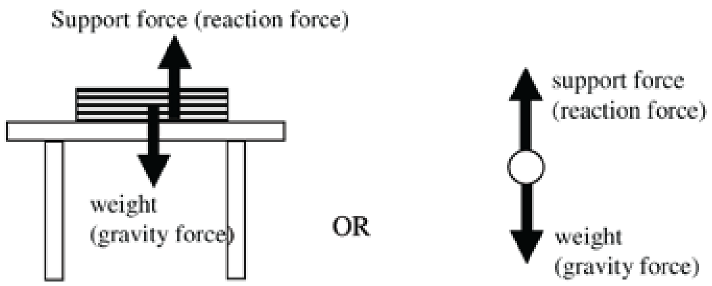
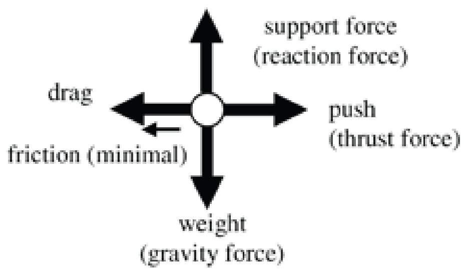
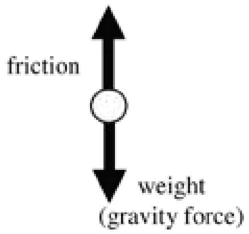
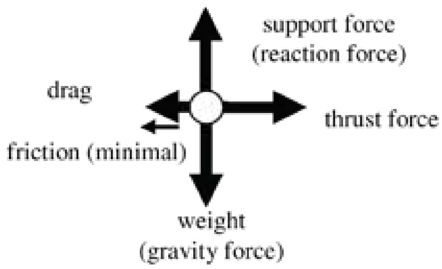
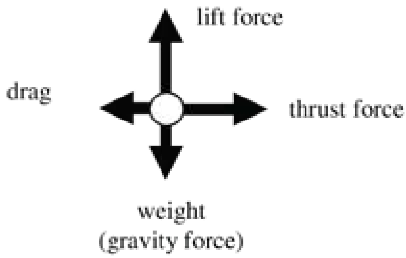
Motion & Forces

Set 3: Force and Newton's Laws

3.1	(a)	$g = \frac{F_w}{m} = \frac{525\ N}{70\ kg} = 7.5\ N\ kg^{-1}$ (or $7.5\ m\ s^{-2}$)
3.2	(a)	The mass is the same on both planets
	(b)	Since weight is directly proportional to the acceleration due to gravity, then $\frac{g_{Earth}}{g_{Mars}} = \frac{9.8\ m\ s^{-2}}{3.72\ m\ s^{-2}} = 2.63$ 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, $F = m\ a = (40\ kg)(2\ m\ s^{-2}) = 80\ N$
	(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)	$\Delta v = v - u = -1.9 \text{ m s}^{-1} - 3.2 \text{ m s}^{-1} = -5.1 \text{ m s}^{-1}$ (negative shows the direction is upwards)
	(b)	$a = \frac{\Delta v}{t} = \frac{-5.1 \text{ m s}^{-1}}{0.15 \text{ s}} = -34.0 \text{ m s}^{-2}$ (negative shows the direction is upwards)
	(c)	$F_{av} = m a = (0.5 \text{ kg})(-34.0 \text{ m s}^{-2}) = -17.0 \text{ N}$ (upwards)
3.7		$F_{av} = \frac{m\Delta v}{t} = \frac{m(v-u)}{t}$ $= \frac{(13 \text{ kg})(0 \text{ m s}^{-1} - 6.5 \text{ m s}^{-1})}{1.3 \text{ s}} = -67.5 \text{ N}$ (negative shows opposite direction to origina
3.8		$Ft = m\Delta v$ $\therefore \Delta v = \frac{Ft}{m} = \frac{(-2100 \text{ N})(2.5 \text{ s})}{750 \text{ kg}} = -7.0 \text{ m s}^{-1}$ but $\Delta v = v - u$ $\therefore v = \Delta v + u = (-7.0 \text{ m s}^{-1} + 16.5 \text{ m s}^{-1}) = 9.5 \text{ m s}^{-1}$ (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)	$F_{friction} = \frac{F_w}{12} = \frac{([525+385]\text{ kg})\ (9.8\text{ m s}^{-2})}{12} = 743\text{ N}$
	(b)	$F_{net} = F_{pull} - F_{friction} = 965\text{ N} - 743\text{ N} = 222\text{ N}$
	(c)	$a = \frac{F_{net}}{m} = \frac{222\text{ N}}{(525+385)\text{ kg}} = 0.244\text{ m s}^{-2}$
	(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)	$F_{friction} = \frac{F_w}{12} = \frac{(525\text{ kg})(9.8\text{ m s}^{-2})}{12} = 429\text{ N}$ $F_{net} = F_{pull} - F_{friction} = 965\text{ N} - 429\text{ N} = 536\text{ N}$ $a = \frac{F_{net}}{m} = \frac{536\text{ N}}{525\text{ kg}} = 1.02\text{ m s}^{-2}$
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: $T_2 = m_2\,a = (1200\text{ kg})(1.45\text{ m s}^{-2}) = 1740\text{ N}$