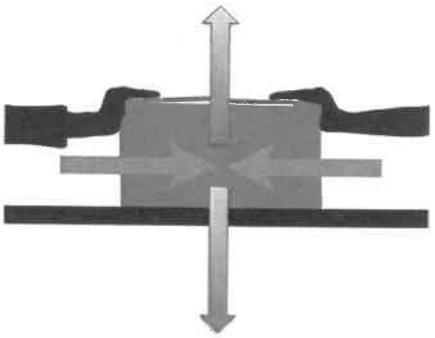
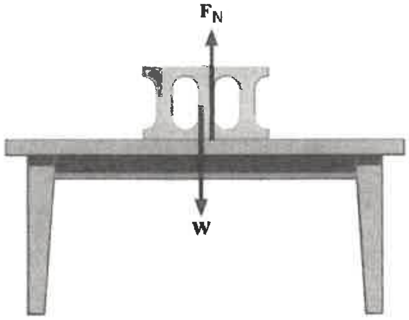
Chapter 4: Newton's Laws of Motion

- a force diagram is a picture that shows the strength and direction of forces acting on an object



- the Size of the arrow shows the size of the force (a longer arrow = a larger force)
- the direction of the arrow shows the direction of the force
- forces always come in pairs



- •When the forces are balanced they are acting in opposite direction with equal strength
- •As a result the object will not move
  if it is stationary

- •When the forces are unbalanced they are acting in opposite direction with different strengths
- •As a result the object will start to move (accelerate)

Newtons's Laws of Motion:

- Three laws summarize the relationship between acceleration and force

Newton's First Law: Inertia

- A body with balanced forces acting on it, remains at rest or moves with constant speed in a straight line. * Eureka video - Inertia

Newton's Second Law: Acceleration

- A body with unbalanced forces acting on it will accelerate at a rate directly proportional to the net force on it and inversely proportional to its mass

$$\boxed{a = F_{NET}/m} \quad \text{or} \quad \boxed{F_{NET} = ma}$$

F = net force

m = mass (kg)

a = acceleration (N/kg or m/s²)

- (net) force and acceleration (both vectors) are in the same direction.
- net force (resultant of all forces acting on a body) causes acceleration
- force that causes a mass of one kilogram to accelerate at a rate of one metre per second = 1N

Ex#1: What is the net force required to accelerate a 1600 kg race car at 3.15 m/s²?

$F_{NET} = ?$

$m = 1600\,kg$

$a = 3.15\,m/s^2$

$F_{NET} = ma$

$= (1600\,kg)(3.15\,m/s^2)$

$= 5040\,N = \boxed{5.0 \times 10^3\,N}$ 2sf

Ex#2: A bus accelerates from rest to 30.0 m/s in 15s. If the net force acting on the bus is 25 000N, what is the mass of the bus?

$V_i = 0\,m/s$

$V_f = 30.0\,m/s$

$t = 15\,s$

$a = ?$

$a = \frac{V_f - V_i}{t}$

$= \frac{30.0\,m/s - 0\,m/s}{15\,s} = 2.0\,m/s$

$F_{NET} = 25000\,N$

$a = 2.0\,m/s$

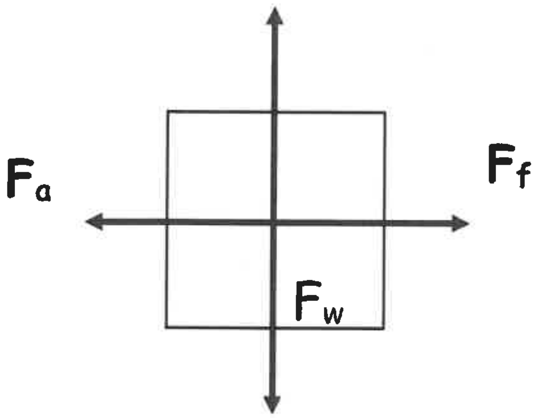
$m = ?$

$m = \frac{F_{NET}}{a} = \frac{25000\,N}{2.0\,N/kg}$

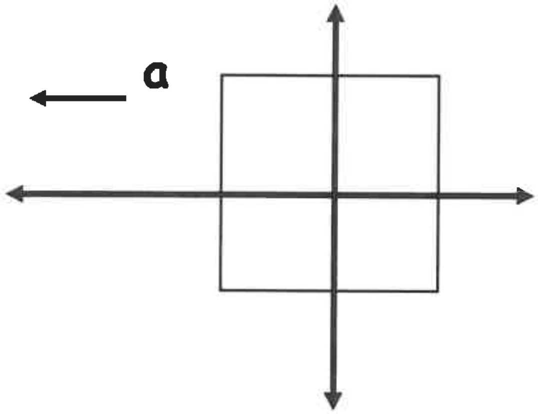
$= 12500\,kg$

or $\boxed{1.3 \times 10^4\,kg}$ 2sf

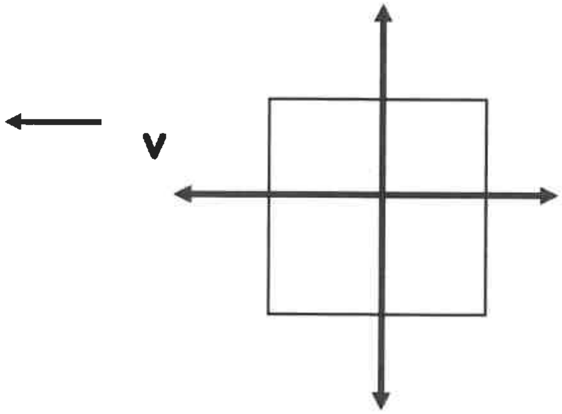
Net Forces Cause Acceleration



- If all forces are balanced on a stationary object, it will not move.

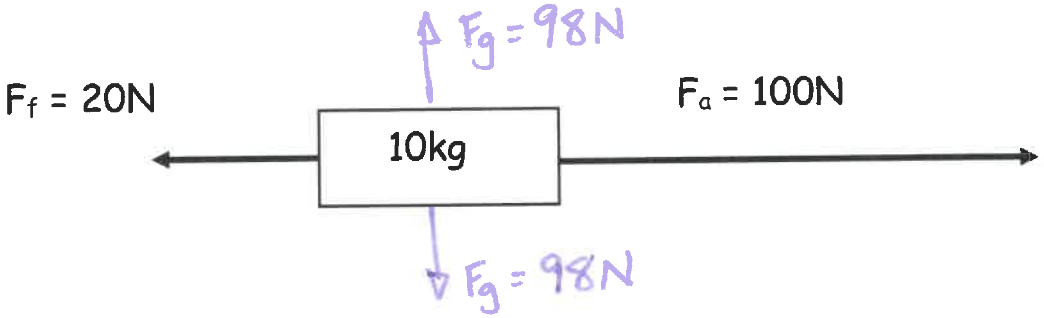


- For the object to move, you have to apply a force greater than the static frictional force. The forces are unbalanced and the object will accelerate.



- If F_a is then reduced so that it is equal to the sliding friction, opposing forces will be balanced once again and the object will continue to move at a constant velocity.

Ex.1 A 10 kg box is dragged along the floor with a force of 100 N. The force of friction is 20 N.



a) What is the force of gravity acting on the block? What is the normal force? Add those forces onto the force diagram above.

$F_g = mg = (10\,kg)(9.8\,N/kg) = \boxed{98\,N}$ $\quad F_N = F_g = \boxed{98\,N}$

b) What is the net force acting on the block? In which direction is it acting?

$F_{NET} = F_A - F_F = \boxed{80\,N \text{ to the right}}$

c) What is the rate at which the block is accelerating?

$F_{NET} = 80\,N$ [right]

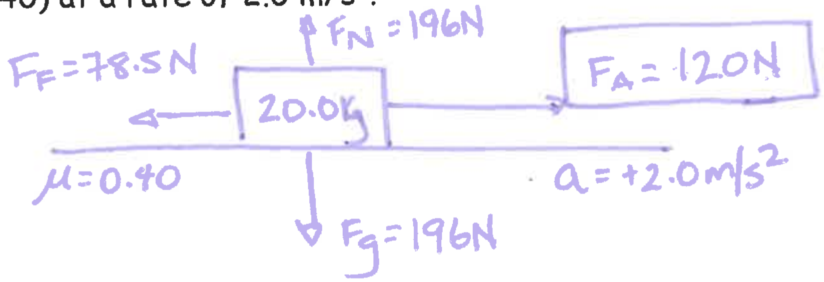
$m = 10\,kg$

$a = ?$

$a = \frac{F_{NET}}{m} = \frac{80\,N}{10\,kg}$

$= \boxed{+8\,m/s^2 \text{ to the right}}$

Ex.2 What tension force is needed to accelerate a 20.0 kg box along a wooden floor (μ = 0.40) at a rate of 2.0 m/s^2?



$F_g = F_N = mg$

$= (20.0\,kg)(9.81\,N/kg)$

$= \boxed{196\,N}$

$F_F = \mu F_N$

$= (0.40)(196\,N)$

$= \boxed{78.5\,N}$

$F_{NET} = ma$

$= (20.0\,kg)(2.0\,N/kg)$

$= \boxed{40\,N}$ (2sf)

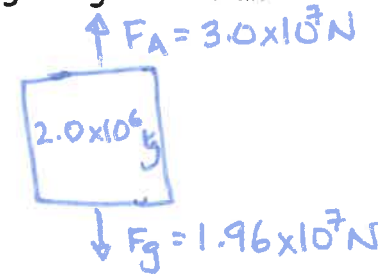
$F_{NET} = |F_A| - |F_F|$

$F_A = F_{NET} + F_F$

$= 40\,N + 78.5\,N$

$= 118.5\,N = \boxed{120\,N}$ (2sf)

Ex#3: The space shuttle has a mass of 2.0 x 10^6 kg. At lift off the engines generate an upward force of 3.0 x 10^7 N.



a) What is the weight of the shuttle?

$$F_g = mg$$
$$= (2.0\times10^6 kg)(9.81 N/kg)$$
$$= \boxed{1.96\times10^7 N \text{ (down)}}$$

b) What is the net force acting on the shuttle? In which direction is it acting? How do you know?

$$F_{NET} = |F_A| - |F_g|$$
$$= 3.0\times10^7 N - 1.96\times10^7 N$$
$$= \boxed{1.04\times10^7 N \text{ (up)}}$$

c) What is the acceleration of the shuttle when launched?

$F_{NET} = 1.04\times10^7 N$

$m = 2.0\times10^6 kg$

$a = ?$

$$a = \frac{F_{NET}}{m} = \frac{1.04\times10^7 N}{2.0\times10^6 kg}$$
$$= \boxed{+5.2 m/s \text{ (up)}}$$

Ex#4: A parachutist has a mass of 65 kg. If the drag on the parachute is 590 N, what is the acceleration of the parachutist?

$$F_g = mg$$
$$= (65 kg)(9.81 N/kg)$$
$$= 638N$$

$$F_{NET} = |F_u| - |F_g|$$
$$= 590N - 638N$$
$$= {}^-48 N \text{ or } 48N \underline{\text{down}}$$

$$a = \frac{F_{NET}}{m} = \frac{{}^-48N}{65 kg} = \boxed{-0.74 m/s^2}$$

Terminal Velocity

When a body falls through a fluid, it increases in speed. However, a maximum velocity is eventually reached.

Terminal velocity occurs when the force of gravity balances the resistive force of the fluid.

Depends on:

a) size and mass of the falling object

b) viscosity of the fluid (resistive force

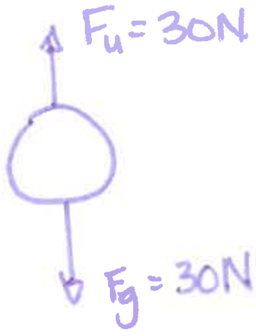
Ex. #1. A skydiver in freefall has a mass of 75.0*kg*. What drag force would air resistance exert when the skydiver is at terminal velocity?

$$F_g = mg$$
$$= (75.0kg)(9.81N/kg)$$
$$= 736N$$

$F_u = F_g$ at terminal velocity

$\therefore$ Drag force $= \boxed{736N\ (up)}$ 3 s.f.

Ex. #2. A steel ball is falling at a constant speed through glycerin. The drag force is 30N. What is the mass of the ball?



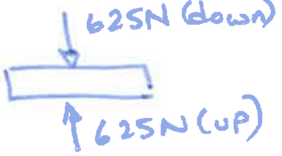
$$F_u = F_g = 30N$$
$$g = 9.81N/kg$$
$$m = ?$$

$$m = \frac{F_g}{g} = \frac{30N}{9.81N/kg}$$
$$= \boxed{3kg}$$ 1 s.f.

Newton's 2nd Law Extra Practice

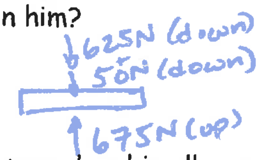
Name: ____________________

1. Suppose Joe, who weighs 625 N, stands on a bathroom scale calibrated in newtons.
   a) What force would the scale exert and in what direction?



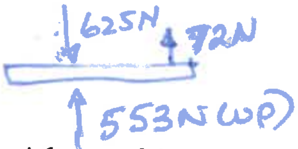
$\boxed{625N\ up}$ (reaction force)

   b) If Joe now holds a 50 N cat in his arms, what force would scale exert on him?



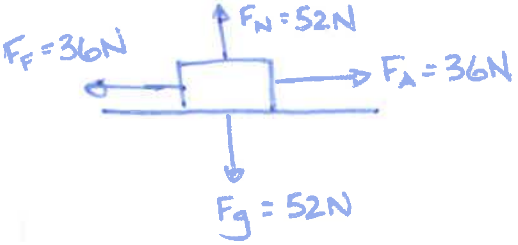
$\boxed{675N\ up}$

   c) After Joe puts down the cat, his father comes up behind him and lifts upward on his elbows with a 72 N force. What force does the scale now exert on him?



$625N - 72N = \boxed{553N\ (up)}$

2. A 52 N sled is pulled across a cement sidewalk at constant speed. A horizontal force of 36 N is exerted. What is the coefficient of friction between the sidewalk and the metal runners of the sled?



Constant speed ∴ $F_{NET} = 0N$

$F_F = F_A = 36N$

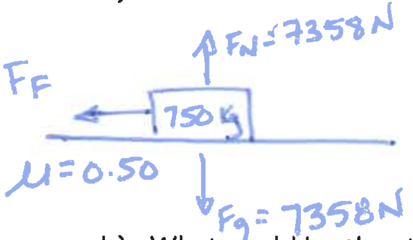
$F_F = 36N$

$F_N = 52N$

$\mu = ?$

$$\mu = \frac{F_F}{F_N} = \frac{36N}{52N} = \boxed{0.69}$$

3. The coefficient of sliding friction between rubber tires and wet pavement is 0.50. The brakes are applied to a 750 kg car traveling 30 m/s and the car skids to a stop.
   a) What is the size and direction of the force of friction that the road exerts on the car?



$F_g = F_N = mg$

$= (750kg)(9.81N/kg)$

$= 7358N$

$F_F = \mu F_N$

$= (0.50)(7358N)$

$= 3679N$

$= \boxed{3700N}$ back

   b) What would be the size and direction of the acceleration of the car? Why would it be constant?

Negative direction (slowing down)

$F_A = 0N$

$F_F = 3679N$

$F_{NET} = |F_A| - |F_F|$

$= -3679N$

$$a = \frac{F_{NET}}{m} = \frac{-3679N}{750kg}$$

$= -4.9 m/s^2$

$= \boxed{4.9 m/s^2}$ 2sf.

   c) How far would the car travel before stopping?

$a = -4.91 m/s^2$

$v_i = 30 m/s$

$v_f = 0 m/s$

$d = ?$

$v_f^2 = v_i^2 + 2ad$

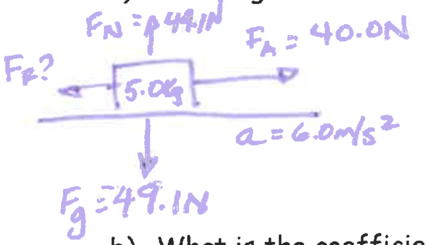
$$d = \frac{v_f^2 - v_i^2}{2a} = \frac{(0m/s)^2 - (30m/s)^2}{(2)(-4.91m/s^2)}$$

$= 91.6 m = \boxed{92m}$

2sf

4. A force of 40.0 N accelerates a 5.0 kg block at 6.0 m/s^2 along a horizontal surface.

a) How large is the frictional force?



$F_{NET} = ma$
$= (5.0kg)(6.0 m/s^2)$
$= ^+30N$

$F_{NET} = |F_A| - |F_F|$
$F_F = |F_A| - F_{NET}$
$= 40.0N - 30.N$
$= ^-10N$ (2 s.f.)
$= \boxed{-1.0 \times 10^{+1} N \text{ (2sf)}}$

b) What is the coefficient of friction?

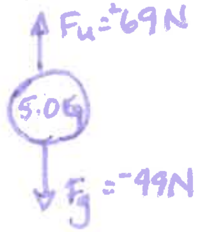
$\mu = \frac{F_F}{F_N} = \frac{10N}{49.1N} = \boxed{0.20}$

5. A rubber ball weighs 49 N.

a) What is the mass of the ball?

$m = \frac{F_g}{g} = \frac{49N}{9.81 N/kg} = 4.99 kg = \boxed{5.0 kg}$ 2 s.f.

b) What is the acceleration of the ball if an upward force of 69 N is applied?



$F_{NET} = |F_u| - |F_g|$
$= ^+69 N - 49N$
$= 20 N$ (2sf)

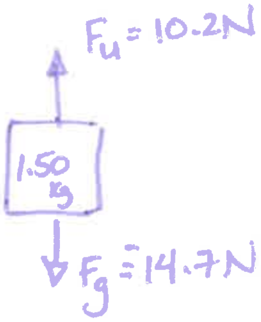
$a = \frac{F_{NET}}{m}$
$= \frac{20N}{5.0kg} = ^+4.0 m/s^2$
(up)

6. A small weather rocket weighs 14.7 N.

a) What is its mass?

$m = \frac{F_g}{g} = \frac{14.7N}{9.81 N/kg} = 1.499kg = \boxed{1.50 kg}$ 3 s.f.

b) The rocket is carried up into the sky by a balloon. The rocket is released from the balloon and fired, but its engine exerts an upward force of 10.2 N. what is the acceleration of the rocket?



$F_{NET} = |F_u| - |F_F|$
$= 10.2N - 14.7N$
$= -4.5N$

$a = \frac{F_{NET}}{m} = \frac{-4.5N}{1.50 kg} = \boxed{-3.0 m/s^2 \text{ (down)}}$

7. An 873 kg dragster, starting from rest, attains a speed of 26.3 m/s in 0.59s.

a) Find the average acceleration of the dragster during this time interval.

$v_i = 0 \text{ m/s}$

$v_f = {}^{+}26.3 \text{ m/s}$

$t = 0.59 \text{ s}$

$a = ?$

$$a = \frac{v_f - v_i}{t}$$

$$= \frac{26.3 \text{ m/s} - 0 \text{ m/s}}{0.59 \text{ s}} = {}^{+}44.6 \text{ m/s}^2 \boxed{= {}^{+}45 \text{ m/s}^2}$$

2sf

b) What is the size of the net ~~average~~ force on the dragster during this time interval? *

$m = 873 \text{ kg}$

$a = +44.6 \text{ m/s}^2$

$F = ?$

$$F = ma$$

$$= (873 \text{ kg})(+44.6 \text{ m/s}^2)$$

$$= {}^{+}38936 \text{ N} = \boxed{{}^{+}3.9 \times 10^4 \text{ N}}$$

2sf

c) Assume the driver has a mass of 68 kg. What net horizontal force does the seat exert on the driver? *

$a = +44.6 \text{ m/s}^2$

$m = 68 \text{ kg}$

$F = ?$

$$F = ma$$

$$= (68 \text{ kg})(+44.6 \text{ m/s}^2)$$

$$= {}^{+}3033 \text{ N} = \boxed{+3.0 \times 10^3 \text{ N}}$$

2 sf

8. A race car has a mass of 710 kg. It starts from rest and travels 40.0 m is 3.0 s. The car is uniformly accelerated during the entire time. What net force is applied to it?

$m = 710 \text{ kg}$

$v_i = 0 \text{ m/s}$

$d = 40.0 \text{ m}$

$t = 3.0 \text{ s}$

$a = ?$

$$d = \cancel{v_i t}^{0} + \tfrac{1}{2}at^2$$

$$a = \frac{2d}{t^2}$$

$$= \frac{(2)(40.0 \text{ m})}{(3.0 \text{ s})^2}$$

$$= {}^{+}8.89 \text{ m/s}^2$$

$$F_{NET} = ma$$

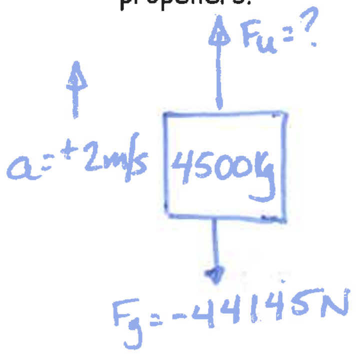
$$= (710 \text{ kg})(+8.89 \text{ m/s}^2)$$

$$= +6312 \text{ N}$$

$$= \boxed{+6.3 \times 10^3 \text{ N}}$$

2 sf

9. A 4500 kg helicopter accelerates upwards at 2.0 m/s^2. What lift force is exerted by the air on the propellers? *



$$F_g = mg$$

$$= (4500 \text{ kg})(9.81 \text{ N/kg})$$

$$= {}^{-}44145 \text{ N}$$

$$F_{NET} = ma$$

$$= (4500 \text{ kg})(+2 \text{ m/s}^2)$$

$$= {}^{+}9000 \text{ N}$$

$$F_{NET} = |F_u| - |F_g|$$

$$F_u = F_{NET} + |F_g|$$

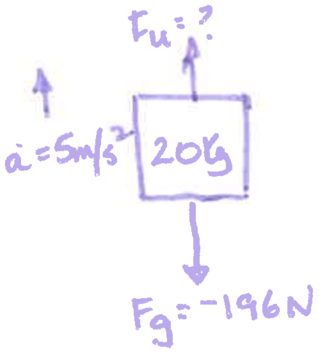
$$= {}^{+}9000 \text{ N} + 44145 \text{ N}$$

$$= {}^{+}53145 \text{ N}$$

$$= \boxed{+5 \times 10^4 \text{ N}}$$

1 sf

10. The maximum force a grocery bay can withstand and not rip is 250 N. if 20 kg of groceries are lifted from the floor to the table with an acceleration of 5 m/s², will the bag hold?



$F_g = mg$
$= (20kg)(9.81 N/kg)$
$= -196N$

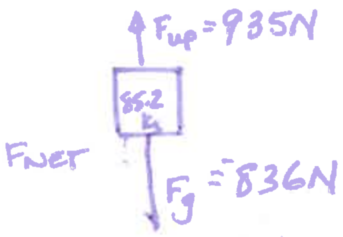
$F_{NET} = ma$
$= (20kg)(^+5.0 m/s^2)$
$= ^+100N$

$F_{NET} = |F_u| - |F_g|$
$|F_u| = F_{NET} + |F_g|$
$= +100N + 196N$
$= +296N = \boxed{+300N}$ 1sf

∴ No, bag will rip

11. A student stands on a bathroom scale in an elevator at rest on the 64th floor of a building. The scale reads 836 N.

a) As the elevator moves up, the scale reading increases to 935 N, then decreases back to 836 N. Find the acceleration of the elevator.

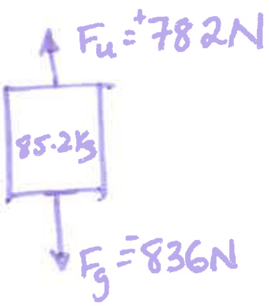


$F_{NET} = |F_u| - |F_g|$
$= 935N - |^-836N|$
$= +99N$

$m = \frac{F_g}{g} = \frac{836N}{9.81N/kg} = 85.2kg$

$a = \frac{F_{NET}}{m} = \frac{+99N}{85.2kg}$
$= +1.16 m/s^2$
$= \boxed{+1.2 m/s^2}$ (up)
2sf

b) As the elevator approaches the 74th floor, the scale reading drops as low as 782 N. What is the acceleration of the elevator?



$F_{NET} = |F_u| - |F_g|$
$= +782N - 836N$
$= -54N$

$a = \frac{F_{NET}}{m} = \frac{-54N}{85.2kg} = -0.634 m/s^2$
$= \boxed{-0.63 m/s^2}$ (down)
2sf

ANSWERS: 1. a) 625N (up); b) ~~657~~ 675N N (up); c) 553 N (up); 2. 0.69; 3. a) -3.7x10³N; b) -4.9m/s²; c) 92m; 4. a) -10 N; b) 0.20; 5. a) 5.0 kg; b) 4.0 m/s² (up); 6. a) 1.5 kg; b) -3.0 m/s²; 7. a) 45 m/s²; b) 3.9x10⁴ N; c) ~~3.1x10³N~~; 3.0x10³N 8. 6.3x10³N; 9. 5.3x10⁴N; 10. No (F=300N); 11. a) 1.2 m/s²; b) -0.63 m/s²

Newton's Third Law: Action - Reaction

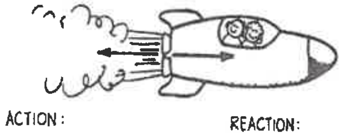
- Whenever one object exerts a force on a second object, the second exerts an equal and opposite force on the first.

i.e., action force - hammer exerts a force on a nail

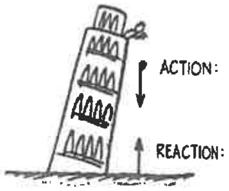
reaction force - nail exerts a force on the hammer.

Action and reaction forces are acting on different bodies.
force on object determines acceleration (2nd Law)

Tires push back on road;
Road pushes back on tires, causing
car to move forward



Rocket pushes gasses backward;
Gasses push back on rocket,
thrusting it forward.



Earth pulls down on ball, while
the ball pulls up on earth.

Note: While the forces on the ball and the earth are equal in magnitude, the masses are very different.

∴ ball's acceleration is much, much larger than the Earth's.

$ma = Ma$

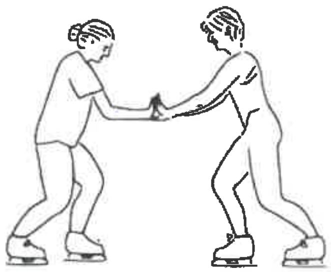
- The Earth does accelerate upwards, but its magnitude is too small for us to measure!

Action and Reaction of Different Masses

- Forces are equal in strength, but the acceleration is different on the masses.

Ex#1: Two girls on ice push each other. Andi weighs 55 kg while Jaime weighs 85 kg. They push each other with a net force of 150 N.

a) What is each girl's acceleration?



Andi
m = 55 kg
F = 150 N

$$a = \frac{F_{NET}}{m} = \frac{+150N}{55kg} = \boxed{+2.7 m/s^2}$$

Jaime
m = 85 kg
F = - 150 N

$$a = \frac{F_{NET}}{m} = \frac{-150N}{85kg} = \boxed{-1.8 m/s^2}$$

b) Why is the force acting on Jaime listed as negative?

It is acting in the opposite direction than the force on Andi.

c) Does it matter who pushes who?

No!

Concepts in Physics - Newton's Laws

1. Galileo found that a ball rolling down one incline will pick up enough speed to roll up another. How high will it roll compared to its initial height if there were no friction?

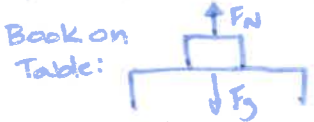
Same height

2. The law of inertia states that no force is required to maintain motion. Why, then, do you have to keep pedalling your bicycle to maintain motion?

Unless you pedal + produce a thrust force equal to the force of friction, forces will be unbalanced and you will decelerate

3. If an object has no acceleration, can you conclude that no forces are acting on it? Explain and draw a free body diagram to illustrate an example.

No - as long as the forces are balanced, the object will not accelerate



$F_N = {}^{-}F_g$ ∴ no movement!

4. What is the effect of friction on a moving object? How is an object able to maintain a constant speed when friction acts upon it?

Frictional forces oppose motion. To maintain a constant speed, an applied force of equal magnitude to the frictional force must be made.

5. Suppose a cart is being moved by a certain net force. If a load is dumped into the cart so its mass is doubled, by how much does the acceleration change?

$F_{NET} = \overset{\times 2}{m}\underset{\div 2}{a}$

If F_{NET} doesn't change, then if the mass doubles, the acceleration must halve.

6. The force of gravity is twice as great on a 2 kg rock as on a 1 kg rock. Why then does the 2 kg rock not fall with twice the acceleration?

$a = \dfrac{F_g \cancel{\times 2}}{m \cancel{\times 2}}$

If you double the mass, you also double the force of gravity so the acceleration remains the same.

7. A rocket fired from its launching pad not only picks up speed, but its acceleration increases significantly as firing continues. Why is this so? (hint: About 90% of the mass of a newly launched rocket is fuel) As the rocket consumes fuel, its mass goes down, while maintaining the same upwards force. Therefore, the rocket accelerates at a greater rate

$F = \underset{\downarrow}{m}\overset{\uparrow}{a}$

8. When a rock is thrown straight upward what is its acceleration at the top of its path?

Any object in free fall accelerates at $-9.81 m/s^2$

9. When you jump up, the world really does recoil downward. Why can't this motion of the world be noticed?

The mass of the Earth is so large that its acceleration is negligeable.

10. Action and reaction forces are equal and opposite, so why don't they cancel one another and make the net forces greater than zero impossible?

Action and reaction forces act on different objects

4.4 Momentum

- the quantity of motion.
- the product of mass and velocity.

$$\boxed{p=mv}$$

p= momentum, kg.m/s
m = mass, kg
v = velocity, m/s

Ex#1: A baseball with a mass of 0.15 kg is moving at 27 m/s. What is the momentum of the baseball?

$m = 0.15\ kg$
$v = 27\ m/s$
$p = ?$

$$p = mv$$
$$= (0.15\ kg)(^{+}27\ m/s)$$
$$= 4.05\ kg\cdot m/s$$
$$= \boxed{^{+}4.1\ kg\cdot m/s}$$

Ex#2: If a bowling ball has a mass of 5.5kg, what velocity would you give it in order to have the same momentum as the baseball?

$P = {}^{+}4.05\ kg\cdot m/s$
$m = 5.5\ kg$
$v = ?$

$$p = mv$$
$$v = \frac{p}{m} = \frac{^{+}4.05\ kg\cdot m/s}{5.5\ kg} = {}^{+}0.736\ m/s$$
$$= \boxed{^{+}0.74\ m/s}$$

Momentum and Newton's 1st Law

If no net force acts on a body, its velocity is constant. If an objects mass and velocity do not change then its momentum is constant.

Momentum and Newton's 2nd Law

Newton's 2nd law describes how momentum changes by a force acting on it:

$$\boxed{F=ma}$$

If $a = \Delta v/\Delta t$

then $F = m(\Delta v/\Delta t)$

or $F\Delta t = m\Delta v = \Delta p$

Impulse (FΔt) or (Δp) *

- the product of force and time during which it acts.
- measured in N.s

Impulse-Momentum Theorem

- impulse given to an object is equal to the change in momentum

Ex#1: What is the impulse exerted on a baseball if a bat exerts a force of 550 N for 0.0070s on the ball? *

$F_{NET} = +550N$

$t = 0.007s$

$\Delta p = ?$

$\Delta p = F_{NET} \cdot t$

$= (+550N)(0.007s)$

$= 3.85 N$

$= \boxed{+3.9 N}$

Ex#2: What force is required to stop a 1200 kg car in 12 s if the car is travelling 60 m/s?

$F_{NET} = ?$

$v_i = +60m/s$

$v_f = 0m/s$

$t = 12s$

$m = 1200kg$

$F_{NET} \cdot t = m(v_f - v_i)$

$F_{NET} = \frac{m(v_f - v_i)}{t} = \frac{(1200kg)(0-60m/s)}{12s}$

$= \boxed{-6000N}$

* **Ex#3:** A 0.144 kg baseball is pitched horizontally at 38~~.0~~ m/s. After it is hit by a bat, it moves horizontally at -38 m/s.

a) What impulse did the baseball deliver to the ball?

$m = 0.144\,kg$

$v_i = +38\,m/s$

$v_f = -38\,m/s$

$\Delta p = ?$

$$\Delta p = m\Delta v$$
$$= m(v_f - v_i)$$
$$= (0.144\,kg)(-38\,m/s - 38\,m/s)$$
$$= (0.144\,kg)(-76\,m/s) = -10.9\,kg \cdot m/s = \boxed{-11\,N \cdot s}$$

b) If the bat and ball were in contact for 0.80 ms, what was the average force exerted on the ball?

$F_{NET} = ?$

$t = 0.80 \times 10^{-3}\,s$

$\Delta p = -10.9\,N \cdot s$

$$F_{NET} \cdot t = \Delta p$$
$$F_{NET} = \frac{\Delta p}{t} = \frac{-10.9\,N \cdot s}{0.80 \times 10^{-3}\,s} = -13680\,N$$
$$= \boxed{-1.4 \times 10^4\,N}$$

c) What is the average acceleration of the ball during its contact with the bat?

$F_{NET} = -13680\,N$

$m = 0.144\,kg$

$a = ?$

$$a = \frac{F_{NET}}{m}$$
$$= \frac{-13680\,N}{0.144\,kg}$$
$$= -95\,000\,m/s^2$$
$$= \boxed{-9.5 \times 10^4\,m/s^2}$$

Momentum

Concept Review:

1. Is the momentum of a car traveling south different from that of the same car moving north at the same speed? Explain.

   No - momentum is a vector ∴ different directions mean a different momentum.

2. If you jump off a table, as your feet hit the floor you let your legs bend at the knees. Explain why.

   $\Delta p = \underset{\downarrow}{F} \cdot \overset{\uparrow}{t}$

   Same change in momentum over a longer time interval means less force acting on your joints.

3. Which has more momentum: a supertanker tied at a dock or a falling raindrop? Explain. Raindrop → momentum is m × v. If an object (even if it's really massive!) is stationary, it has no momentum!

4. An archer shoots arrows at a target. Some of the arrows stick in the target while others bounce off. Assuming the mass and initial velocity are the same, which arrows give a bigger impulse to the target? (HINT: Consider the change of momentum of the arrow).

   The change in velocity is greater when the arrow bounces backwards. Since $\Delta p = m\Delta v$, if $\Delta v \uparrow$, then $\Delta p \uparrow$ and the impulse is larger!

Problems

1. A compact car, mass 725 kg, is moving at +100 km/h. ← assume 2 s.f.

   a. Find its momentum.

   $m = 725\,kg$

   $v = 100\,km/h \times \frac{1000\,m}{1\,km} \times \frac{1}{3600\,s} = 27.8\,m/s$

   $p = ?$

   $p = mv$

   $= (725\,kg)(+27.8\,m/s)$

   $= +20155\,kg \cdot m/s$

   $= \boxed{+2.0 \times 10^4\,kg \cdot m/s}$

   b. At what velocity is the momentum of a larger car, mass 2175 kg, equal to that of the smaller car?

   $p = +20155\,kg \cdot m/s$

   $m = 2175\,kg$

   $v = ?$

   $p = mv$

   $v = \frac{p}{m} = \frac{+20155\,kg \cdot m/s}{2175\,kg} = 9.267\,m/s$

   $9.267\,m/s \times \frac{1\,km}{1000\,m} \times \frac{3600\,s}{1\,h}$ $\boxed{33\,km/h}$

2. A snowmobile has a mass of 2.50×10^2 kg. A constant force is exerted on it for 60.0s. The snowmobile's initial velocity is 6.00 m/s and its final velocity is 28.0 m/s.

   a. What is its change in momentum?

$\Delta p = ?$
$m = 250\,kg$
$v_i = 6.00\,m/s$
$v_f = 28.0\,m/s$

$\Delta p = m\Delta v$
$= (250\,kg)(+28.0\,m/s - {}^{+}6.0\,m/s)$
$= +5500\,kg\cdot m/s$
$= \boxed{+5.50\times10^3\,kg\cdot m/s}$

   b. What is the magnitude of the force exerted on it?

$\Delta p = +5500\,kg\cdot m/s$
$t = 60.0\,s$
$F = ?$

$\Delta p = Ft$
$F = \frac{\Delta p}{t} = \frac{+5500\,kg\cdot m/s}{60.0\,s} = \boxed{+91.7\,N}$
3sf

3. The brakes exert a 6.40×10^2 N force on a car weighing 15680 N and moving at 20.0 m/s. The car finally stops.

   a. What is th car's mass?

$F_g = 15680\,N$
$g = 9.81\,N/kg$
$m = ?$

$m = \frac{F_g}{g} = \frac{15680\,N}{9.81\,N/kg} = 1598\,kg$
$= \boxed{1.60\times10^3\,kg}$
3 sf.

   b. What is its initial momentum?

$m = 1598\,kg$
$v_i = 20.0\,m/s$
$p_i = ?$

$p_i = mv_i$
$= (1598\,kg)(+20.0\,m/s)$
$= +31960\,kg\cdot m/s \approx \boxed{+3.20\times10^4\,kg\cdot m/s}$

   c. What is the change in the car's momentum?

$p_i = +31960\,kg\cdot m/s$
$p_f = 0\,kg\cdot m/s$ (rest)
$\Delta p = ?$

$\Delta p = p_f - p_i$
$= 0\,kg\cdot m/s - 31960\,kg\cdot m/s$
$= \boxed{-3.20\times10^4\,kg\cdot m/s}$

   d. How long does the braking force act on the cart to bring it to a halt?

$F = -6.40\times10^2\,N$
$\Delta p = -31960\,N\cdot s$
$t = ?$

$\Delta p = Ft$
$t = \frac{\Delta p}{F} = \frac{-31960\,N\cdot s}{-640\,N} = \boxed{49.9\,s}$

ANSWERS: 1a) 2×10^4kgm/s b) 33km/h 2a) 5.50×10^3kgm/s b) 91.7N 3a) 1.60×10^3kg b) 3.20×10^4 kgm/s c) -3.20×10^4 kgm/s d) ~~50.0s~~ 49.9s

Conservation of Momentum

The total momentum before any collision is the same as the total momentum after the collision. The momentum of the system is not changed, it is conserved.

$$P_A + P_B = P_A' + P_B' = P_T$$

Ex#1: A loaded 6000. kg railway car rolls at 2.0 m/s into an empty 3000. kg railway car. The empty car was moving at 3.0 m/s towards the loaded car.

a) Calculate the momentum of the loaded car.

$m_L = 6000\,kg$

$V_L = +2.0\,m/s$

$P_L = ?$

$$P_L = m_L V_L = (6000\,kg)(+2.0\,m/s) = \boxed{+12000\,kg\cdot m/s}$$

b) Calculate the momentum of the empty car.

$m_E = 3000\,kg$

$V_E = -3.0\,m/s$

$P_E = ?$

$$P_E = m_E V_E = (3000\,kg)(-3.0\,m/s) = \boxed{-9000\,kg\cdot m/s}$$

c) What is the total momentum of the system if both cars stick together when they collide?

$$P_T = P_L + P_E = +12000\,kg\cdot m/s + (-9000\,kg\cdot m/s) = \boxed{+3000\,kg\cdot m/s}$$

d) What is the velocity of the system?

$P_T = +3000\,kg\cdot m/s$

$m_T = 6000\,kg + 3000\,kg = 9000\,kg$

$V_T = ?$

$P_T = m_T V_T$

$$V_T = \frac{P_T}{m_T} = \frac{3000\,kg\cdot m/s}{9000\,kg} = \boxed{0.33\,m/s}$$

Ex#2: Sedin and Crosby are standing on the ice rink when they argue about a call. Crosby pushes Sedin and acquires a velocity of 3.0 m/s. If Sedin has a mass of 92 kg and Crosby has a mass of 87 kg, what is Sedin's velocity?

$$P_c + P_s = P_c' + P_s' \therefore P_c' + P_s' = 0$$

$$\boxed{\begin{array}{l} P_c = 0\,kg\cdot m/s\ (\text{stationary}) \\ P_s = 0\,kg\cdot m/s \end{array}}$$

$P_c' = -P_s'$

$m_c V_c' = m_s V_s'$

$$V_s' = \frac{m_c V_c'}{m_s} = \frac{(87\,kg)(+3.0\,m/s)}{92\,kg} = \boxed{-2.8\,m/s}$$

Conservation of Momentum Practice

* Ignore sig. figs. for this activity.

1. Ball A has a mass of 10 kg and Ball B has a mass of 5 kg. Ball A, travelling at +4 m/s collides with a stationary Ball B, bounces back with a velocity of -2m/s.
   a. What is Ball A's momentum before collision?

   $P_A = m_A V_A = (10\text{ Kg})(+4.0\text{ m/s}) = \boxed{+40\text{ Kg}\cdot\text{m/s}}$

   b. What is Ball B's momentum before collision?

   $P_B = m_B V_B = (5\text{ Kg})(0\text{ m/s}) = \boxed{0\text{ Kg}\cdot\text{m/s}}$

   c. What is the total momentum of Ball A and B before collision?

   $P_T = P_A + P_B = 40\text{ Kg}\cdot\text{m/s} + 0\text{ Kg}\cdot\text{m/s} = \boxed{+40\text{ Kg}\cdot\text{m/s}}$

   d. What is the Ball A's momentum after collision?

   $P_A' = m_A V_A' = (10\text{ Kg})(-2\text{ m/s}) = \boxed{-20\text{ Kg}\cdot\text{m/s}}$

   e. What should Ball B's momentum be after collision?

   $P_T = P_A' + P_B'$; $P_B' = P_T - P_A'$

   $= +40\text{ Kg}\cdot\text{m/s} - (-20\text{ Kg}\cdot\text{m/s}) = \boxed{+60\text{ Kg}\cdot\text{m/s}}$

   f. How fast will Ball B travel after the collision?

   $P_B' = m_B V_B'$; $V_B' = \frac{P_B'}{m_B} = \frac{+60\text{ Kg}\cdot\text{m/s}}{5\text{ Kg}} = \boxed{+12\text{ m/s}}$

2. Ball C has a mass of 10 kg and Ball D has a mass of 5 kg. Ball C is travelling at +6 m/s when it collides with a stationary Ball D. Both balls stick together after collision.
   a. What is the total momentum of Ball C and Ball D before collision?

   $P_T = P_C + P_D = m_C V_C + m_D V_D = (10\text{Kg})(+6\text{m/s}) + (5\text{Kg})(0\text{m/s}) = \boxed{+60\text{ Kg}\cdot\text{m/s}}$

   b. What would the total momentum of Ball C and D be after collision?

   $\boxed{P_T' = +60\text{ Kg}\cdot\text{m/s}}$

   c. What is the total mass of Balls C and D?

   $m_T = m_C + m_D = 10\text{Kg} + 5\text{Kg} = \boxed{15\text{ Kg}}$

   d. How fast will Balls C and D move after sticking together?

   $P_T' = m_T V_T'$ $\quad V_T' = \frac{P_T'}{m_T} = \frac{60\text{Kg}\cdot\text{m/s}}{15\text{Kg}} = \boxed{+4\text{ m/s}}$

3. Ball E has a mass of 10 kg and Ball F has a mass of 5 kg. Ball E is travelling at +4 m/s when it collides with Ball F, which is travelling towards it at -10 m/s. After collision, Ball E is travelling at -6 m/s. What is Ball F's velocity after collision?

$$P_E + P_F = P_E' + P_F'$$

$$m_E V_E + m_F V_F = m_E V_E' + m_F V_F'$$

$$(10kg)(+4m/s) + (5kg)(-10m/s) = (10kg)(-6m/s) + (5kg)(V_F')$$

$$40\,kg \cdot m/s + -50\,kg \cdot m/s = -60\,kg \cdot m/s + (5kg)V_F'$$

$$+10\,kg \cdot m/s = (5kg)V_F'$$

$$\boxed{V_F' = +2\,m/s}$$

4. Ball G has a mass of 10 kg and is travelling at +5 m/s. After colliding with a stationary Ball H, Ball G bounces back with a velocity of -3 m/s, while Ball H is pushed forward with a velocity of +4 m/s. What is the mass of Ball H?

$$P_G + P_H = P_G' + P_H'$$

$$m_G V_G + 0 = m_G V_G' + m_H V_H'$$

$$(10)(5) + 0 = (10)(-3) + (m_H)(+4)$$

$$50 + 0 = -30 + 4m_H$$

$$4m_H = 80 \quad m_H = \boxed{20\,kg}$$

5. Ball J is travelling at +5m/s when it collides with Ball K, which has a mass of 2 kg and is travelling at -3m/s. After collision, the two balls move off together at a speed of +1 m/s. What is the mass of Ball J?

BEFORE		AFTER	
m_J	2Kg	m_J	2Kg
$V_J = +5m/s$	$V_K = -3m/s$	$V_J' = +1m/s$	$V_K = +1m/s$
$P_J = (m_J)(5)$	$P_K = (2)(-3)$	$P_K' = m_J(1m/s)$	$P_K' = (2kg)(+1m/s)$
$= (5m_J)\,kg \cdot m/s$	$= (-6)\,kg \cdot m/s$	$= (+1m_J)\,kg \cdot m/s$	$= (2)\,kg \cdot m/s$

$$P_J + P_K = P_J' + P_K'$$

$$5m_J + -6 = +1m_J + 2$$

$$4m_J = 8 \; ; \; m_J = \boxed{2\,Kg}$$

Conservation of Momentum

Concept Review:

1. Two soccer players come from opposite directions. They leap in the air to try to hit the ball, but collide with each other instead, coming to rest in midair. What can you say about their original momentum?

$P_A' + P_B' = 0$ kg·m/s if both come to a stop

$\therefore$ since $P_T = 0$, $P_A + P_B = 0$ and $P_A = -P_B$.

The players had equal but opposite momentum.

2. During a tennis serve, momentum gained by the ball is lost by the racket. If momentum is conserved, why doesn't the racket's speed change much?

$$\Delta P = m \Delta v$$

$$m_{Racket} \Delta v_{racket} = -m_{Ball} \Delta V_{Ball}$$

The racket-arm system is much more massive than the ball & therefore Δv is much smaller

3. Someone throws a heavy ball to you when you are standing on a skateboard. You catch it and roll backward with the skateboard. Explain using momentum conservation.

The total momentum before collision is equal to the momentum of the ball (You have no momentum as you are still). Upon collision, the total momentum is shared between you and the ball, causing both you and the ball to move. As the total mass is large, velocity will be small.

Additional Problems:

1. A 0.105 kg hockey puck moving at 48 m/s is caught by a 75 kg goalie at rest. With what speed does the goalie slide on the ice?

Before Collision:

$= m_P V_P + m_G V_G$

$= (0.105 kg)(+48 m/s) + (75 kg)(0 m/s)$

$= +5.04$ kg·m/s

After collision:

$m_T = 75 kg + 0.105 kg$

$= 75.105 kg$

$V_T' = ?$

$P_T = +5.04$ kg·m/s

$P_T = m_T V_T'$

$V_T' = \frac{P_T}{m_T} = \frac{+5.04 \text{ kg·m/s}}{75.105 \text{ kg}} = \boxed{+0.067 \text{ m/s}}$

0.0350kg

2. A 35.0 g bullet strikes a 5.0 kg stationary wooden block and embeds itself in the block. The block and bullet fly off together at 8.6 m/s. What was the original velocity of the bullet?

stationary

$m_B = 0.0350\,kg$

$v_B = ?$

$m_w = 5.0\,kg$

$v_w = 0\,m/s$ $\Big\}\ P_w = 0$

$m_T = 5.035\,kg$

$v_T' = 8.6\,m/s$

$$P_B + \cancel{P_w} = P_T'$$

$$m_B v_B = m_T v_T'$$

$$v_B = \frac{m_T v_T'}{m_B} = \frac{(5.035\,kg)(8.6\,m/s)}{0.035\,kg}$$

$$= 1237\,m/s = \boxed{1.2\times10^3\,m/s}$$

3. A 35.0 g bullet moving at 475 m/s strikes a 2.5 kg wooden block. The bullet passes through the block, leaving at 275 m/s. The block was at rest when it was hit. How fast is it moving when the bullet leaves?

$m_B = 0.0350\,kg$

$v_B = 475\,m/s$

$m_w = 2.5\,kg$

$v_w = 0\,m/s$ $\Big\}\ P_w = 0\,kg\cdot m/s$

$v_B' = 275\,m/s$

$v_w' = ?$

$$P_B + P_w = P_B' + P_w'$$

$$m_B v_B + 0 = m_B v_B' + m_w v_w'$$

$$v_w = \frac{m_B v_B - m_B v_B'}{m_w}$$

$$= \frac{(0.0350\,kg)(475\,m/s) - (0.0350\,kg)(275\,m/s)}{2.5\,kg}$$

$$\boxed{= 2.8\,m/s}$$

4. A 0.50 kg ball traveling at 6.0 m/s collides head-on with a 1.00 kg ball moving in the opposite direction at a velocity of -12.0 m/s. The 0.50 kg ball moves away at -14 m/s after the collision. Find the velocity of the second ball.

$m_A = 0.50\,kg$

$v_A = 6.0\,m/s$

$m_B = 1.00\,kg$

$v_B = -12\,m/s$

$v_A' = -14\,m/s$

$v_B' = ?$

$$P_A + P_B = P_A' + P_B'$$

$$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$$

$$\therefore v_B' = \frac{m_A v_A + m_B v_B - m_A v_A'}{m_B}$$

$$= \frac{(0.50\,kg)(6.0\,m/s) + (1.00\,kg)(-12\,m/s) - (0.5\,kg)(-14\,m/s)}{1.00\,kg}$$

$$= \boxed{-2.0\,m/s}$$

ANSWERS: 1) 0.067m/s 2) 1.2×10^3m/s 3) 2.8m/s 4) -2.0m/s

DYNAMICS REVIEW

1. Which of Newton's laws best explains why motorists should buckle up?
   - [✓ a.] The first law
   - b. The second law
   - c. The third Law
   - d. The law of gravitation

Object in motion wants to stay in motion!

2. When you sit on a chair, the net force on you is…
   - a. Down
   - b. Up
   - [✓ c.] Zero
   - d. Dependent on your weight

(No movement = Balanced forces)

3. In the absence of an external force, a moving object will…
   - [✓ a.] Move with constant velocity
   - b. Slow down and eventually come to a stop
   - c. Go faster and faster
   - d. Stop immediately

(Inertia)

4. You are standing in a moving bus, facing forward, and you suddenly fall forward. You can infer from this that the bus's…
   - a. Speed remained the same, but it is turning to the right
   - b. Velocity increased
   - [✓ c.] Velocity decreased
   - d. Speed remained the same, but it is turning to the left

Inertia → your body wants to keep going at same speed

5. A constant net force acts on an object. Describe the motion of the object.
   - a. Increasing acceleration
   - b. Constant velocity
   - [✓ c.] Constant acceleration
   - d. Constant speed

(Assuming constant ≠ 0 N)

6. If you blow up a balloon and then release it, the balloon will fly away. This is an illustration of…
   - a. Newton's first law
   - b. Newton's second law
   - c. Galileo's law of inertia
   - [✓ d.] Newton's third law

Balloon pushes air out backwards, air pushes forward on balloon resulting in a forward net force on the balloon

7. A 20-ton truck collides with a 1000 kg car and causes a lot of damage to the car. In this situation,
   - [✓ a.] The force of the truck is equal to the force on the car. (Newton's 3rd Law)
   - b. The truck did not slow down during the collision.
   - c. The force on the truck is greater than the force on the car.
   - d. The force on the truck is smaller than the force on the car.

8. An object of mass m sits on a flat table. The earth pulls on this object with force mg which we will call the action force. What is the reaction force?
   - [✓ a.] The table pushing up on the object with force mg.
   - b. The table pushing down on the object with force mg.
   - c. The object pushing down on the table with force mg.
   - [✓ d.] The object pushing upward on the Earth with force mg.

Not a good question. (table pushes up on object, table + rock pull upwards on Earth)

9. Mass and weight...
   - a. Both measure the same thing.
   - b. Are exactly equal.
   - c. Are both measured in kilograms.
   - [✓ d.] Are two different quantities.

10. The acceleration due to gravity is lower on the Moon than on Earth. Which of the following is true about the mass and weight of an astronaut on the Moon's surface, relative to the Earth?
   - a. Mass is less, weight is the same. Mass is the same everywhere!
   - b. Both mass and weight are the same.
   - c. Both mass and weight are less.
   - [✓ d.] Mass is the same, weight is less.

11. A stone is thrown straight up. T the top of its path, the net force acting on it is...
   - a. Greater than zero, but less than its weight.
   - b. Greater than its weight.
   - [✓ c.] Equal to its weight.
   - d. Instantaneously equal to zero.

Once released from your hand, the only force acting on it is gravity.

12. An object of mass m is hanging by a string from the ceiling of an elevator. The elevator is amoving up at a constant speed. What is the tension on the string?
   - [✓ a.] Exactly mg. ↳ Balanced forces
   - b. Less than mg.
   - c. Greater than mg.
   - d. Always acting on different objects.

ANSWERS: 1a, 2c, 3a, 4c, 5c, 6d, 7a, 8d, 9d, 10d, 11c, 12a

13. Calculate the net force and acceleration for the following cases. Include free body diagrams in your answer.

a. A 0.65 kg ball that has been thrown up from the ground is at its maximum height.

$F_g = mg = (0.65 kg)(-9.81 N/kg)$

$= \boxed{-6.4 N (down)}$ 2sf ; $a = \boxed{-9.8 m/s^2}$ 2sf (In Freefall)

-6.4N, -9.8m/s²

b. A 2 kg book sitting on a table.

Stationary ∴ $F_{NET} = 0 N$

$a = 0 m/s^2$

0N, 0 m/s²

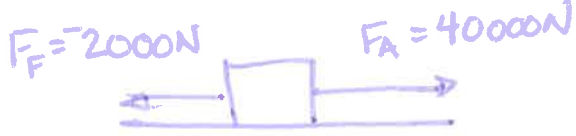
c. A 2 kg book on a frictionless table that is being pulled to the right by a horizontal force of 100 N.

$F_{NET} = |F_A| - |F_F| = 100N - 0N = \boxed{100N (forward)}$ 1sf.

$a = \frac{F_{NET}}{m} = \frac{100N}{2kg} = \boxed{50 m/s^2}$ 1sf

100N, 50m/s²

d. A 747 jumbo jet of mass 30 000 kg on the runway when the thrust from the engines is 40 000 N and the air resistance force is 2000 N.



$F_{NET} = |F_A| - |F_F|$

$= 40000N - 2000N$

$= 38000N$

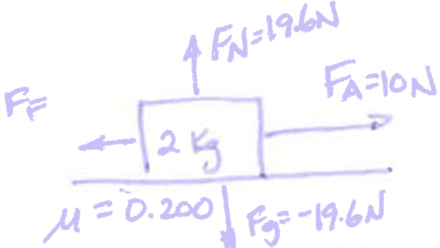
$= \boxed{40 000N (1sf)}$

$a = \frac{F_{NET}}{m} = \frac{38000N}{30000kg}$

$= \boxed{+1.3 m/s^2}$

38000N, 1.3m/s²

e. A 2 kg book that is being pulled with a force of 10 N on a table with a coefficient of friction of 0.200.



$F_g = mg$

$= (2kg)(9.81 N/kg)$

$= 19.6N$

$F_N = -19.6N$

$F_F = \mu F_N$

$= (0.200)(19.6N)$

$= -3.9N$

$F_{NET} = |F_A| - |F_F|$

$= 10N - 3.9N = \boxed{6.1N}$

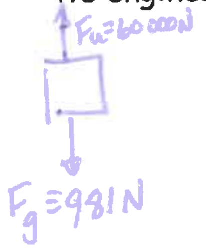
$a = \frac{F_{NET}}{m} = \frac{6.1N}{2kg}$

$= \boxed{3.05 m/s^2}$

6.08N, 3.04 m/s²

6.1N, 3.05 m/s²

f. A 100 kg rocket that is moving straight up with a thrust force of 60 000 N from its engines.



$F_g = mg$

$= (100kg)(9.81 N/kg)$

$= 981N$

$F_{NET} = |F_u| - |F_g|$

$= 60000N - 981N$

$= \boxed{+59 000 N}$

$a = \frac{F_{NET}}{m} = \frac{(59000N)}{100 kg}$

$= \boxed{590 m/s^2}$

59000N, 590m/s²

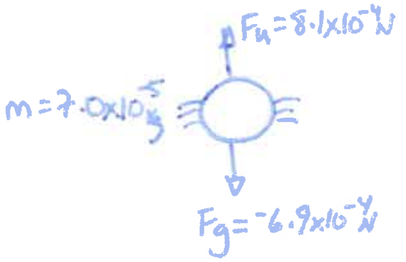
14. When a shot-putter exerts a net force of 140 N on a shot, the shot has an acceleration of 19 m/s². Draw a free body diagram of the shot, and calculate its mass (ignore air resistance).

$F_{NET} = 140N$
$a = 19 m/s^2$
$m = ?$

$m = \frac{F_{NET}}{a}$
$= \frac{140N}{19 m/s^2}$
$= \boxed{7.4 kg}$ 2s.f.

7.4kg

15. Imagine a spider with mass 7.0 x 10^{-5} kg moving downward on its thread. The thread exerts a force that results in a net upward force on the spider of 1.2 x 10^{-4} N. Draw a free body diagram of the spider and find its acceleration.



$F_{NET} = +1.2x10^{-4}N$

$F_g = mg$
$= (7.0x10^{-5} kg)(9.81 N/kg)$
$= -6.87x10^{-4}N$

$F_{NET} = |F_u| - |F_g|$
$|F_u| = F_{NET} + |F_g|$
$= 1.2x10^{-4}N + 6.87x10^{-4}N$
$= 8.1x10^{-4}N$

$a = \frac{F_{NET}}{m} = \frac{+1.2x10^{-4}N}{7.0x10^{-5}kg} = \boxed{+1.7 m/s^2}$ 2s.f.

1.7m/s^2

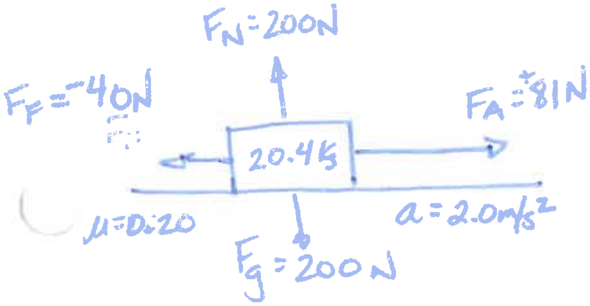
16. Together a motorbike and rider have a mass of 275 kg . The motorbike is slowed down with an acceleration of -450 m/s². What is the net force on the motorbike? Illustrate the forces acting on the bike in a diagram. Describe the direction of this force and the meaning of the negative sign.

$a = -450 m/s^2$
$m = 275 kg$
$F_{NET} = ?$

$F_{NET} = ma$
$= (275kg)(-450 m/s^2)$
$= -123750N$
$= \boxed{-1.2x10^5N}$ 2s.f.

-1.2x10^{5}N

17. A cardboard carton weighing 200 N is resting on a marble floor. If the coefficient of friction between the cardboard and the smooth marble is 0.20, how much force would it take to accelerate the box at a rate of 2.0 m/s²? Draw a free body diagram showing the forces acting on the box. Include an arrow showing the direction of acceleration.



$F_F = \mu F_N$
$= (0.20)(200N)$
$= 40N$

$m = \frac{F_g}{g} = \frac{200N}{9.81 N/kg}$
$= 20.4kg$

$F_{NET} = ma$
$= (20.4kg)(2.0 m/s^2)$
$= 40.8N$

$F_{NET} = |F_A| - |F_F|$
$|F_A| = F_{NET} + F_F$
$= 40.8N + 40N$
$= \boxed{80.8N} \approx \boxed{+81N}$

80.4N 81N

Momentum Review

1. In the case of a heavy truck at rest and a skateboarder rolling,
    a) Which has the greater mass? truck
    b) Which has the greater momentum? skateboarder

2. When the average force of impact on a object is extended in time, how does this change the impulse?

   $\Delta \overset{\uparrow}{p} = F \cdot \overset{\uparrow}{t}$ If $t\uparrow$, $\Delta p\uparrow$

3. When you ride a bicycle at full speed, which has the greater momentum - you or the bike? Explain why you go over the handlebars if the bike is brought to an abrupt halt. You do → greater mass = more momentum.

   You tend to keep moving forward due to inertia

4. You can't throw a raw egg against a wall without breaking it, but you can throw it with the same speed into a sagging sheet without breaking it. Explain.

   Same Δp, but when the egg hits the sheet, the time of impulse increases. $\Delta p = \underset{\downarrow}{F} \cdot t\uparrow$ If $t\uparrow$, $F\downarrow$ on egg.

5. If you throw a heavy rock from your hands while standing on a skateboard, you roll backwards. Would you roll backwards if you didn't actually throw the rock but went through the motions of doing so? Explain.

   No - until the rock is released, there is no change in momentum, so no impulse to cause motion.

6. A bug and the windshield of a fast-moving car collide. Explain whether the following statements are true or false.
    a) The forces of impact on the bug and the car are the same magnitude.

       True

    b) The impulse on the bug and the car are the same size.

       True

    c) The changes in speed of the bug and the car are the same.

       False

    d) The changes in momentum of the bug and the car are the same size.

       True

1. A fullback of mass 120 kg travelling at 20.0 m/s collides with another player and comes to rest in 1.5 s. What was the force of the impact?

$F = ?$ $v_i = 20.0\ m/s$ $Ft = m\Delta v$

$t = 1.5 s$ $v_f = 0\ m/s$

$m = 120\ kg.$

$$F = \frac{m(v_f - v_i)}{t} = \frac{(120\ kg)(-20.0\ m/s - 0\ m/s)}{1.5 s} = \boxed{-1600 N}$$

2sf

(-1600 N)

2. A golf ball of mass 0.050 kg acquires a speed of 80.0 m/s when hit with a force of 3.0×10^3 N. How long was the club in contact with the ball?

$m = 0.050\ kg$

$v_i = 0\ m/s$

$v_f = 80.0\ m/s$

$F = 3.0 \times 10^3 N$

$$Ft = m(v_f - v_i)$$

$$t = \frac{m(v_f - v_i)}{F} = \frac{(0.050\ kg)(80.0\ m/s - 0\ m/s)}{3.0 \times 10^3 N} = \boxed{0.0013 s}$$

2sf

(0.0013 s)

3. A 65 kg ice skater travelling at 6.0 m/s runs head-on into an 85 kg skater travelling in the same direction at 4.5 m/s. At what speed and in what direction do the ice skaters travel if the move together after the collision?

$m_A = 65\ kg$

$v_A = +6.0\ m/s$

$m_B = 85\ kg$

$v_B = +4.5\ m/s$

$$P_T = P_A + P_B$$
$$= m_A v_A + m_B v_B$$
$$= (65\ kg)(6.0\ m/s) + (85\ kg)(4.5\ m/s)$$
$$= 772.5\ kg \cdot m/s$$

$P_T = 772.5\ kg \cdot m/s$

$m_T = 65 + 85 = 150\ kg$

$v_T = ?$

$$v_T = \frac{P_T}{m_T} = \frac{772.5\ kg \cdot m/s}{150\ kg} \boxed{5.2\ m/s}$$

(5.2 m/s)

4. A 4.0 kg object travelling westward at 25 m/s hits a 15 kg object at rest. The 4.0 kg object bounces eastward at 8.0 m/s. What is the speed and direction of the 15 kg object?

$m_A = 4.0\ kg$ $m_B = 15\ kg$

$v_A = -25\ m/s$ $v_B = 0\ m/s$

$v_A' = +8.0\ m/s$ $v_B' = ?$

$$P_A + \cancel{P_B}^{0} = P_A + P_B'$$
$$m_A v_A = m_A v_A' + m_B v_B'$$
$$v_B' = \frac{m_A v_A - m_A v_A'}{m_B} = \frac{(4.0\ kg)(-25\ m/s) - (4.0\ kg)(+8.0\ m/s)}{15\ kg} = \boxed{-8.8\ m/s}$$

(+8.8 m/s)

5. A bullet of mass 0.065 kg is fired from a 4.0 kg gun with a speed of 5.0×10^2 m/s. What is the recoil velocity of the gun?

$m_B = 0.065\ kg$ $m_G = 4.0\ kg$

$v_B = 0\ m/s$ $v_G = 0\ m/s$

$v_B' = 500\ m/s$ $v_G' = ?$

$$P_B + P_G = P_B' + P_G'$$
$$0 + 0 = P_B' + P_G'$$
$$P_B' = -P_G' \rightarrow m_B v_B' = -m_G v_G'$$
$$\rightarrow v_G' = \frac{-m_B v_B'}{m_G} = \frac{(0.065\ kg)(500\ m/s)}{4.0\ kg}$$

$=$ (8.1 m/s)

6. A 62 kg child is sitting on a wagon full of bricks that has a mass of 150 kg. In order to move the wagon without touching the ground, the child throws two bricks each of mass 3.0 kg in the direction opposite to the direction the wagon is to go. How fast will the wagon move if the bricks are thrown at 2.0 m/s?

Initial total $p = 0\ kg \cdot m/s$

$$\therefore P_B' + P_w' = 0$$
$$P_B' = -P_w'$$
$$m_B v_B' = -m_w v_w'$$

$m_B = 6\ kg$

$m_w = 206\ kg$

$v_B' = 2.0\ m/s$

$v_w' = ?$

$$v_w' = \frac{-m_B v_B'}{m_w} = \frac{(6.0\ kg)(2.0\ m/s)}{206\ kg} = \boxed{-0.058\ m/s}$$

(0.058 m/s)

Chapter 5 – Vectors and Projectile Motion

Scalar Quantities - express only magnitude

ie. time, distance, speed

Vector Quantities - express magnitude and direction.

ie.	velocity	80 km/h, 58°
	displacement	10 km (E)
	acceleration	4.0 m/s^2, 27°
	force	100 N, 110°

- represented by an arrow. 
- length of arrow indicates magnitude(drawn to scale), arrowhead indicates direction.

Graphical Analysis of Vectors

1. Add vectors by placing the tail of one vector at the head of the other vector.
2. A third vector is drawn connecting the tail of the first vector with the tip of the last vector. This vector, the resultant, represents the sum of the vectors.
3. Order of addition does not matter.

Vector Addition in 1 Dimension

Ex.1 A = 8.0 m, E
B = 6.0 m, E

Ex 2. A = 8.0 m, E
B = 6.0 m, W

Ex.3 A = 8.0 m, W
B = 6.0 m, E