SPEED, VELOCITY AND ACCELERATION

Before we start, we need a quick reflection on how to change kmh^{-1} to ms^{-1} and back again.

kmh^{-1} to ms^{-1} divide by 3.6
ms^{-1} to kmh^{-1} multiply by 3.6 Easy isn't it!

SPEED:
Consider again your run across the park. As you exercised, your distance from where you started is changing and the rate at which your distance changes is your speed. The **instantaneous** speed tells us how fast we are going at a particular instance in time, not much use if you are describing a total journey. Your **average** speed can be considered as your total distance travelled divided by the total time taken and this will give you your average speed for a journey.

Definition: The rate of change of distance OR Distance travelled divided by time taken

Units: metres per second (ms^{-1}) Symbol: speed.

Example:
While exercising vigorously, it took you 12 minutes to run 4.0 km, what was your average speed.

distance = 4 000 m
time, t = 12 x 60
t = 720 s

$$\text{speed (ave)} = \frac{\text{distance}}{t} = \frac{4000}{720}$$

speed (ave) = 5.6 ms^{-1}

Unfortunately, that is all we can tell about the speed. For more information we need velocity as that is a vector quantity and will give us not only a magnitude but also a direction.

VELOCITY

Let's return to your run across the park. While your average speed will tell you how fast, on average, you were travelling, your velocity will tell you the rate at which your displacement changes and in what direction.

AVERAGE VELOCITY:
This is your total displacement (where you started to where you finished) divided by the time it took. Average velocity explains why your exercising in the park produced a zero velocity as your displacement was zero.

Definition: The rate of change of displacement OR Displacement divided by time taken

Units: metres per second (ms^{-1}) Symbol: v_{av} for velocity; u for initial velocity and v for final velocity

Example: You are running across the park from the east towards the west. You have run the first kilometre towards the west then have returned 0.50 km east. If that part of the run took 4.5 minutes, what was your average velocity for that part of the run?

Displacement = 1000 m W ← ; 500 m E → ; s = 500 m W

s = 500 m W
t = 4.5 minutes
t = 4.5 x 60
t = 270 s

$$v_{av} = \frac{s}{t} = \frac{500}{270}$$

v_{av} = 1.9 ms^{-1} west

It is important to distinguish between instantaneous velocity and average velocity. If you pass a speed camera, it is measuring your **instantaneous** velocity, or your velocity at that moment; the police are not interested in the fact that your **average** velocity for the total journey was below the speed limit, they are measuring if, at a particular instance in time, you are travelling above the speed limit.

Finally, another way to look at average velocity is to add two known velocities together and divide by 2 as shown on the right.

$$v_{av} = \frac{v+u}{2}$$

Example: During your run you travel 30 m at 4.6 ms^{-1} east then for 20 m you travel at 6.5 ms^{-1} east, what was your average velocity over this displacement?

$$v_{av} = \frac{v+u}{2} = \frac{6.5+4.6}{2} = \frac{11.1}{2}$$

v_{av} = 5.6 ms^{-1} East

ACCELERATION

During your exercise session, your instantaneous velocity at any one point can be different to your instantaneous velocity at another point, so during your run you must have been accelerating and decelerating (which is also negative acceleration).

Acceleration describes the rate of change of velocity. Acceleration is also a vector quantity, so direction must also be considered. For year 11 Physics we will focus on acceleration in one dimension only.

Definition: The rate of change of velocity. OR Change in velocity divided by time

Units: metres per second squared (ms^{-2}) Symbol: a

$$a = \frac{(v - u)}{t}$$

where:
a = acceleration (ms^{-2})
u = initial velocity (ms^{-1})
v = final velocity (ms^{-1})
t = seconds (s)

also $v = u + at$ as an alternative formula.

NOTE: Positive acceleration is going faster, negative acceleration is slowing down.

Example:

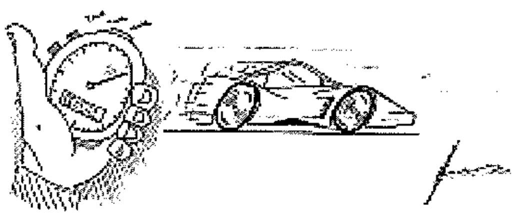
The official method to find a car's acceleration is to find out how quickly it can obtain 60.0 miles per hour from a standing start. Currently, the world's fastest accelerating car is a Barabus TKR which can go from a shimmering standstill to 60.0 miles per hour (96.56 kmh^{-1}) in only 1.67 seconds. Calculate the car's acceleration.

u = 0 ms^{-1}
v = 96.56 kmh^{-1}
= 26.82 ms^{-1}
t = 1.67 s

$$a = \frac{(v - u)}{t}$$

$$\mathbf{a = \frac{(26.82 - 0)}{1.67}}$$

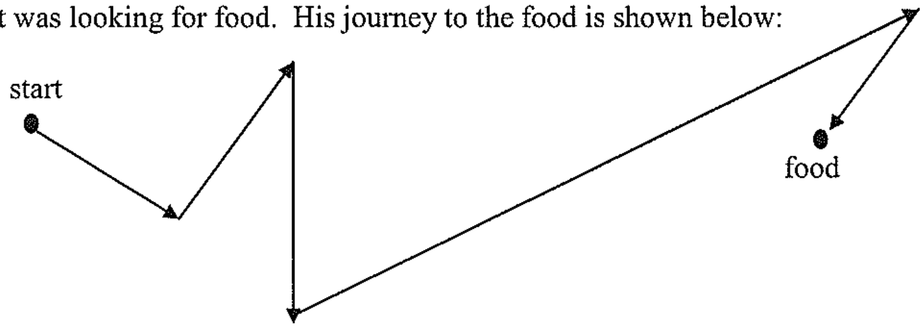
a = 16.1 ms^{-2}



NOTE: For all you Top Gear fans, the fastest street legal production car is of course the Bugatti Veyron (£850,000) which, with its 1001 hp and 10 radiators, can reach a staggering 408.47 kmh^{-1} (about 253 mph) which is faster than the fastest formula one car (around 230 mph) although not the fastest speed travelled in a car (specially designed rocket cars) which was around 320 mph. Also remember that as James May points out, "the tyres will only last for about fifteen minutes, but it's OK because the fuel runs out in twelve."

Distance, Displacement, Speed, Velocity and Acceleration

1. Edgar Ant was looking for food. His journey to the food is shown below:

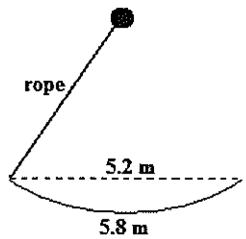


   a. Measure the distances and determine what distance Edgar travelled. ___________________

   b. Now measure Edgar's displacement. ________________________________

2. Elma is hunting rabbits! Elma sees Bugs in the woods in front of him but to get to Bugs, Elma must travel 15.0 m west then 7.00 m south around the lake. By the time he gets there, Bugs has gone! If Elma had simply fired his gun at Bugs, what would the bullet's displacement have been?

3. Young Billy is swinging on a rope from one platform to another. The platforms are 5.20 m apart but Billy travels 5.80 m as shown. If it took 2.60 s to swing to the second platform,



   a. at what speed did Billy travel at?

   b. what was Billy's velocity?

4. Before speed cameras were used to catch speeders, motorists were picked up when they drove over two cables placed 2.70 m apart on the road. One motorist, in a 50.0 kmh^{-1} zone, took 0.180 s to pass between the two cables. Was he speeding?

5. Dill, Tommy's little brother, is following Tommy around the back yard. For one particular part of the journey, Dill crawls 3.60 m south then 4.10 m east. If this took 9.80 s,
   a. what was Dill's speed?

   b. what was Dill's velocity?

6. Leela (my Norwegian Elkhound) is walking along at 1.90 ms^{-1} when she sees the neighbour's sheep wandering in our yard. She immediately takes off at a run (obviously to herd them back home) at 6.30 ms^{-1} in the same direction. If the change in velocity took place in 0.900 s, what was Leela's acceleration?

7. Minnie Mouse is walking along at 1.40 ms^{-1} when she looks around and sees Tom the cat sneaking up behind her. If she accelerates at 2.90 ms^{-2} for 2.40 s, what is her final velocity?

8. Freddy Frog hops along at 0.60 ms^{-1} he accelerates at 1.70 ms^{-2} to reach a final velocity of 1.40 ms^{-1}. How long did it take to reach his final velocity?

9. This morning Fern, my ginger cat, walks into the house with a mouse in her mouth. Fern is then frightened by Kira (remember my German Shepherd), so drops the mouse which immediately takes off with an acceleration of 0.80 ms^{-2} to reach a velocity of 1.60 ms^{-1} in 0.340 s. Assuming that the mouse had an initial velocity equal to that of Fern (well it was in her mouth!) and that the whole journey was in a straight line, what was the initial velocity of the mouse?