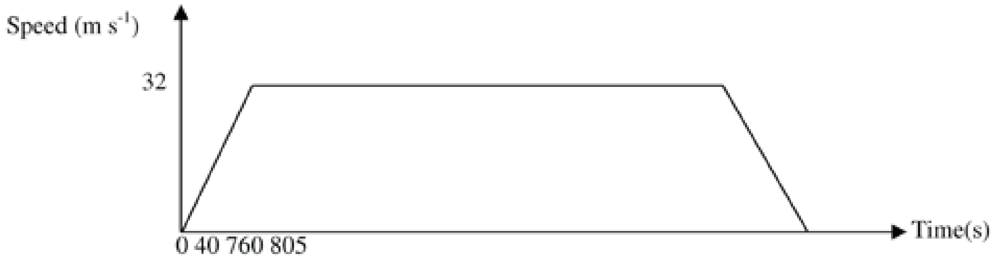
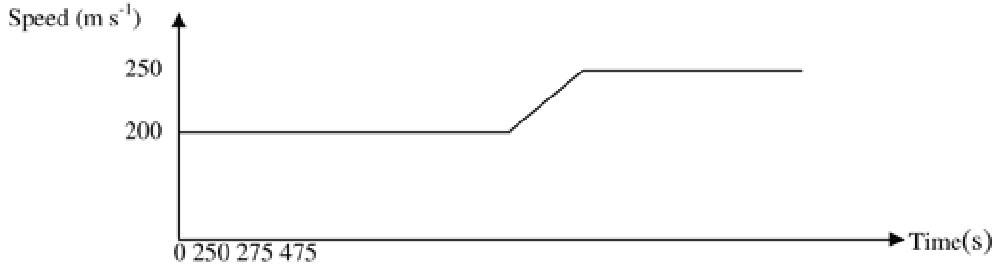
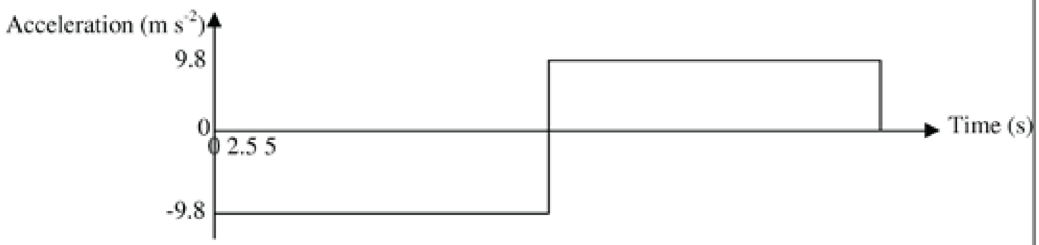
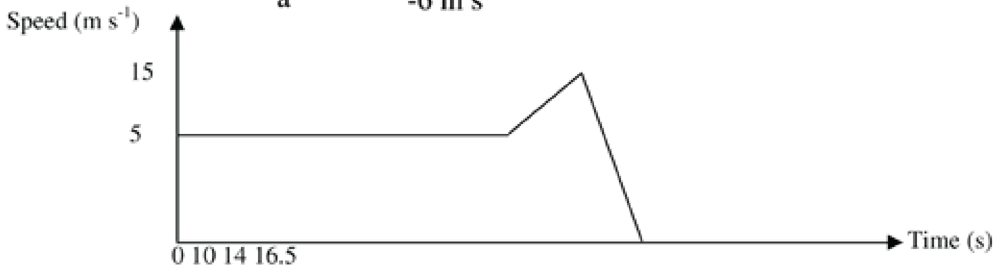
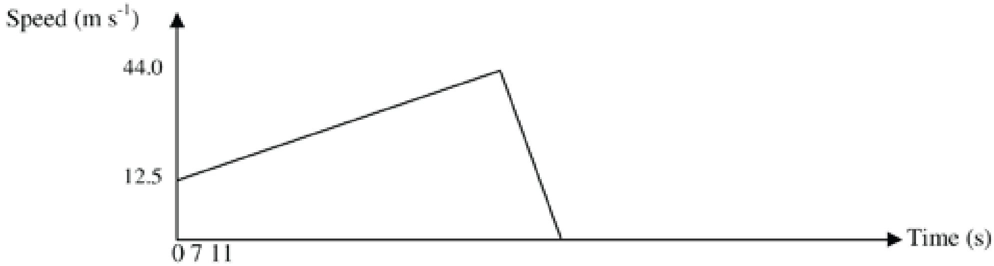
Motion & Forces

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)	$32 \text{ m s}^{-1} = \left(\dfrac{32 \text{ x } 3600}{1000}\right) \text{ km h}^{-1} = 115 \text{ km h}^{-1}$
	(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)	$45 \text{ km h}^{-1} = \left(\dfrac{45 \text{ x } 1000}{3600}\right) \text{ m s}^{-1} = 12.5 \text{ m s}^{-1}$ $a = \dfrac{v-u}{t} = \dfrac{12.5 \text{ m s}^{-1} - 0}{2.65 \text{ s}} = 4.72 \text{ m s}^{-2}$
2.4	(a)	Change in velocity, $\Delta v = at = 21.3 \text{ m s}^{-2} \text{ x } 5.35 \text{ s} = 114 \text{ m s}^{-1}$ 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)	$v = u + at = 0 + (1.7 \text{ m s}^{-2})(12.3 \text{ s}) = 20.9 \text{ m s}^{-1}$