0.10)}{\ln(0.5)} = 3.32$ Since n = $n = \frac{t}{t_{½}}$ then t = n x $t_{½}$ = 3.32 x 15 h = 49.8 hours

7.15	(a)	Radon undergoes $\frac{20\text{ days}}{4\text{ days}} = 5\text{ half lives}$ During 5 x $t_{½}$, there will be ($\frac{1}{32}$) of the original radon remaining so the new activity, A = $\frac{1}{32}$ x 3.8 kBq = 0.12 kBq (or 120 Bq)
	(b)	Both are alpha emitters so once ingested or absorbed could cause significant cell damage through ionisation. The blood organs would particularly be affected and harmed. However, since the half life of polonium is only 3 minutes, it will decay and effectively disappear within hours, so this would be less harmful than radon which has a relatively much larger half life and will therefore hang about longer.
7.16		if 95% has decayed, then 5% remains, so $\frac{A}{A_0} = 0.5^n = 0.05$ then $n = \frac{\ln(0.05)}{\ln(0.5)} = 4.32$ Since n = $n = \frac{t}{t_{½}}$ then t = n x $t_{½}$ = 4.32 x 28.9 y = 125 years
7.17	(a)	Since the activity of 50 g is 200 min^{-1}, then 1 g would have an activity $A = \frac{200}{50} = 4\text{ min}^{-1}$ $\frac{A}{A_0} = 0.5^n$ so $\frac{A}{A_0} = \frac{4\text{ min}^{-1}}{15\text{ min}^{-1}} = 0.267 = 0.5^n$ then $n = \frac{\ln(0.267)}{\ln(0.5)} = 1.91$ Since $n = \frac{t}{t_{½}}$ then $t = n \times t_{½} = 1.91 \times 5730\text{ y} = 10\,940\text{ y}$
	(b)	This value assumes that the ration of carbon-12 to carbon-14 in living things, being the same as the ratio in the earth's atmosphere, has remained constant over a very long period of time.
7.18	(a)	Artificially produced radioisotopes, being man-made, which decay very quickly have not had the opportunity to influence nature, something that has become established over millions of years.
	(b)	Naturally occurring radioisotopes however have adapted to the environment and have been absorbed into many of nature's resources, perhaps producing products which themselves have longer half lives.

Nuclear Physics

Set 8: Binding Energy

8.1		The difference is a single neutron, so the mass difference = 1 u = 931 MeV
8.2	(a)	${}^{0}_{0}\gamma \rightarrow {}^{0}_{+1}e + {}^{0}_{-1}e$
	(b)	mass equivalent, m = electron mass + positron mass = 2 x 0.000549 u = 0.001098 u energy equivalent, E = 0.001098 x 931MeV = 0.001098 x 931 x 10^{6}eV x 1.6 x 10^{-19}J = 1.64 x 10^{-13} J
8.3		mass defect = mass of (92 protons + 143 neutrons) - mass of a uranium-235 nucleus = (92 x 1.00728 u) + (143 x 1.00867 u) – 235.04393 u = 1.86564 u energy equivalent, E = 1.86564 x 931 MeV = 1736.91 MeV (this is the binding energy) so the binding energy per nucleon = 1736.91 MeV ÷ 235 = 7.39 MeV $nucleon^{-1}$
8.4		Binding energy per nucleon is a measure of the stability of the nucleus, so nucleus B is more stable.
8.5	(a)	mass defect = mass of 3 protons + mass of 4 neutrons - mass of a lithium-7 nucleus = (3 x 1.00728 u) + (4 x 1.00867 u) – 7.01601 u = 0.04051 u energy equivalent, E = 0.04051 x 931 MeV = 37.7 MeV (this is the binding energy) so the binding energy per nucleon = 37.71MeV ÷ 7 = 5.39 MeV $nucleon^{-1}$
	(b)	mass defect = mass of 53 protons + mass of 78 neutrons - mass of an iodine-131 nucleus = (53 x 1.00728 u) + (78 x 1.00867 u) – 130.90613 u = 1.1560 u energy equivalent, E = 1.1560 x 931 MeV = 1076.21 MeV (this is the binding energy) so the binding energy per nucleon = 1076.21 MeV ÷ 131 = 8.22 MeV $nucleon^{-1}$
8.6		H-2: mass defect = mass of 1 proton + mass of 1 neutron - mass of a helium-2 nucleus = 1.00728 u + 1.00867 u – 2.01355 u = 0.0024 u energy equivalent, E = 0.0024 x 931 MeV = 2.23 MeV (this is the binding energy) so the binding energy per nucleon = 2.23 MeV ÷ 2 = 1.12 MeV $nucleon^{-1}$ H-3: mass defect = mass of 1 proton + mass of 2 neutrons - mass of a helium-3 nucleus = (1.00728 u) + (2 x 1.00867 u) – 3.01605u = 0.00857 u energy equivalent, E = 0.00857 x 931 MeV = 7.98 MeV (this is the binding energy) so the binding energy per nucleon = 7.98 MeV ÷ 3 = 2.6 MeV $nucleon^{-1}$ Tritium has the higher BE per nucleon
8.7		C-12: mass defect = mass of 6 protons + mass of 6 neutrons - mass of a carbon-12 nucleus = (6 x 1.00728 u) + (6 x 1.00867 u) – 12 u = 0.0957 u energy equivalent, E = 0.0957 x 931 MeV = 89.1 MeV (this is the binding energy)

		so the binding energy per nucleon = 89.1 MeV ÷ 12 = 7.42 MeV nucleon^{-1} C-14: mass defect = mass of 6 protons + mass of 6 neutrons - mass of a carbon-12 nucleus = (6 x 1.00728 u) + (8 x 1.00867 u) – 14.00324 u = 0.1098 u energy equivalent, E = 0.1098 x 931 MeV = 102.22 MeV (this is the binding energy) so the binding energy per nucleon = 102.22 MeV ÷ 14 = 7.30 MeV nucleon^{-1} C-12 has a greater BE per nucleon so it is more stable.
8.8	(a)	a positron
	(b)	mass of reactants = 2 x 1.00783 u = 2.01456 u mass of products = 2.01355 u + 0.000549 u = 2.0141 u mass defect = 2.01456 u – 2.0141 u = 0.00046 u = 0.00046 x 1.66054 x 10^{-27} kg = 7.64 x 10^{-31} kg
	(c)	E = m x c^2 = 7.64 x 10^{-31} kg x (3 x 10^8 m s^{-1})^2 = 6.875 x 10^{-14} J = 6.875 x 10^{-14} J (÷1.60 x 10^{-13} J) = 0.430 MeV
8.9	(a)	mass of reactants = 2.01355 u + 3.01605 u = 5.0285 u mass of products = 4.00260 u + 1.00867 u = 5.0102 u mass defect = 5.0285 u – 5.0102 u = 0.0183 u = 0.0133 x 1.66054 x 10^{-27}kg = 3.04 x 10^{-29} kg
	(b)	E = m x c^2 = 3.04 x 10^{-29} kg x (3 x 10^8 m s^{-1})^2 = 2.74 x 10^{-12} J = 2.74 x 10^{-12} J (÷1.60 x 10^{-13} J) = 17.1 MeV
8.10		mass of reactants = [238.05079 u – (92 x 0.000549u)] = 238.00028 u mass of products = [4.00260 u – (2 x 0.000549u)] + [234.0436 u – (90 x 0.000549u)] = 237.9957 u mass defect = 238.00028 u – 237.9957 u = 0.00458 u = 0.00458 x 1.66054 x 10^{-27} kg = 7.6053 x 10^{-30} kg E = m x c^2 = 7.6053 x 10^{-30} kg x (3 x 10^8 m s^{-1})^2 = 6.845 x 10^{-13} J = 6.845 x 10^{-13} J (÷1.60 x 10^{-13} J) = 4.28 MeV
8.11	(a)	${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{142}_{54}Xe + {}^{90}_{38}Sr + 4{}^{1}_{0}n$ - there are four neutrons released in this fission reaction
	(b)	mass of reactants = [(235.04393 u – (92 x 0.000549u)] + 1.00867 = 236.00209 u mass of products = [141.92971 u – (54 x 0.000549u)]+[89.90774 u – (38 x 0.000549u)]+ (4 x 1.00867 u) = 235.8216 u mass defect = 236.00209 u – 235.8216 u = 0.1805 u = 0.1805 x 1.66054 x 10^{-27}kg = 2.9973 x 10^{-28} kg

		$E = m \times c^2 = 2.9973 \times 10^{-28}$ kg x $(3 \times 10^8 \text{ m s}^{-1})^2 = 2.698 \times 10^{-11}$ J $= 2.698 \times 10^{-11}$ J $(\div 1.60 \times 10^{-13}$ J$) = 169$ MeV
	(c)	In a nuclear reactor the chain reaction is controlled however with a nuclear bomb, the reaction is not controlled.
8.12	(a)	The nuclear reaction involves "lost" mass which is converted into energy. The products produced have huge amounts of kinetic energy, generating the thermal energy which then drives the reactor.
	(b)	This energy is not directed to a specific place and requires a coolant to safely take it away where it can be used to produce steam to drive turbines.
8.13	(a)	${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 3{}^{1}_{0}\text{n}$
	(b)	mass of reactants = [(235.04393 u – (92 x 0.000549u)] + 1.00867 u = 236.00209 u mass of products = [140.91441 u – (56 x 0.000549u)]+[91.92616 u – (36 x 0.000549u)]+ (3 x 1.00867 u) = 235.8161 u mass defect = 236.00209 u – 235.8161 u = 0.1860 u $= 0.1860 \times 1.66054 \times 10^{-27}$ kg $= 3.0886 \times 10^{-28}$ kg $E = m \times c^2 = 3.0886 \times 10^{-28}$ kg x $(3 \times 10^8 \text{ m s}^{-1})^2 = 2.780 \times 10^{-11}$ J $= 2.780 \times 10^{-11}$ J $(\div 1.60 \times 10^{-13}$ J$) = 174$ MeV
	(c)	mass of uranium atom = 235.04393 u x 1.66054×10^{-27} kg $= 3.903 \times 10^{-25}$ kg
	(d)	number of atoms in 1.00kg of uranium-235 = 1 kg $\div$ 3.903×10^{-25} kg $= 2.56 \times 10^{24}$
	(e)	energy per fission reaction = 174 MeV so energy released when 1.00 kg of pure uranium-235 fissions = 2.780×10^{-11} J x 2.56×10^{24} $= 7.1 \times 10^{13}$ J Assuming that there is one nucleus per uranium atom and that they all undergo the fission process producing the exact same products as specified in part a).
	(f)	Mass of uranium required = 9.76×10^{13} J $\div$ 7.1×10^{13} J = 1.37 kg
8.14	(a)	${}^{1}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{3}_{2}\text{He}$
	(b)	mass of reactants = (2.01355 u + 1.00783 u) = 3.020282 u mass of products = 3.01603 u mass defect = 3.020282 u – 3.014932 u = 0.00535 u $= 0.00535 \times 1.66054 \times 10^{-27}$ kg $= 8.884 \times 10^{-30}$ kg $E = m \times c^2 = 8.884 \times 10^{-30}$ kg x $(3 \times 10^8 \text{ m s}^{-1})^2 = 7.996 \times 10^{-13}$ J $= 7.996 \times 10^{-13}$ J $(\div 1.60 \times 10^{-13}$ J$) = 4.998$ MeV

	(c)	mass of deuterium atom = 2.01355 u x 1.66054 x 10^{-27} kg = 3.34 x 10^{-27} kg number of atoms in 1.00kg of deuterium = 1 kg ÷ 3.34 x 10^{-27} kg = 2.99 x 10^{26}
	(d)	2.39 x 10^{14} J
8.15		mass of reactants = [(14.00307 u – (7 x 0.000549u)] + [(4.0026 u – (2 x 0.000549u)] = 18.000729 u mass of products = [(16.994738 u – (8 x 0.000549u)] + 1.00728 u = 18.002018 u mass defect = 18.000729 – 18.002018 u = -0.001289 u = -0.001289 x 1.66054 x 10^{-27} kg = -2.14 x 10^{-30} kg E = m x c^2 = -2.14 x 10^{-30} kg x (3 x 10^8 m $s^{-1})^2$ = -1.926 x 10^{-13} J = -1.926 x 10^{-13} J (÷1.60 x 10^{-13} J) = -1.204 MeV Adding on the original 3 MeV of kinetic energy possessed by the bombarding alpha particle, then the reaction products will have a total KE = 3 + (-1.204) = 1.80 MeV
8.16	(a)	${}^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{1}_{1}p$ - the nucleon released is a proton
	(b)	mass of reactants = [(14.00307 u – (7 x 0.000549u)] + 1.00867 u = 15.007897 u mass of products = [(14.00324 u – (6 x 0.000549u)] + 1.00728 u = 15.007226 u mass defect = 15.007897 u – 15.007226 u = 0.000671 u = 0.000671 x 1.66054 x 10^{-27} kg = 1.11 x 10^{-30} kg
	(c)	E = m x c^2 = 1.11 x 10^{-30} kg x (3 x 10^8 m $s^{-1})^2$ = 9.99 x 10^{-14} J = 9.99 x 10^{-14} J (÷1.60 x 10^{-13} J) = 0.624 MeV
	(d)	V = √(2 x E_k ÷ m_p) = √[(2 x 9.99 x 10^{-14} J ÷ (1.67262 x 10^{-27} kg)] = 1.09 x 10^7 m s^{-1}

Set 9: Radiation and the Environment

9.1	(a)	Because α particles are much larger (of the same order of size as atoms) than other common radiated particles they collide with many atoms, rapidly losing their kinetic energy. These collisions cause lots of ionisation but the rapid loss of energy means that the α particles do not penetrate very far. β particles are high speed electrons or positrons. Their small size means that they lose energy by collisions with atoms less rapidly. Thus they cause less ionisation but by retaining their energy longer penetrate further. γ rays are high energy photons of electromagnetic radiation. They travel large distances through matter without being absorbed. When absorption occurs electrons are emitted causing ionisation.
	(b)	An α particle is absorbed in the first centimetre of tissue, but causes large amounts of ionisation while doing so. When an α emitter is ingested it can adhere to lung tissue or stomach tissue where it can cause considerable ionisation damage. If the cell reproduction in this tissue is rapid (for example, in the testes and ovaries), the damage is more serious. External sources are usually promptly washed off, but particles lodged internally may continue to do damage over a long period of time.
9.2	(a)	Shielding: When using the source she wears a lead apron and may stand behind a lead screen. Lead is very dense, and high-density material absorbs radiation better than low-density material. Distance: She stands further away from the radioactive source than the patient. Radiation becomes less intense as the distance increases according to the inverse square law, eg. doubling the distance decreases the dose to one quarter.
	(b)	Lead is very dense; high-density material absorbs radiation better than low-density material.
	(c)	See 9.1 part b).
9.3	(a)	Gamma radiation would be used because it is the only radiation that would penetrate far enough.
	(b)	No, healthy tissue would also be affected but cancer cells tend to absorb more radiation.
	(c)	This maintains continuous irradiation of the tumour site while minimising the dose to any surrounding healthy tissue. Some damage will always be caused by the beam on its way to the target tissue but this is now spread over a lot of tissue.
	(d)	No - gamma photons do not cause changes in the nuclei of cells and the absorbed gamma photons are not themselves radioactive.
9.4	(a)	Alpha particles are considered a relatively harmless source outside the body due to their inability to penetrate large distances. However, they are the most ionising form of radiation and as such can use major cell damage if an alpha source is ingested or inhaled.
	(b)	Ventilate the facility well using industrial extractor fans and/or wear face masks.
9.5		The effect of radiation on humans is measured in terms of the quality factor. The quality factor for fast neutrons is 10 compared to 3 for slow neutrons. This is because of the higher energy of the fast neutrons and they will therefore be more harmful.
9.6	(a)	dose equivalent = absorbed dose x quality factor = 36 mGy x 20 = 720 mSv

	(b)	Since beta and gamma have a quality factor = 1, then this absorbed dose would provide a much smaller dose equivalent and therefore be less harmful.
9.7	(a)	A lethal dose of 50/50 suggests that 50% of the people exposed would die within 50 days of exposure.
	(b)	A lethal dose of 100/20 suggests that ALL the people exposed would die within 20 days of exposure.
9.8	(a)	$\text{Absorbed dose } = \frac{\text{energy}}{\text{mass}} = \frac{16.6\text{ J}}{78.5\text{ kg}} = 0.206\text{ Gy}$
	(b)	dose equivalent = absorbed dose x quality factor = 0.206 Gy x 20 = 4.12 Sv
	(c)	Yes – 4 Sv will almost certainly be fatal, causing leukaemia and tumours.
	(d)	$\text{Absorbed dose } = \frac{\text{energy}}{\text{mass}} = \frac{16.6\text{ J}}{0.6\text{ kg}} = 27\ \text{ Gy}$ so dose equivalent = absorbed dose x quality factor = 27 Gy x 20 = 540 Sv which will cause complete eradication of the exposed tissue, which is probably diseased or damaged tissue anyway so the objective would be achieved. There would be some damage to surrounding tissue also.
9.9		$\text{Absorbed dose per year } = \frac{\text{dose equivalent per year}}{\text{quality factor}} = \frac{1.4\ \text{mSv}}{1} = 1.4\ \text{mGy y}^{-1}$ so energy received per year = absorbed dose per year x mass = 1.4 mGy y^{-1} x 50 kg = 70 mJ y^{-1}
9.10	(a)	Radioactive fallout is the resulting daughter products produced following a nuclear explosion, which is basically the uncontrolled chain reaction of numerous fission processes.
	(b)	These products tend to have extremely long half lives so they are present for years. Such products get absorbed by soil and into the water table, which therefore contaminate crops and animals. People then eat the crops and animals, so the cycle of long term harm continues.
9.11	(a)	Radon is largely produced within the Earth itself and will therefore be found in soil and rocks, such as granite.
	(b)	Radon concentrations where the Earth has been drilled or dug into, or where the Earth has been disturbed, will tend to be highest. So mine sites or areas of recent volcanic activity would be susceptible.
9.12	(a)	$\text{Absorbed dose } = \frac{\text{energy}}{\text{mass}} = \frac{28.7\text{ J}}{64.2\text{ kg}} = 0.447\text{ Gy}$
	(b)	Dose equivalent = absorbed dose x quality factor = 0.447 Gy x 1 = 0.447 Sv
	(c)	No, it is non-fatal but may cause some radiation sickness.
	(d)	Since the quality factor is now x 20, the dose equivalent = 8.94 Sv. She would be unlikely to survive.

9.13	(a)	${}^{198}_{79}\text{Au} \rightarrow {}^{228-0=198}_{79-(-1)=80}\text{Hg} + {}^{0}_{-1}\text{e}$
	(b)	mass of radioisotope = 197.96824 u = 197.924869 u mass of products = 197.96677 u + 0.000549 u] = 197.923399 u mass defect = 197.924869u – 197.923399u = 0.00147 u = 0.00147 x 1.66054 x 10^{-27} kg = 2.44 x 10^{-30} kg E = m x c^2 = 2.44 x 10^{-30} kg x (3 x 10^8 m $s^{-1})^2$ = 2.197 x 10^{-13} J = 2.197 x 10^{-13} J (÷1.60 x 10^{-13} J) = 1.37 MeV
	(c)	Mix the sewage with the gold radioisotope and then use a Geiger Muller counter to monitor the beta radiation as it moves along with the sewage.
9.14	(a)	energy released / second = activity x energy per decay = 100 x 10^6 Bq x 2 x 10^{-13} J = 2.0 x 10^{-5} J s^{-1}
	(b)	Daily absorbed dose = energy ÷ mass = (2.0 x 10^{-5} J s^{-1} x 24hrs x 3600s) ÷ 60 = 0.029 Gy day^{-1}
	(c)	Daily dose equivalent = daily absorbed dose x quality factor = 0.029Gy day^{-1} x 1 = 0.029 Sv day^{-1} = 29 mSv day^{-1}
	(d)	number of days needed to receive a total of $5\ \text{Sv} = \dfrac{5\ \text{Sv}}{0.029\ \text{Sv day}^{-1}} = 172\ \text{days}$ So, there is a 50% chance of surviving almost 6 months
9.15	(a)	Cosmic radiation.
	(b)	Aircrew have less atmosphere to protect them since they are closer to the cosmos than ground based transport industries so they are more susceptible to exposure.
	(c)	The sensitive film suffers a degree of darkening due to the ionising ability of radiation.
	(d)	Alpha particle radiation is not very penetrable and would be almost certainly absorbed by the surrounding air before reaching the film badge.
	(e)	Since beta radiation is made up of fast moving, relatively light particles, the exposure would appear as scattered specks and maybe be more pronounced. However, gamma rays have no mass so their appearance would be more cloudy.
9.16		Potassium iodide tablets can prevent about 99% of the damage to the thyroid gland that would otherwise result from exposure to the radioisotope iodine-131. The gland readily absorbs both radioactive and non-radioactive iodine and normally retains much of this element in either or both forms. If ordinary, non-radioactive iodine is made available, in the form of tablets, which then becomes absorbed by the thyroid before radioactive iodine is present, then the gland will soon become saturated. In this state of saturation, the thyroid can only absorb about 1% as much additional iodine, including radioactive forms that later may become available in the blood – it is said to be blocked. Excess iodine in the blood is rapidly eliminated by the action of the kidneys.
9.17	(a)	Dose equivalent =(7.5 mGy x 1) + (6.0 mGy x 1) + (0.3 mGy x 10) + (1.5 mGy x 3) + (0.15

		mGy x 20) so in one year, dose equivalent = 24 mSv, which is three times too much. Therefore, they should only be allowed to work in the mine for ⅓ of the year (about 121 – 122 days)
	(b)	Assuming that the levels of each type of radiation source remains constant and that the mine workers are of a similar size and body mass.

Heating & Cooling

Set 10: Heat, Temperature and Thermal Energy

10.1	(a)	the Sun
	(b)	electric current (rapidly moving free electrons)
	(c)	frictional forces created by moving parts
10.2		$\text{Efficiency} = \frac{\text{useful output energy}}{\text{total input energy}} = \frac{215\text{ J}}{985\text{ J}} \times 100\% = 21.8\%$
10.3		The engine's coolant takes the heat away from the engine and then attempts to lose this heat energy to the atmosphere. On a cool day, there is a bigger temperature difference between the engine and the surrounding air so the rate of heat flow will be greater – heat will flow away more effectively, meaning the engine will remain that bit cooler.
10.4	(a)	energy lost = 45 J – 18 J = 27 J $\% \text{ of energy lost} = \frac{27\text{ J}}{45\text{ J}} \times 100\% = 60\%$
	(b)	Drop the squash ball from a measured height and measure the height of the rebound. Since height is directly proportional to potential energy and potential energy lost is equal to the kinetic energy gained (ignoring air resistance), then $\frac{\text{height of rebound}}{\text{height of drop}}$ should confirm the squash ball's inefficiency. Repeat several times from a range of heights. Measuring the temperature of the ball before and then after several rallies would also confirm that the ball itself is acquiring heat energy from somewhere.
	(c)	It is transferred to the surrounding air as heat and sound, with the ball itself getting warmer due to absorbing some of the "lost" energy.
10.5	(a)	Heat energy (and some sound energy).
	(b)	The immediate surroundings acquire this energy – the brake pads, the car tyres, the road surface and the air.
10.6		The freezer would continually lose cold air into the room, so it would have to work harder. In doing so, it would actually transfer more heat energy from the fins at the rear of the freezer to the surrounding air effectively making the room warmer.
10.7		Most electric heaters create heat directly, using elements which heat up when an electric current passes through them. These 'direct element' heaters include portable heaters, panel convectors and off-peak storage heaters. They have a maximum efficiency of 100%, when all the electricity is converted to heat and delivered to the room. Reverse cycle air conditioning extracts heat from the outside air, even on mid-winter nights, and transfers it inside. A refrigerant is passed through an external coil, absorbing heat from the outside air. This refrigerant is then pumped through a compressor into a fan coil unit (or 'condenser') inside the home, releasing its heat into the room. Up to three or more units of heat can be transferred for every unit of electricity used to run reverse cycle air conditioning. Therefore, running costs can be as low as one-third of those for direct element heaters. By reversing the flow of this refrigerant, reverse cycle air conditioners also provide efficient refrigerative cooling in summer.

10.8	(a)	Low grade energy is often a wasted or non-useful form of energy or energy that cannot be easily used.
	(b)	High grade energy is the kind of energy you want to obtain from a machine or transducer and it is often the purpose for using the particular device – it is a useful energy form.
	(c)	High grade energy would include the electrical energy produced by a power station or the kinetic energy produced by the engines of motor vehicles (via the chemical energy stored in its fuel).
10.9	(a)	Use a feedback system to put the thermal energy back into the power station in order to heat the offices, or the hot water system, or even back into the electricity making process aspect of the station itself.
	(b)	Australian working environments tend to require cooling systems, rather than heating systems.
10.10	(a)	High temperatures mean the particles will have much greater kinetic energy so the resultant effect will make a greater amount of mechanical energy available to the engine.
	(b)	In cold weather there is a greater temperature difference between the heat engine and the surrounding air. Heat flows more easily (quickly) under such circumstances.
10.11		Electrical energy produced each day = power x time = 1000 MW x (24 h x 3600 s h^{-1}) = 8.64×10^{13} J Since the power station is only 50% efficient, it needs twice this amount of input energy from the coal it burns each day Required input energy each day = 1.728×10^{14} J $\text{Mass of coal required per day} = \frac{\text{energy needed each day}}{\text{energy provided per kilogram}} = \frac{1.728 \times 10^{14}\ \text{J}}{25 \times 10^{6}\ \text{J kg}^{-1}} = 6.91 \times 10^{6}\ \text{kg}$ (or 6912 tonnes).

Heating & Cooling

Set 11: Heat Transfer

11.1		This material is used to reduce heat transfer by radiation. The shiny surface causes the reflection of either heat energy back into the building in winter or reflection of external heat energy out again in summer.
11.2		The water near the surface is heated directly by the Sun's radiation. When the water is warmed it becomes less dense and therefore floats on the more dense unheated water below it. So there will be no convectional mixing and if the water is still the only method of heat transfer to the deeper water it will be by conduction, which will be slow because water is a poor conductor.
11.3		The cold air in the freezer is denser than the surrounding air and so will not rise and cause convection currents. As long as the air is still in the area the heat gain is only due to radiation and conduction, which occur sufficiently slowly for the freezer compressor to remove it.
11.4		Your feet feel cold because heat flows from them. As the concrete floor is a better conductor than the carpet, more heat flows out from your feet in that case. (The carpet soon warms up to the same temperature as your feet and no more heat flows.)
11.5		Metals are better conductors than plastics so the metal fork will take heat away from your hand more quickly, effectively feeling colder.
11.6	(a)	The electrical energy supplied by the energy company causes the particles in the internal metal wire to vibrate more violently (the wire becomes hot). This hot wire emits red light and infrared radiation. The shiny backing around the element reflects the radiation, ensuring that most of the heat energy is sent in the desired direction. There is also some heating of the room in the air by convection, but as bar heaters are usually mounted high up, this hot air rises to the ceiling where it does little to increase the comfort of people in the room.
	(b)	Forced convection by the fan moves warm air horizontally for some distance instead of allowing it to rise straight up. This makes the user feel warmer without using significantly more power.
11.7		Dull, black, matt objects are the best absorbers of heat radiated by the sun whereas light coloured or white clothing tends to reflect this radiated heat away.
11.8		Clothes trap layers of air between your body and the surrounding environment and since air is an excellent insulator, it reduces heat loss through conduction. Also, since this air is fairly well trapped and cannot easily move around, it also reduces heat loss by convection. In the absence of clothing, air close to the skin is constantly being replaced (wind or draughts) by air that has not already been warmed by body heat. Wool is a better fabric than silk as it consists of relatively thick fibres which trap more air.
11.9		Glass is a poor conductor of heat. In addition the air between the fibres is an even poorer conductor. The air cannot transmit heat energy by convection because it is trapped and cannot move. (Some heat is transferred by radiation, which could be reduced by covering the pads with aluminium foil.)
11.10		The curtains are insulators. They also absorb radiation from the hot objects in the room and re-emit that as heat energy that is retained in the room. If the curtains have a pelmet a body of air is trapped that acts as an additional insulator. This is of course in addition to the fact that the curtains trap a layer of air between them and the window.
11.11		This is the result of localised heating of air over hot spots on the ground, predominantly darker areas, such as wheat fields, towns or sunlit hillsides. The extra hot air is less dense than the air above it and so it rises. As it rises it expands and cools. It stops rising when its

		density again matches the air around it.
11.12		The hotter the tea compared to the ambient temperature, the faster it will cool. So it would be better to add the milk immediately, in order to slow down the cooling process. However, if too much milk is added (e.g. an equal volume compared to that of the tea), then the method of mixtures suggests the teat will cool significantly on adding the milk. So it all depends on the amount of milk added.
11.13		Dull, black, matt objects are the best absorbers of heat radiated by hot coals or burning wood, whereas shiny materials will tend to reflect this radiated heat away.
11.14	(a)	Like water, glycol also has a high specific heat capacity however it is not as corrosive as water.
	(b)	It is made of a good conductor, it has a large surface area, it has narrow water tubes so the water cools quickly.
	(c)	The fan creates a forced convection component which increases the mass of cooler air flowing over the hot radiator.
	(d)	The engine operates more efficiently when it is hot. The thermostat acts like a switch would activate at a particular temperature. The coolant does not circulate when the engine is cold since is does not need to. The coolant circulates when the engine is hot, to avoid overheating.
	(e)	Relatively good conductor, low coefficient of expansion when hot, strong/tough enough that it does not break as the fuel burns and expansion moves the pistons.
11.15	(a)	Evaporation occurs from the surface of a material. When the tea is spread out on the saucer it has a greater surface area and more evaporation occurs. The escaping molecules of vapour take their latent heat of vaporisation from the remaining liquid, thereby cooling it.
	(b)	The blowing removes vaporised molecules more quickly from near the liquid surface. It is a form of forced convection which prevents the immediate area of air becoming saturated. This prevents them from recondensing and allows more molecules to escape from the surface. These escaping molecules of vapour take their latent heat of vaporisation from the remaining liquid cooling it.
11.16	(a)	Infrared radiation from the hot bricks and also some convected air currents produced immediately above the brick surface.
	(b)	The sun's nuclear reactions cause very high temperatures, which cause emission of infrared, visible and ultra-violet electromagnetic radiation. Much of the ultra-violet is absorbed by the earth's atmosphere, but the wall absorbs most of the remaining radiation.
11.17		The trapped layer of air acts as a good insulator and since the glass itself is a more conductor, very little heat will enter this gap and so fewer convection currents will be produced.
11.18		Aluminium is a better conductor of heat than either glass or plastic, so for the same temperature difference more heat would be conducted through the can thereby warming the drink faster than that in the bottle.
11.19		Unless your water comes from a partly frozen mountain stream, it would be better to wrap the bottle in a cloth and then wet this with the water from the bucket. In this situation, the water evaporates and cools the bottle and its contents below the temperature of the water in the bucket.

Set 12: Specific Heat Capacity

12.1		No, since they have different specific heat capacities.
12.2	(a)	Convection losses from the surface of each cup should be the same, however heat would flow more quickly through the thinner more delicate china so this cup would cool down quicker.
	(b)	Brass has a higher specific heat capacity than pewter so the brass urn will take more heat away from the hot olive oil, meaning that the oil in the pewter urn will be hotter after 30 seconds.
12.3		$Q = m\,c\,\Delta T = 153\text{ kg} \times 4180\text{ J kg}^{-1}\text{ K}^{-1} \times (75\text{ °C} - 15\text{ °C}) = 38.4\text{ MJ}$
12.4		$Q = m\,c\,\Delta T = 0.782\text{ kg} \times 445\text{ J kg}^{-1}\text{ K}^{-1} \times (20\text{ °C} - 445\text{ °C}) = -148\text{ kJ}$
12.5		$\Delta T = \frac{Q}{mc} = \frac{1.548 \times 10^{6}\text{ J}}{72.6\text{ kg} \times 10^{3}\text{ J kg}^{-1}\text{ K}^{-1}} = 21.2\text{ °C}$
12.6		electrical energy supplied = heat gained by kettle + heat gained by water 1 L of water has a mass of 1 kg $Q = m_{kettle} \times C_{kettle} \times \Delta T_{kettle} + m_{water} \times C_{water} \times \Delta T_{water}$ $Q = (0.355\text{ kg})(445\text{ J kg}^{-1}\text{ K}^{-1})(100\text{ °C} - 15\text{ °C}) + (0.850\text{ kg})(4180\text{ J kg}^{-1}\text{ K}^{-1})(100\text{ °C} - 15\text{ °C})$ $= 315\text{ kJ}$
12.7		$c = \frac{Q}{m\Delta T} = \frac{255.3 \times 10^{6}\text{ J}}{286\text{ kg} \times (452\text{ °C} - 22\text{ °C})} = 450\text{ J kg K}^{-1}$
12.8		$\Delta T = \frac{Q}{mc} = \frac{2.84 \times 10^{5}\text{ J}}{2.75\text{ kg} \times 4130\text{ J kg}^{-1}\text{ K}^{-1}} = 25.0\text{ °C}$
12.9		$Q = m\,c\,\Delta T = 0.865\text{ kg} \times 900\text{ J kg}^{-1}\text{ K}^{-1} \times (120\text{ °C} - 55\text{ °C}) = 50.6\text{ kJ}$
12.10		$c_{av} = \frac{Q}{m\Delta T} = \frac{118 \times 10^{3}\text{ J}}{0.385\text{ kg} \times (98.6\text{ °C} - 18\text{ °C})} = 3800\text{ J kg K}^{-1}$
12.11		The crust has a lower heat capacity than the filling and hence has less heat energy to transfer to your mouth and therefore has less energy to raise the temperature of your mouth and burn you. A minor effect is that the liquid filling may be a better conductor of heat to your mouth.
12.12		Heat a measured mass, M of the alloy to a known temperature, T and put into a well insulated and measured mass, m of water at known temperature, t. The measured final temperature, T_f of the mixture can be related to the specific heat capacity of the alloy: Heat lost by alloy + heat gained by water = 0 $M\,c_{alloy}\,(T_f - T) + m\,c_{water}\,(T_f - t) = 0$ hence c_{alloy} can be calculated.
12.13	(a)	Time to heat is inversely proportional to specific heat capacity. Ethylene glycol has a lower specific heat capacity than water and will reach 100 °C faster by a factor of:

		$\frac{c_{water}}{c_{glycol}} = \frac{4180\ \text{J kg}^{-1}\ \text{K}^{-1}}{2400\ \text{J kg}^{-1}\ \text{K}^{-1}} = 1.74$ So, it takes 1.74 times longer to heat the water.
	(b)	Water has a significantly higher specific heat capacity than ethylene glycol. Other factors, such as boiling point and corrosive effects, are also important. In terms of its ability to absorb heat energy without a large rise in temperature water is more efficient. However, even under pressure water will boil at about 120 °C. If the designer wants to run an engine at higher temperature (which is potentially more efficient) then a higher boiling point liquid is needed. Ethylene glycol boils at 198 °C and also is less corrosive to the metal parts than water. Often a mixture of the two is used.
	(c)	If a bigger mass of coolant was used, or if it were pumped through the system more rapidly, cooling could be improved.
12.14		The storage system must be fully enclosed and very well lagged to prevent heat escaping through its walls, its upper and lower surfaces. It should have a low coefficient of expansion so there is very little increase in size and less chance of fracturing. It should have a high melting point. Its inner walls should be silvery or shiny to prevent heat escaping by radiation.
12.15		$m = \frac{Q}{c\Delta T} = \frac{2.93 \times 10^6\ \text{J}}{4180\ \text{J kg K}^{-1} \times (100\,°\text{C} - 20\,°\text{C})} = 8.76\ \text{kg}$ (or just a little more than this in order to **prevent** the coolant water from boiling).
12.16		Energy required by water, $Q = m\,c\,\Delta T = 245\ \text{kg} \times 4180\ \text{J kg}^{-1}\ \text{K}^{-1} \times (68\,°\text{C} - 12\,°\text{C})$ $= 57.35\ \text{MJ}$ At 62% efficiency, the oil would therefore have to supply $\frac{57.35 \times 10^6\ \text{J}}{0.62} = 92.5\ \text{MJ}$ So mass of oil required, $m = \frac{Q}{Q_{per\ kg}} = \frac{92.5 \times 10^6\ \text{J}}{4.15 \times 10^7\ \text{J kg}^{-1}} = 2.23\ \text{kg}$
12.17		The longer the water remains in the bath tub, the more heat it will transfer to the colder air in the room as it attempts to reach the same ambient temperature and achieve thermal equilibrium. So it would effectively warm up the room.
12.18		Water has a much higher specific heat capacity than land. Hence the same heat input from the sun will raise the temperature of the land by much more than that for an equivalent amount of water.
12.19		microwave energy supplied = heat gained by glass + heat gained by water, $Q = (m_{glass}\, c_{glass}\, \Delta T_{glass}) + (m_{water}\, c_{water}\, \Delta T_{water})$ $Q = (0.215\ \text{kg})(670\ \text{J kg}^{-1}\ \text{K}^{-1})(98.5\ °\text{C} - 18.5\ °\text{C}) + (0.145\ \text{kg})(4180\ \text{J kg}^{-1}\ \text{K}^{-1})(98.5\ °\text{C} - 18.5\ °\text{C}) = 60\ \text{kJ}$
12.20		final temperature of soup, T_f = final temperature of the bowl = 97 °C Heat lost by soup + heat gained by bowl = 0 $m_{soup}\, c_{soup}\, (T_f - T)_{soup} + m_{bowl}\, c_{bowl}\, (T_f - t)_{bowl} = 0$ $(0.800\ \text{kg})(c_{soup})(97\ °\text{C} - 98\ °\text{C}) + (0.100\ \text{kg})(320\ \text{J kg}^{-1}\ \text{K}^{-1})(97\ °\text{C} - 10\ °\text{C}) = 0$ $c_{soup} = 3480\ \text{J kg}^{-1}\ \text{K}^{-1}$

12.21		Heat lost by tea + heat gained by water $= 0$ $m_{tea}\, c_{tea}\, (T_f - T)_{tea} + m_{water}\, c_{water}\, (T_f - t)_{water} = 0$ $(0.185\text{ kg})(4180\text{ J kg}^{-1}\text{ K}^{-1})(T_f - 85.5\ ^{\circ}\text{C}) + (0.035\text{ kg})(4180\text{ J kg}^{-1}\text{ K}^{-1})(T_f - 18\ ^{\circ}\text{C}) = 0$ gives $T_f = 74.8\ ^{\circ}\text{C}$
12.22		1 L water has mass 1 kg Each hour, mass of water flowing, $m = 1300\text{ kg min}^{-1} \times 60\text{ min h}^{-1} = 78\,000\text{ kg h}^{-1}$ Each hour, energy transferred to water by the pump $= 10\,000\text{ J s}^{-1} \times 3600\text{ s h}^{-1} = 3.6 \times 10^{7}\text{ J h}^{-1}$ 35% of this energy is transferred as heat, $Q = 0.35 \times 3.6 \times 10^{7}\text{ J h}^{-1} = 1.26 \times 10^{7}\text{ J h}^{-1}$ So, during the hour, $\Delta T = \dfrac{Q}{mc} = \dfrac{1.26 \times 10^{7}\text{ J h}^{-1}}{78\,000\text{ kg h}^{-1} \times 4180\text{ J kg}^{-1}\text{ K}^{-1}} = 0.039\ ^{\circ}\text{C}$
12.23		$\text{electrical energy input} = \dfrac{\text{heat gained by kettle} + \text{heat gained by water}}{0.65}$ since it is 65% efficient $Q = \dfrac{(m_{kettle}\, c_{kettle}\, \Delta T_{kettle}) + (m_{water}\, c_{water}\, \Delta T_{water})}{0.65}$ $Q = \dfrac{(5.25\text{ kg})(445\text{ J kg}^{-1}\text{ K}^{-1})(96\ ^{\circ}\text{C} - 12\ ^{\circ}\text{C}) + (1.55\text{ kg})(4180\text{ J kg}^{-1}\text{ K}^{-1})(96\ ^{\circ}\text{C} - 12\ ^{\circ}\text{C})}{0.65}$ $= 1.14 \times 10^{6}$ J (or 1.14 MJ)
12.24		85 % of the heat lost by hot water + heat gained by cold water = 0 (since bath & surroundings absorb 15%) $0.85\, (m_{hot})(c_{hot})(T_f - T)_{tea} + m_{cold}\, c_{cold}\, (T_f - t)_{cold} = 0$ $(0.85)(m_{hot})(4180\text{ J kg}^{-1}\text{ K}^{-1})(75.3\ ^{\circ}\text{C} - 45\ ^{\circ}\text{C}) + (40\text{ kg})(4180\text{ J kg}^{-1}\text{ K}^{-1})(45\ ^{\circ}\text{C} - 16.5\ ^{\circ}\text{C}) = 0$ gives $m_{hot} = 44.3$ kg
12.25		heat gained by glycol + (heat lost by radiator + heat lost by water) = 0 $(m_{glycol})(c_{glycol})(\Delta T_{glycol}) + (m_{radiator})(c_{radiator})(\Delta T_{radiator}) + (m_{water})(c_{water})(\Delta T_{water}) = 0$ $(0.655\text{ kg})(2400\text{ J kg}^{-1}\text{ K}^{-1})(T_f - 22^{\circ}\text{C}) + (4.5\text{ kg})(390\text{ J kg}^{-1}\text{ K}^{-1})(T_f - 92\ ^{\circ}\text{C}) + (6.75\text{ kg})(4180\text{ J kg}^{-1}\text{ K}^{-1})(T_f - 92\ ^{\circ}\text{C}) = 0$ gives $T_f = 88.5\ ^{\circ}\text{C}$

Set 13: Changes of State and Latent Heat

13.1	(a)	$Q = m L_f = 28.6 \text{ kg} \times 3.34 \times 10^5 \text{ J kg}^{-1} = 9.55 \text{ MJ}$
	(b)	$Q = m L_v = 0.423 \text{ kg} \times 2.26 \times 10^6 \text{ J kg}^{-1} = 956 \text{ kJ}$
	(c)	$Q = m L_v = 0.00458 \text{ kg} \times 2.35 \times 10^6 \text{ J kg}^{-1} = 10.8 \text{ kJ}$
13.2		$L_v = \frac{Q}{m} = \frac{1.85 \times 10^4 \text{ J}}{0.208 \text{ kg}} = 8.89 \times 10^4 \text{ J kg}^{-1}$
13.3		$m = \frac{Q}{L_f} = \frac{9.53 \times 10^4 \text{ J}}{1.05 \times 10^5 \text{ J kg}^{-1}} = 0.908 \text{ kg or } 908 \text{ g}$
13.4	(a)	The latent heat absorbed when a liquid changes to a gas does the cooling.
	(b)	The air conditioner actually removes heat from warm air. It then blows the cooled air into the car's cabin and the cooled air removes heat from the interior mainly by conduction. The cooling process involves compressing refrigerant gas, which heats up as it compresses. The hot compressed gas is fan-cooled and it condenses to liquid. The now cool liquid then has the pressure taken off and it partly evaporates. This cools the remaining liquid. Warm air is cooled by the cool refrigerant liquid.
13.5		If equal masses of water are involved in the two incidents, more heat will be transferred to your hand by the steam because as well as transferring heat by cooling from 100°C, it also releases heat as it condenses on your hand (latent heat of vaporisation).
13.6		The heat energy from the iron is principally used to vaporise the water rather than to raise the temperature of Mario's finger.
13.7	(a)	The mugs are both warmer than the ice and since heat energy always travels from 'hot to cold', they will transfer energy to their respective blocks of ice. As a result, the ice will absorb this released energy and begin a change of state phase (since it is already at 0 °C) and begin melting.
	(b)	As the glass cools from room temperature to 0 °C, it releases heat energy at a greater rate (since it has a higher specific heat capacity) than the pewter and therefore melts the ice more quickly.
	(c)	Since pewter is an alloy of lead and tin, two metals and therefore good conductors of heat, this mug would conduct heat through its base at a greater rate than the glass mug. It may therefore sink faster.
13.8		The lake has a large heat capacity due to the high specific heat capacity of water. This means that it cools down much more slowly than the surrounding earth. Heat energy flows from the relatively warmer lake to melt any nearby snow.
13.9	(a)	Since 4.00 L of water has mass 4.00 kg: $Q = m L_v = (4 \text{ kg})(2.42 \times 10^6 \text{ J kg}^{-1}) = 9.68 \text{ MJ}$
	(b)	$\Delta T = \frac{Q}{mc} = \frac{9.86 \times 10^6 \text{ J}}{(55 \text{ kg})(3.5 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1})} = 50.3 \text{ °C}$

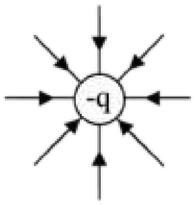
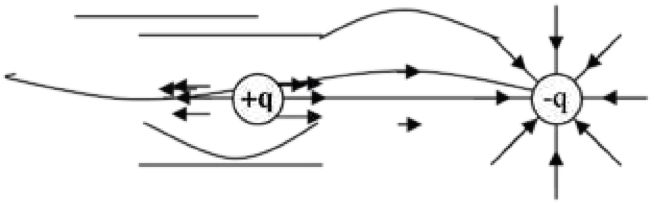
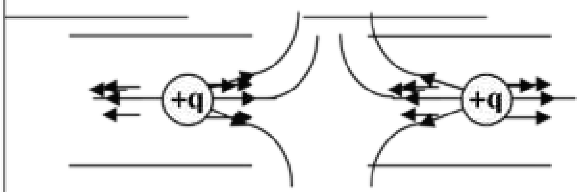
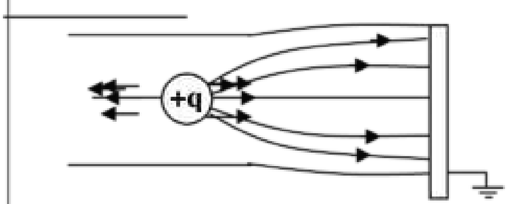
	(c)	Air movement over your skin helps to evaporate perspiration from your skin. The latent heat needed for this phase change comes from your body. The combination of evaporation and forced convection cools you down.
	(d)	When out of the water, air movement (or movement of the swimmer) results in significant amounts of water being evaporated from the swimmer's skin. The energy to do this is largely drawn from the swimmers body, thus cooling the swimmer.
13.10	(a)	$s = ut + \frac{1}{2}gt^2$ since u = zero, then: $s = \frac{1}{2}(9.8\,\text{m s}^{-2})(6\,\text{s})^2 = 176\,\text{m}$
	(b)	L_f for iron = 2.76 x 10^5 J kg^{-1} and L_f for lead = 2.5 x 10^4 J kg^{-1} So the value for iron is 11 times greater than that of lead, which means that in order for iron to begin the solidification process it must lose 11 times the amount of energy per kilogram. This means that the tower would have to be a lot taller if iron ball bearings were to be made in this way. This assumes that the surrounding air will take away the heat from the bearings and that the iron will lose heat at a steady rate, that the air temperature will be constant and that the air pressure exerted around the ball bearing and the surface tension forces are sufficient to maintain the spherical shape, particularly at the higher altitude. It also assumes that the iron ball bearing will keep accelerating until it hits the ground.
	(c)	Since air at higher altitude is likely to be much cooler than air nearer the ground, the rate of loss of heat from the iron ball bearings would probably be greater initially so the tower could perhaps be made a little shorter. This is further reinforced by the fact that since iron has a higher melting point than lead, it does not have to cool down as much to begin solidifying. Finally, and maybe most significantly, since the tower would have to be much taller, the iron bearings would almost certainly reach their terminal velocity well before they hit the pool of water. This means they would take longer to fall through the air which is additional evidence that a smaller tower than that suggested above would do the job.
13.11	(a)	$Q = m\,c_{liquid}\,\Delta T$ = (0.055 kg)(105 J kg^{-1} K^{-1})(427 °C – 327 °C) = 578 J
	(b)	$Q = m\,L_f$ = (0.055 kg)(2.5 x 10^4 J kg^{-1}) = 1.38 kJ
	(c)	$Q = m\,c_{solid}\,\Delta T$ = (0.055 kg)(130 J kg^{-1} K^{-1})(327 °C – 21.5 °C) = 2.18 kJ
	(d)	Q_{total} = 578 J + 1380 J + 2180 J = 4140 J (or 4.14 kJ)
13.12	(a)	Heat needed, $Q = m\,c\,\Delta T$ = (0.0125 kg)(4180 J kg^{-1} K^{-1})(100 °C – 26.5 °C) = 3840 J $\text{time taken } t = \frac{Q}{P} = \frac{3840\,\text{J}}{48\,\text{J s}^{-1}} = 80\,\text{s}$
	(b)	Heat needed, $Q = m\,L_v$ = (0.0125 kg)(2.26 x 10^6 J kg^{-1}) = 28.3 kJ $\text{time taken } t = \frac{Q}{P} = \frac{28\,300\,\text{J}}{48\,\text{J s}^{-1}} = 590\,\text{s}$
	(c)	total time = 80s + 590s = 670 s (or 11 mins 10 s)
13.13		Heat lost to cool water, $Q = m\,c\,\Delta T$ = (2.15 kg)(4180 J kg^{-1} K^{-1})(0 °C – 21.5 °C) = – 0.193 MJ

		Heat lost to freeze the water, $Q = m\,L_f = (2.15\text{ kg})(-3.34 \times 10^5\text{ J kg}^{-1}) = -0.718\text{ MJ}$ Water needs to lose a total heat energy, $Q_{total} = -0.193\text{ MJ} - 0.718\text{ MJ} = -0.911\text{ MJ}$ which takes 2 hours, so, $P = \frac{Q_{total}}{t} = \frac{-0.911 \times 10^6\text{ J}}{(2\text{ h} \times 3600\text{ s h}^{-1})} = -127\text{J s}^{-1}$ rate of cooling is thus 127 J s^{-1}
13.14		The colder spaghetti will absorb some of the heat energy from the water, thereby decreasing the temperature of the water.
13.15		Heat supplied per second as steam cools: $Q = m\,c\,\Delta T = (0.455\text{kg} \div 60\text{s}) \times 2010\text{Jkg}^{-1}\text{K}^{-1} \times (105^{\circ}\text{C} - 100^{\circ}\text{C}) = 76.2\text{ J s}^{-1}$ Heat supplied per second as steam condenses: $Q = m \times L_v = (0.455\text{kg} \div 60\text{s}) \times 2.26 \times 10^6\text{ J kg}^{-1} = 17.14\text{ kJ s}^{-1}$ Total heat supplied per second, $P = 76.2 + 17.14 \times 10^3 = 1.72 \times 10^4\text{ J s}^{-1}$
13.16	(a)	$C = Q \div (m \times \Delta T) = 55.6 \times 10^6\text{ J} \div [286\text{kg} \times (452\,^{\circ}\text{C} - 22\,^{\circ}\text{C})] = 452\text{ Jkg}^{-1}\text{K}^{-1}$
	(b)	Total heat taken away by water, $Q = m \times C \times \Delta T + m \times L_v$ so, $55.6 \times 10^6\text{ J} = [m \times 4180 \times (100\,^{\circ}\text{C} - 22\,^{\circ}\text{C})] + (m \times 2.26 \times 10^6\text{ J kg}^{-1})$ gives $m_{min} = 21.5\text{ kg}$
	(c)	The steel does not lose heat any other way, eg. by radiation, or by heating the air around it.
13.17	(a)	Heat absorbed to warm ice, $Q = m\,c\,\Delta T = 0.0232\text{ kg} \times 2100\text{ J kg}^{-1}\text{ K}^{-1} \times 10\,^{\circ}\text{C} = 0.49\text{ kJ}$ Heat absorbed to melt ice, $Q = m\,L_f = 0.0232\text{ kg} \times 3.34 \times 10^5\text{ J kg}^{-1} = 7.75\text{ kJ}$ Heat absorbed to warm water, $Q = m\,c\,\Delta T = 0.0232\text{ kg} \times 4180\text{ J kg}^{-1}\text{ K}^{-1} \times 10\,^{\circ}\text{C} = 0.97\text{ kJ}$ Total amount of heat required $= 0.49\text{ kJ} + 7.75\text{ kJ} + 0.97\text{ kJ} = 9.21\text{ kJ}$
	(b)	The energy comes from the surrounding air and the actual glass itself.
13.18	(a)	Heat to be removed form the BBQ $= m \times C \times \Delta T = 12\text{kg} \times 445\text{Jkg}^{-1}\text{K}^{-1} \times (395\,^{\circ}\text{C} - 185\,^{\circ}\text{C})] = 1.12\text{ M J}$ so, total heat to taken away by water, $Q = 1.12\text{ MJ} = m \times C \times \Delta T + m \times L_v$ so, $1.12 \times 10^6\text{ J} = [m \times 4180 \times (100\,^{\circ}\text{C} - 20\,^{\circ}\text{C})] + (m \times 2.26 \times 10^6\text{ J kg}^{-1})$ gives $m = 0.432\text{ kg}$ (or 432 g)
	(b)	Total heat to taken away by ice, $Q = 1.12\text{ MJ} = (m \times L_f) + (m \times C \times \Delta T) + (m \times L_v)$ so, $1.12 \times 10^6\text{ J} = (m \times 3.34 \times 10^5\text{ J kg}^{-1}) + [m \times 4180 \times (100\,^{\circ}\text{C} - 20\,^{\circ}\text{C})] + (m \times 2.26 \times 10^6\text{ J kg}^{-1})$ gives $m = 0.383\text{ kg}$ (or 383 g)
13.19		heat lost by water + heat lost by glass = heat gained by ice heat lost by water + heat lost by glass $= (m_{water} \times C_{water} \times \Delta T_{water}) + (m_{glass} \times C_{glass} \times \Delta T_{glass})$ $= [0.195\text{kg} \times 4180 \times (19.7\,^{\circ}\text{C} - 3.6\,^{\circ}\text{C})] + [0.215\text{kg} \times 670 \times (19.7\,^{\circ}\text{C} - 3.6\,^{\circ}\text{C})] = 15.4\text{ kJ}$ so, heat gained by ice $= 15.4\text{ kJ} = (m_{ice} \times C_{ice} \times \Delta T_{ice}) + (m_{ice} \times L_f) + (m_{ice/\underline{water}} \times C_{water} \times \Delta T_{water})$

		therefore, 15400 J = (m_{ice} x 2100 x 11.3 °C) + (m_{ice} x 3.34 x 10^5 J kg^{-1}) + ($m_{ice/water}$ x 4180 x 3.6 °C) gives m_{ice} = 0.0414 kg (or 41.4 g)
13.20		heat lost by steam/water + heat gained by ice/water = 0 (m_{steam} x L_v) + ($m_{steam/water}$ x c_{water} x ΔT_{water}) = (m_{ice} x L_f) + (m_{water} x c_{water} x ΔT_{water}) (m_{steam} x 2.26 x 10^6 J kg^{-1}) + [$m_{steam/water}$ x 4180 J kg^{-1} K^{-1} x (100 °C – 24.5 °C)] = (1.5 kg x 3.34 x 10^5 J kg^{-1}) + [1.5 kg x 4180 J kg^{-1} K^{-1} x (24.5 °C – 0 °C)] gives m_{steam} = 0.254 kg (or 254 g)

Electrical Fundamentals

Set 14: Electrical Charges and Fields

14.1	(a)	
	(b)	
	(c)	
	(d)	
14.2		As the car moves and its rubber tyres rub against the ground static charge accumulates around the car shell. The car is effectively isolated from the ground as rubber is an insulator however when you touch it, you provide the charge with a path to Earth which it readily accepts and you may feel a small shock.
14.3	(a)	q = 1000 x e = 100 x 1.6 x 10^{-19} C = 1.6 x 10^{-16} C

	(b)	$F = 9 \times 10^9 \frac{q_1 q_2}{d^2} = 9 \times 10^9 \frac{(1.6 \times 10^{-16}\ C)(-1.6 \times 10^{-16}\ C)}{(0.01 \times 10^{-3}\ m)^2} = -2.3 \times 10^{-12}\ N$ negative forces are attractive forces
	(c)	see diagram 1b). above
14.4		0.7 pC is equivalent to a $\text{number of electrons} = \frac{q}{e} = \frac{0.7 \times 10^{-12}\ C}{1.6 \times 10^{-19}\ C} = 4.4 \times 10^6$ so, if 7 x 10^6 electrons are suddenly released into the chip, thereby more than doubling the existing number, the relatively huge repelling force exerted on these electrons will cause chaos.
14.5	(a)	Electrostatic attraction due to opposite charges being on the L plate and the window – the L plate will definitely be charged and the window probably uncharged.
	(b)	Friction between the rubbing of the L plate on clothing – electrons will be transferred from one of these materials to the other, leaving them each with an equal but opposite charge.
	(c)	Metallic surfaces since the charge would not remain concentrated in one point (metals are good conductors) and they would begin evenly distributing themselves over the surface. Also, any surface which has a similar charge to the L plate already on it, since like charges repel.
	(d)	No since the L plate is plastic and static charge will occur only at the point of rubbing where it will be more concentrated. It is unlikely that all parts of the L plate are rubbed exactly the same.
14.6		$I = \frac{q}{t} = \frac{2 \times 10^{-9}\ C}{1 \times 10^{-6}\ s} = 2.0 \times 10^{-3}\ \text{A or } 2.0\ \text{mA}$
14.7	(a)	$q = I \times t = 2\ A \times (4\ h \times 3600\ s) = 2.88 \times 10^4\ C$
	(b)	$\text{number of electrons} = \frac{q}{e} = \frac{2.88 \times 10^4\ C}{1.6 \times 10^{-19}\ C} = 1.8 \times 10^{23}$
14.8	(a)	$q = I \times t = 4\ A \times 90\ s = 360\ C$
	(b)	since voltage is work done per unit charge, then $W = V \times q = 240\ V \times 360\ C = 86\,400\ J$ (or 86.4 kJ)
14.9		When taking the coffee cups out of the stacks in the carton you charge them electrically. Since polystyrene is an insulator the charge is retained and since they are set out close together there is an electrostatic force between them. Whether this is attractive or repulsive makes no difference, there will be some movement since the cups have little mass and therefore little inertia to overcome the force.
14.10	(a)	$F = 9 \times 10^9 \frac{q_1 q_2}{d^2}$ since the charges are the same, then $q = \sqrt{\frac{Fd^2}{9 \times 10^9}} = \sqrt{\frac{0.5\ N \times (0.8 \times 10^{-3}\ m)^2}{9 \times 10^9}}$ gives $q = 5.96 \times 10^{-9}$ C (or 5.96 nC)

	(b)	This equation applies to point charges and the articles of clothing cannot really be considered as such.
14.11	(a)	In order for the oil drop to be attracted towards the upper plate (thereby opposing the gravitational pull acting upon it), it must be oppositely charged to that plate. So, the oil drop will be negatively charged.
	(b)	The force must be exactly balanced by the gravitational force, so $F_{elec} = 2 \times 10^{-3}$ N
	(c)	If F_{elec} is greater than F_{grav} then there will be an upward resultant force and the oil drop will move toward the upper plate.
	(d)	$\text{number of electrons} = \frac{q}{e} = \frac{6.4 \times 10^{-18}\ \text{C}}{1.6 \times 10^{-19}\ \text{C}} = 40$
	(e)	$F = 9 \times 10^9 \frac{q_1 q_2}{d^2} = 9 \times 10^9 \frac{6.4 \times 10^{-18}\ \text{C} \times 6.4 \times 10^{-18}\ \text{C}}{(0.02 \times 10^{-3}\ \text{m})^2} = 9.22 \times 10^{-22}\ \text{N}$ positive forces are repulsive forces
	(f)	Any suggestion that involves friction charging the oil drop as it enters the gap between the plates, e.g. inserting it through a syringe.
14.12	(a)	Current follows the path of "least resistance" and that is to a conductor on the ground. The air is ionised and the spark or ionised flash represents that current path. Air, even humid air, is not a good conductor of electricity. Typical values: the electric field for a spark is of the order of 10^6 V m^{-1} so the difference in voltage between the ends would be of the order of 10^9 V, assuming a cloud to Earth distance of about 1000 m.
	(b)	The cause is friction between particles which constitute the clouds with each other and other air particles. Since the cloud is an isolated system, the charge and hence the voltage (since q is proportional to V) accumulates.
	(c)	E = P x t = 100 W x (3 months x 30 days x 24 h x 3600 s) = 7.8×10^8 J
	(d)	$q = \frac{W}{V} = \frac{7.8 \times 10^8\ \text{J}}{10^9\ \text{V}} = 0.78\ \text{C}$
	(e)	$I = \frac{q}{t} = \frac{0.78\ \text{C}}{50 \times 10^{-6}\ \text{s}} = 15\,600\ \text{A or } 15.6\ \text{kA}$

Set 15: Electrical Energy and Power

15.1	(a)	$I = \frac{P}{V} = \frac{1200\ W}{240\ V} = 5.0\ A$
	(b)	$R = \frac{V}{I} = \frac{240\ V}{5\ A} = 48.0\ \Omega$
15.2	(a)	$V = \frac{P}{I} = \frac{6\ W}{0.5\ A} = 12.0\ V$
	(b)	$R = \frac{V}{I} = \frac{12\ V}{0.5\ A} = 24.0\ \Omega$
15.3		$R = \frac{V^2}{P} = \frac{(240\ V)^2}{100\ W} = 576\ \Omega$
15.4	(a)	E = V x I x t = 12 V x 2 A x (20 min x 60 s) = 28.8 kJ
	(b)	P = I x V = 2 A x 12 V = 24.0 W
	(c)	q = I x t = 2 A x (20 min x 60 s) = 2.4 x 10^3 C
15.5	(a)	It is designed to run from a power supply of voltage, $V = \frac{P}{I} = \frac{4\ W}{0.017\ A} = 235\ V$ since household mains electricity has an RMS value of about 240 V, then it must be a household lamp since car batteries only deliver 12 V.
	(b)	$R = \frac{P}{I^2} = \frac{4\ W}{(0.017\ A)^2} = 13.8\ k\Omega$
15.6	(a)	It is designed to run from a power supply of voltage, $V = \frac{P}{I} = \frac{2.3\ W}{0.38\ A} = 6.1\ V$ This is typical of a battery or maybe a transformer.
	(b)	$R = \frac{P}{I^2} = \frac{2.3\ W}{(0.38\ A)^2} = 15.9\ \Omega$
15.7	(a)	$I = \frac{P}{V} = \frac{55\ W}{12\ V} = 4.6\ A$
	(b)	$R = \frac{V}{I} = \frac{12\ V}{4.6\ A} = 2.6\ \Omega$
15.8	(a)	E (in kWh) = P (in kW) x t (in h) = 0.060 kW x (9 weeks x 5 days x 3 h) = 8.1 kWh so the cost = 8.1 kWh x 13c kWh^{-1} = 105c (or $1.05)
	(b)	E (in kWh) = P (in kW) x t (in h) = 0.011 kW x (9 weeks x 5 days x 4 h) = 1.49 kWh so the cost = 1.49 kWh x 13c kWh^{-1} = 19c
	(c)	E (in kWh) = P (in kW) x t (in h) = 2.4kW x 4h = 9.6 kWh

		so the cost = 9.6 kWh x 13c kWh^{-1} = 125c (or \$1.25)
	(d)	E (in kWh) = P (in kW) x t (in h) = 1.7 kW x $\left(\frac{5\text{ min}}{60\text{ min h}^{-1}}\right)$ = 0.14 kWh so the cost = 0.14 kWh x 13c kWh^{-1} = 1.8c
15.9	(a)	E (in kWh) = P (in kW) x t (in h) = 2kW x 3h = 6 kWh so the cost = 6 kWh x 13c kWh^{-1} = 78c
	(b)	$P = \frac{V^2}{R} = \frac{(240\text{ V})^2}{26\,\Omega} = 2215\text{ W or }2.22\text{ kW}$ E (in kW h) = P (in kW) x t (in hrs) = 2.22kW x 4hrs = 8.88 kW h so the cost = 8.88 kW h x 13c kWh^{-1} = 115c (or \$1.15)
	(c)	P = I x V = 8 A x 240 V = 1920 W E (in kWh) = P (in kW) x t (in h) = 1.92 kW x $\left(\frac{30\text{ min}}{60\text{ min h}^{-1}}\right)$ = 0.96 kWh so the cost = 0.96 kWh x 13c kWh^{-1} = 12.5c
15.10		For a house which has 18 ceiling lights @ 100 W each and 12 table lamps @ 75 W each, the total power = (18 x 100 W) + (12 x 75 W) = 2700 W (2.7 kW) During autumn / winter they could all be on for 6 h each evening, so t = (6 months x 30 days x 6 h) = 1080 h During spring / summer they may only all be on for 2 h each evening, so t = (6 months x 30 days x 2 h) = 360 h E (in kWh) = P (in kW) x t (in h) = 2.7kW x (1080 h + 360 h) = 3888 kWh so the cost = 3888 kW h x 13c kWh^{-1} = 50500c (about \$500)
15.11	(a)	$I = \frac{P}{V} = \frac{150\text{ W}}{240\text{ V}} = 0.625\text{ A or }625\text{ mA}$
	(b)	$R = \frac{V}{I} = \frac{240\text{ V}}{0.625\text{ A}} = 384\,\Omega$
	(c)	total energy produced each hour, E = P x t = 150 W x (1 h x 3600s) = 240 kJ light energy produced each hour = 5% of 240 kJ = 0.05 x 240 kJ = 27 kJ
	(d)	E = P x t = 0.15 kW x 5 h = 0.75 kWh so the cost = 0.75 kW h x 13c kWh^{-1} = 9.8c
15.12	(a)	Energy saving each hot day, E = P x t = 4 kW x 3 h = 12 kWh which is equivalent to a monetary saving of = 12 kWh x 13c kWh^{-1} = 156c (or \$1.56) so the number of hot days to recoup the \$800 insulation cost = $\frac{\$800}{\$1.56\text{ day}^{-1}} = 513\text{ days}$
	(b)	In Australia, we probably have 3 months (about 90 hot days) each year when we use our air

		conditioners. So, the cost of the insulation should be covered in $\frac{513 \text{ days}}{90 \text{ days year}^{-1}} = 5.7$ years
15.13	(a)	E = V x I x t = 12V x 1A x (40 h x 3600 s) = 1.73 MJ (using a combination of 1 A for 40 hours)
	(b)	E = V x I x t = 12V x 1A x (75 h x 3600 s) = 3.24 MJ (using a combination of 1 A for 75 hours) time to operate 2 emergency lights, $t = \frac{E}{P} = \frac{3.24 \times 10^6 \text{ J}}{2 \times 55 \text{ W}} = 2.95 \times 10^4$ s or 8.2 h
15.14		E = V x I x t = 1.4V x 1A x (2.3 h x 3600 s) = 11.6 kJ (using a combination of 1 A for 2.3 hours) time to operate a 'key light', $t = \frac{E}{P} = \frac{11.6 \times 10^3 \text{ J}}{3 \text{ W}} = 3.87 \times 10^3$ s or 64.5 min

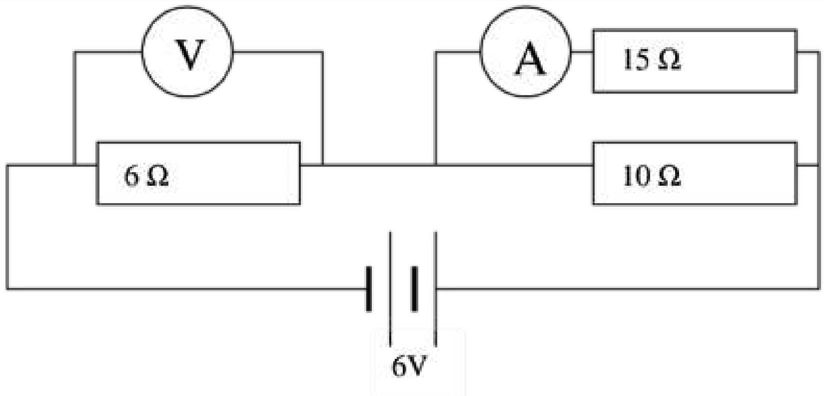
Set 16: Circuits and Ohm's Law

16.1	(a)	$R = \frac{V}{I} = \frac{2.55\ V}{0.012\ A} = 213\ \Omega$
	(b)	$I = \frac{V}{R} = \frac{3.42\ V}{147\,000\ \Omega} = 2.33 \times 10^{-5}\ A$ or $23.3\ \mu A$
	(c)	$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{1.6\ W}{2000\ \Omega}} = 0.0283\ A$ or $28.2\ mA$
16.2		$V = I \times R = 0.007\ A \times 8000\ \Omega = 56.0\ V$
16.3		$R = \frac{V}{I} = \frac{14\ V}{0.5\ A} = 28.0\ \Omega$
16.4		$V = I \times R = 0.32\ A \times 4.7\ \Omega = 1.50\ V$
16.5	(a)	Since V is constant, then according to Ohm's Law (I is inversely proportional to R), if the resistance increases then the current should decrease. However, in practice, in order to maintain the operating power rating of the heater ($P = I \times V$), electrical energy will be consumed at a greater rate in an attempt to keep the current the same – the heater has to work harder.
	(b)	The atoms and free electrons will increase their vibration as the temperature increases so the free electron flow through the lattice will encounter greater opposition, therefore the resistance increases.
	(c)	$R = \frac{V}{I} = \frac{240\ V}{10\ A} = 24.0\ \Omega$
	(d)	$P = I \times V = 10\ A \times 240\ V = 2400\ W$ – electrical energy is consumed at a rate of $2.4\ kJ\ s^{-1}$
	(e)	If the voltage drops then so will the operating current, therefore the heater will not work as effectively. This means that it will not get as hot so its resistance will decrease. It will obviously consume less energy.
16.6	(a)	R_{max} per metre of cable $= \frac{18.1\ \Omega}{1000\ m} = 0.0181\ \Omega\ m^{-1}$ for 36m of cable, $R_{max} = 36 \times 0.0181\ \Omega\ m^{-1} = 0.65\ \Omega$ at 20 °C
	(b)	$I = \frac{V_{max}}{R} = \frac{415\ V}{0.65\ \Omega} = 638\ A$
16.7	(a)	The component's I-V characteristic is linear up to 6 A, so it acts as an ohmic conductor from 0 – 6 A.
	(b)	R = gradient of linear section of the graph $= \frac{V}{I} = \frac{4\ V}{6\ A} = 0.67\ \Omega$
	(c)	As voltage increases, the current also increases but at a reduced rate – the slope of the curve has an increasing gradient. This suggests that the resistance of the component is increasing.

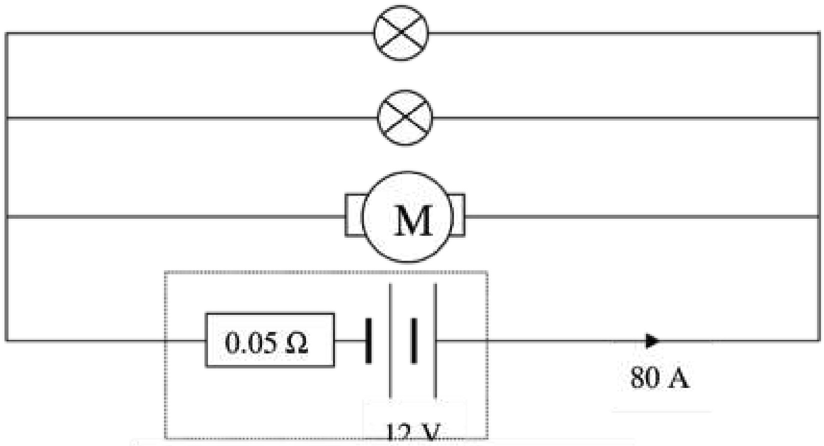
	(d)	This is probably caused by an increase in temperature within the component.
16.8		Current requires a potential difference to flow, however when birds sit on a high voltage transmission line, the potential difference between the bird's legs is negligible. They are effectively sitting on an isolated electrical system. If the birds were grounded, then the potential difference would be much higher, current would flow and they would be killed. However the air between the lines and the ground provides adequate insulation to prevent this happening.
16.9	(a)	Decrease in skin resistance. Sweat contains a high concentration of salts and so has a high concentration of ions (charged particles), which conduct electricity in solutions.
	(b)	A decrease in resistance implies an increase in current, since according to Ohm's Law, I is inversely proportional to R. This would result in greater movement / deflection of the needle.
	(c)	$R = \frac{V}{I} = \frac{12\ \text{V}}{0.035\ \text{A}} = 343\ \Omega$

Set 17: Parallel and Series Circuits

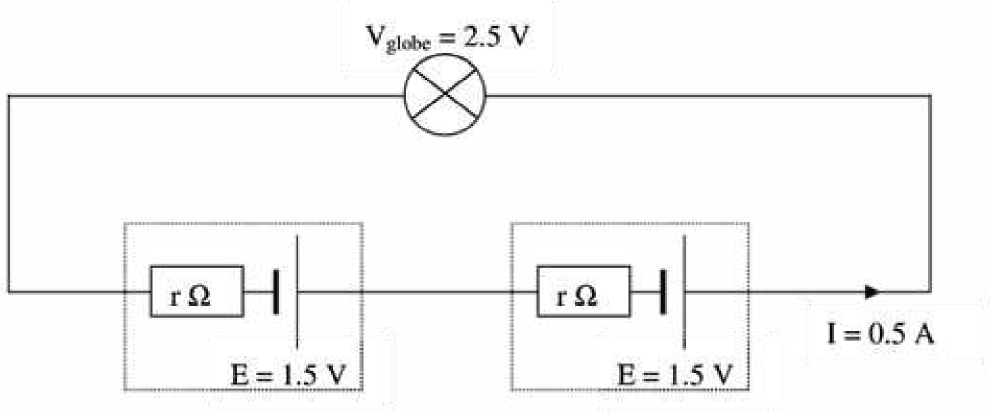
17.1		The appliances are connected in parallel with each other, since if one device blows the others keep working (a property of parallel circuits). Also, if are independent of each other so that if you turn one on or off, it does not affect other appliances. This would not happen if they were connected in series.
17.2		$R_{total} = 12 \times 30\ \Omega = 360\ \Omega$
17.3	(a)	$V_{total} = V_1 + V_2 = 12\ V + 12\ V = 24.0\ V$
	(b)	$R_{total} = R_1 + R_2 + R_3 = 20\ \Omega + 20\ \Omega + 20\ \Omega = 60\ \Omega$ $I = \frac{V_{total}}{R_{total}} = \frac{24\ V}{60\ \Omega} = 0.40\ A$ or $400\ mA$
	(c)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{3}{20\Omega}$ gives $R_t = 6.67\ \Omega$
	(d)	A smaller resistance means that from the same power supply, the parallel arrangement will draw a larger current than the series lights, so the situation in part c). will be more intense (brighter).
17.4		The series resistor must account for 20 V of the electricity supply and since it is to be connected in series with the radio, 4 A will also flow through it. Its resistance, $R = \frac{V}{I} = \frac{20\ V}{4\ A} = 5.0\ \Omega$
17.5	(a)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{2}{2\ \Omega}$ gives $R_t = 1.0\ \Omega$ for the parallel section of the circuit so $R_{total} = R_{parallel} + R_{buzzer} = 1\ \Omega + 3\ \Omega = 4.0\ \Omega$
	(b)	$I = \frac{V_{total}}{R_{total}} = \frac{(2 \times 9\ V)}{4\ \Omega} = 4.5\ A$
	(c)	The buzzer will be loudest when both switches are closed. If only one was closed, then the circuit is effectively a series circuit and the new current, $I = \frac{V}{(R_2 + R_3)} = \frac{18\ V}{(2\ \Omega + 3\ \Omega)} = 3.6\ A$ (almost 1 A less). If both switches are open, the buzzer will not work at all since there will not be a closed circuit.
	(d)	At its softest setting, the current = 3.6 A (see part c). above). $E = V \times I \times t = 18\ V \times 3.6\ A \times (3\ min \times 60s) = 11.7\ kJ$
17.6	(a)	$R_{ammeter} = 2.0\ \Omega$ $R_{min} = 300\ \Omega$, so $I_{max} = \frac{V}{(R_{min} + R_{ammeter})} = \frac{12\ V}{(300\ \Omega + 2.0\ \Omega)} = 0.0397\ A$

		$R_{max} = (300\ \Omega + 150\ \Omega)$, so $I_{min} = \dfrac{V}{(R_{max} + R_{ammeter})} = \dfrac{12\ V}{(450\ \Omega + 2.0\ \Omega)} = 0.0265\ A$ Heath can achieve current values from 26.5 mA to 39.7 mA
	(b)	$\dfrac{1}{R_{min}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} = \dfrac{1}{300\ \Omega} + \dfrac{1}{150\ \Omega} = \dfrac{3}{300\ \Omega}$ gives $R_{min} = 100\ \Omega$ so $I_{max} = \dfrac{V}{(R_{min} + R_{ammeter})} = \dfrac{12\ V}{(100\ \Omega + 2.0\ \Omega)} = 0.118\ A$ or $118\ mA$ $R_{max} = 150\ \Omega$, so $I_{min} = V \div (R_{max} + R_{ammeter}) = 12V \div (150\Omega + 2.0\ \Omega) = 0.0789\ A$ (or 78.9 mA) Jenni can achieve current values from 78.9 mA to 118 mA
	(c)	$R_{min} = 0\ \Omega$, so $I_{max} = \dfrac{V}{(R_{min} + R_{ammeter})} = \dfrac{12\ V}{(0 + 2.0\ \Omega)} = 6.0\ A$ $R_{max} = 150\ \Omega$, so $I_{min} = \dfrac{V}{(R_{max} + R_{ammeter})} = \dfrac{12\ V}{(150\ \Omega + 2.0\ \Omega)} = 0.0789\ A$ or $78.9\ mA$ Shani can achieve current values from 78.9 mA to 6.0 A
17.7	(a)	
	(b)	$\dfrac{1}{R_{parallel}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} = \dfrac{1}{10\ \Omega} + \dfrac{1}{15\ \Omega} = \dfrac{10}{60\ \Omega}$ gives $R_{parallel} = 6.0\ \Omega$ $I_{total} = \dfrac{V_{total}}{(R_{parallel} + R_6)} = \dfrac{6\ V}{(6\ \Omega + 6\ \Omega)} = 0.50\ A$ Voltmeter reading, $V = I_{total} \times R_6 = 0.5\ A \times 6\ \Omega = 3.0\ V$
	(c)	The voltage across the parallel arrangement = 3.0 V also. Ammeter reading, $I = \dfrac{V}{R_{15}} = \dfrac{3\ V}{15\ \Omega} = 0.2\ A$ or $200\ mA$

17.8	(a)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ so $\frac{1}{R_t} = \frac{1}{4\,\Omega} + \frac{1}{8\,\Omega} + \frac{1}{40\,\Omega} = \frac{16}{40\,\Omega}$ gives $R_t = 2.5\ \Omega$
	(b)	Voltage across all resistors is the same, so $V = I_4 \times R_4 = 2\text{ A} \times 4\ \Omega = 8.0\text{ V}$
	(c)	$I_8 = \frac{V}{R_8} = \frac{8\text{ V}}{8\,\Omega} = 1.0\text{ A}$
	(d)	$I_{40} = \frac{V}{R_{40}} = \frac{8\text{ V}}{40\,\Omega} = 0.2\text{ A or } 200\text{ mA}$
17.9	(a)	parallel
	(b)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{1440\,\Omega} + \frac{1}{960\,\Omega} = \frac{5}{2880\,\Omega}$ gives $R_t = 576\ \Omega$
	(c)	$I_{total} = \frac{V}{R_{total}} = \frac{240\text{ V}}{576\,\Omega} = 0.417\text{ A or } 417\text{ mA}$
17.10	(a)	$I_{microwave} = \frac{P_{microwave}}{V} = \frac{600\text{ W}}{240\text{ V}} = 2.50\text{ A}$ $I_{toaster} = \frac{P_{toaster}}{V} = \frac{450\text{ W}}{240\text{ V}} = 1.88\text{ A}$ $I_{kettle} = \frac{P_{kettle}}{V} = \frac{1000\text{ W}}{240\text{ V}} = 4.17\text{ A}$ gives $I_{total} = (2.50\text{ A} + 1.88\text{ A} + 4.17\text{ A}) = 8.55\text{ A}$
	(b)	$I_{grinder} = \frac{P_{grinder}}{V} = \frac{150\text{ W}}{240\text{ V}} = 0.625\text{ A}$ The total current would therefore increase to 9.18 A if the coffee grinder was turned on.
17.11	(a)	$R_{total} = R_1 + R_2 = 100\ \Omega + 100\ \Omega = 200\ \Omega$
	(b)	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{100\,\Omega} + \frac{1}{100\,\Omega} = \frac{2}{100\,\Omega}$ gives $R_t = 50\ \Omega$
	(c)	Connect in parallel since this offers the least resistance and will therefore result in a greater current so a shorter heating time.
17.12	(a)	Two identical resistors in parallel provide half the effective resistance of a single resistor. Therefore, circuit A will have double the resistance of circuit B.
	(b)	Since the resistance has halved, the total current will double. Also, the current through the globes will be the same and their value will be half of the total. So, $A_1 = 12.0$ A, $A_2 = 6.0$ A, $A_3 = 6.0$ A
	(c)	Each globe is receiving a current of 6 A, so they will all glow with the same intensity (brightness).

17.13	(a)	Since the internal resistance of the battery is effectively connected in series with the external resistance, the current through each must be the same.
	(b)	When starting the motor, voltage drop across the battery, v = I x r = 80 A x 0.05 Ω = 4.0 V
	(c)	Since the starter motor current needs to be huge (between 80 A to 100 A), then this can only be achieved from a battery with a very low internal resistance.
	(d)	At start up, the voltage dropped across the car battery is 4.0 V (see part (b), above). Therefore, although the car battery is rated at 12.0 V, only 8.0 V of this will be available to the headlights. Assuming they normally operate at 12 V, they will appear dim, at least until the motor is running and the current from the battery drops to a much lower value.  Car battery, EMF = 12.0 V and r = 0.050 Ω
17.14	(a)	P_{total} = 60 W + 60 W + 10 W + 10 W = 140 W
	(b)	$R_{total} = \frac{V^2}{P} = \frac{(12\text{ V})^2}{140\text{ W}} = 1.03\,\Omega$
	(c)	$R_{60} = \frac{V^2}{P} = \frac{(12\text{ V})^2}{60\text{ W}} = 2.40\,\Omega$
	(d)	$R_{10} = \frac{V^2}{P} = \frac{(12\text{ V})^2}{10\text{ W}} = 14.4\,\Omega$
	(e)	$I_{total} = \frac{P}{V} = \frac{140\text{ W}}{12\text{ V}} = 11.7\text{ A}$
17.15	(a)	The type A lamps are connected in series so if one burns out then there is no longer a complete circuit and all the lamps will fail to light. However, the type B lamps are connected

<table>
<tr><td></td><td></td><td>in parallel so if one of them burns out then as they are all independent of each other, the other 14 lamps continue working normally, with no difference to their brightness.</td></tr>
<tr><td></td><td>(b)</td><td>For the series (A) lamps, each lamp takes an equal share $\left(\frac{1}{15}\right)$ of the power supply voltage to which they are attached, so $R_A = \frac{V^2}{P} = \frac{\left(\frac{240\ V}{15}\right)^2}{4\ W} = 64\ \Omega$</td></tr>
<tr><td></td><td>(c)</td><td>For the parallel (B) lamps, each lamp receives the full power supply voltage available,
so $R_B = \frac{V^2}{P} = \frac{(240\ V)^2}{4\ W} = 14.4\ k\Omega$</td></tr>
<tr><td></td><td>(d)</td><td>If a B type globe was mistakenly swapped for one of the A type lamps in the series circuit, then the effective resistance of the circuit would be huge, resulting in a much smaller current flow. The fourteen remaining A type lamps would light very dimly, if at all and may give the impression that they are not working. However, the B lamp, which uses a very small operating current, would light, with perhaps a small loss in intensity.

If an A type lamp was mistakenly swapped for one of the B type lamps in the parallel circuit, then the effective resistance of the circuit would fall dramatically, resulting in a much greater current flow from the power supply. There would be no apparent change to the existing 14 type B lamps since they are all independent of each other and the new lamp. However, this A type lamp would now be operating from the whole 240 V supply (as opposed to its fifteenth share of this supply), therefore receive a massive current flow which would probably light extremely brightly and then almost instantly burn out. So, overall, no change to this circuit – there will still be a dead lamp.</td></tr>
<tr><td>17.16</td><td>(a)</td><td>
</td></tr>
<tr><td></td><td>(b)</td><td>Once the cells are connected to a load and a current is then drawn from them, their internal resistances come into play and some voltage will be dropped within them. This means that the external circuit, in this case the 2.5 V globe, will experience the combined EMF of the cells minus the dropped voltage.</td></tr>
</table>

	(c)	$E_{total} = I \times (r_{int} + R_{ext}) = (I \times r_{int}) + (I \times R_{ext}) = (I \times r_{int})$ + external voltage so $(1.5V + 1.5V) = (0.5A \times r_{int}) + 2.5V$ gives $r_{int} = \frac{\text{voltage drop}}{\text{current}} = \frac{0.5\text{ V}}{0.5\,\Omega} = 1.0\,\Omega$ - this is the internal resistance provided by both cells and since they are connected in series and they are identical, then their individual internal resistance = 0.50 Ω
17.17	(a)	The difference is due to the internal resistance of the solar cell, causing a small voltage drop within the cell itself once a load is connected and a current is being drawn.
	(b)	The EMF of the cell (as measured by the very high resistance voltmeter), E = 1.2 V Once the lower resistance voltmeter is connected (which effectively acts as a 1000 Ω load), a current, I flows and a voltage reading of 1.0 V is measured. This current, $I = \frac{V}{R} = \frac{1\text{ V}}{1000\,\Omega} = 0.001\text{ A}$ The voltage drop across the cell = E – V = 1.2V – 1.0V = 0.2 V So, the internal resistance of the solar cell, $r_{int} = \frac{\text{voltage drop}}{\text{current}} = \frac{0.2\text{ V}}{0.001\,\Omega} = 200\,\Omega$

Electrical Fundamentals

Set 18: Circuits and Safety

18.1		The active or live wire is the conductor at the high potential, nominally $V_{rms} = 240$ V The neutral wire is at a potential very close to zero relative to the active wire. The earth wire is a safety feature which is permanently connected to ground and therefore at a potential of 0 V.
18.2		Even small potential differences, such as 12 V car batteries, can deliver huge currents (up to 100 A) which can be fatal. However, a school laboratory Van der Graaf generator can build up a potential of thousands of volts, but if a student touches it, thereby establishing an equivalent potential difference, it may provide a slight, but non-fatal shock. Generally, the resistance of the load (combined with the internal resistance of the supply) will determine the current, not the potential difference itself.
18.3		$I_{globe} = \frac{P}{V} = \frac{40\text{ W}}{240\text{ V}} = 0.166\text{ A}$ so the number of globes possible = $\frac{15\text{ A}}{0.166\text{ A}} = 90\text{ globes}$ In practice, the circuit breaker would probably not cut out at exactly 15 A, so you could probably run a few more globes than this from the lighting circuit.
18.4		$I_{min} = \frac{V}{R} = \frac{12\text{ V}}{2.4\,\Omega} = 5.0\text{ A}$
18.5	(a)	In the event of a short circuit, a huge current surge would generate significant heat energy which would melt / damage the guilty conductor and cause a break in the circuit, thereby stopping the current flow before an electric shock could occur.
	(b)	'Time-current' is a combination of the magnitude of the current flow and the time for which it acts. Direct current does produce similar biological effects to that of alternating current, however the least DC time-current that will cause biological problems is greater than the corresponding AC time-current.
	(c)	The Earth wire is an essential safety feature which allows the safe operation of appliances with metal casings. However, if the appliance was doubly insulated, then in the event that a casing should become 'live' due to a fault, then the higher resistance of the protective layer would result in a much lower current flowing to the outer shell.
18.6	(a)	$I_{heater} = \frac{P}{V} = \frac{1200\text{ W}}{240\text{ V}} = 5.0\text{ A}$
	(b)	The 15 A circuit-breaker should not become an issue until the current drawn by the appliances is around 15 A. Since two heaters would only draw 10.0 A in total, then they would operate fine.
18.7		Total power consumption = 1000W + 2400W + 2000W = 5400 W The resulting current flow, $I_{total} = \frac{P}{V} = \frac{5400\text{ W}}{240\text{ V}} = 22.5\text{ A}$ This would obviously trip the 15 A circuit-breaker, so you should not use these three appliances.

18.8		The larger resistance wires can accommodate a bigger current flow and still function safely, therefore a fuse with a larger current rating should be installed.
18.9		All three safety features will ultimately break an electrical circuit and stop current flowing, although it may take anything from a fraction of a second to several seconds to do so. This may prevent a shock hazard in most cases, particularly in domestic situations, although they will not prevent all hazards.
18.10	(a)	$I_{globe} = \frac{P}{V} = \frac{100\text{ W}}{240\text{ V}} = 0.417\text{ A}$ so the number of globes possible = $\frac{10\text{ A}}{0.417\text{ A}} = 24\text{ globes}$
	(b)	Total power consumption = 1800W + 2400W = 4200 W The resulting current flow, $I = \frac{P}{V} = \frac{4200\text{ W}}{240\text{ V}} = 17.5\text{ A}$ This too great current would obviously 'blow' the 15 A fuse.
	(c)	The fuse in both cases protects the user of the appliances from an electrical shock hazard or an electrical burn, however it also protects the appliances themselves from permanent damage which could prove financially costly.
	(d)	Thick copper wire would have a very low resistance and therefore allow a much larger and potentially fatal current, to flow through it before 'blowing'.
	(e)	In the event of a short circuit, a huge current surge would generate significant heat energy which would melt / damage the guilty conductor and cause a break in the circuit, thereby stopping the current flow before an electric shock could occur. Hence, the risk of electrocution maybe prevented.
18.11		Power boards demand appliances be connected in parallel and they operate from a 240 V supply. $I_{heater} = \frac{V}{R} = \frac{240\text{ V}}{35\,\Omega} = 6.86\text{ A}$ $I_{lamp} = \frac{V}{R} = \frac{240\text{ V}}{110\,\Omega} = 2.18\text{ A}$ $I_{CD\ player} = \frac{V}{R} = \frac{240\text{ V}}{750\,\Omega} = 0.32\text{ A}$ $I_{cassette\ player} = \frac{V}{R} = \frac{240\text{ V}}{640\,\Omega} = 0.375\text{ A}$ $I_{amplifier} = \frac{V}{R} = \frac{240\text{ V}}{350\,\Omega} = 0.686\text{ A}$ The total current drawn form the power board, I_{total} = 10.42 A This exceeds the 10 A safety margin so Alec's circuit will not work.
18.12	(a)	$R = \frac{V}{I} = \frac{240\text{ V}}{0.04\text{ A}} = 6.0\text{ k}\Omega$
	(b)	$I_{neutral}$ = 1500mA – 40mA = 1460 mA (or 1.46 A)

18.13	(a)	$I_{griller} = \frac{P}{V} = \frac{1500\text{ W}}{240\text{ V}} = 6.25\text{ A}$
	(b)	$R_{fridge} = \frac{V}{I} = \frac{240\text{ V}}{10\text{ A}} = 24.0\,\Omega$
	(c)	I_{total} = 10A + 6.25A = 16.25 A, so the circuit breaker will be activated when the fridge starts up.
18.14	(a)	$I_{max} = \frac{V}{R_{min}} = \frac{3000\text{ V}}{50 \times 10^6\,\Omega} = 6 \times 10^{-5}\text{ A or } 60\,\mu\text{A}$
	(b)	A typical torch bulb may be rated at 3 V, 500 mA when operating normally. This would suggest a resistance, $R = \frac{V}{I} = \frac{3\text{ V}}{0.5\text{ A}} = 6.0\,\Omega$. When competing with the 50 MΩ series safety resistor, its share of the voltage supply will be minimal: $I = \frac{V}{R} = \frac{3000\text{ V}}{(6\,\Omega + 50000006\,\Omega)} = 5.999 \times 10^{-5}\text{ A or } 59.9\,\mu\text{A}$ so $V_{torch} = I \times R_{torch} = 5.999 \times 10^{-5}\text{A} \times 6\,\Omega = 3.59 \times 10^{-4}$ V (about 360 μV)
	(c)	The 50 MΩ resistor acts like an internal resistance, such that even in the event of a short circuit when the external resistance could be very close to 0 Ω, the maximum current that can result is limited to 60 μA which should be non-fatal.
18.15	(a)	$I_{John} = \frac{V}{R} = \frac{240\text{ V}}{4400\,\Omega} = 5.45 \times 10^{-2}\text{ A or } 54.5\text{ mA}$
	(b)	Carmen is effectively joining John in parallel, so the combined resistance will now be less thereby drawing a bigger current. Although there are two separate current paths, John will effectively have both running through his heart - the original 54.5mA and now the extra current running along his arm span to Carmen.
	(c)	$I_{Carmen} = \frac{V}{R} = \frac{240\text{ V}}{(8000\,\Omega + 400\,\Omega)} = 2.86 \times 10^{-2}\text{ A or } 28.6\text{ mA}$
	(d)	Carmen should have isolated the power supply initially – turned off the electricity.
	(e)	The total current flowing = 54.5 mA + 28.6 mA = 83.1 mA, although potentially hazardous for John, it is not large enough to 'blow' the fuse in the power points circuit.