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Newton's Laws & viscosity

Dr Michael Adeleye
Dr Poulton
Mr Sean Moore

Learning Objective :

1. Recap of Newton's Laws of Motions and to connect viscosity to them.
2. To further explore terminal velocity.
3. Consider factors affecting terminal velocity.
4. Drag Force & Stoke's Equation/Law

Newton's First Law

"A body continues to maintain its state of rest or of uniform motion unless acted upon by an external unbalanced force."

For an object to change: speed, direction or shape there must be a resultant unbalanced force.

No unbalanced force : things stay as they are.

Newton's Second Law

"F = ma: the net force on an object is equal to the mass of the object multiplied by its acceleration."

Newton's Third Law

"To every action there is an equal and opposite reaction."

If object A exerts a force F on object B, then object B also exerts a force, (of the same magnitude but opposite direction) on A

Normal Reaction (Support forces)

Review of Terminal Velocity

When an object is moving through a fluid (gas or liquid), the object experiences drag.

The size of this drag is related to the speed of the object. If the object is accelerating, eventually the size of the drag will equal the size of the force causing the acceleration.

The object will no longer accelerate, a constant velocity will have been reached.

We call this the "terminal velocity"

Factors Affecting Terminal Velocity

Factors affecting terminal velocity

The shape:

More streamlined-> higher terminal velocity

The Viscosity of the fluid:

The thicker, (more viscous) the fluid the lower the terminal velocity

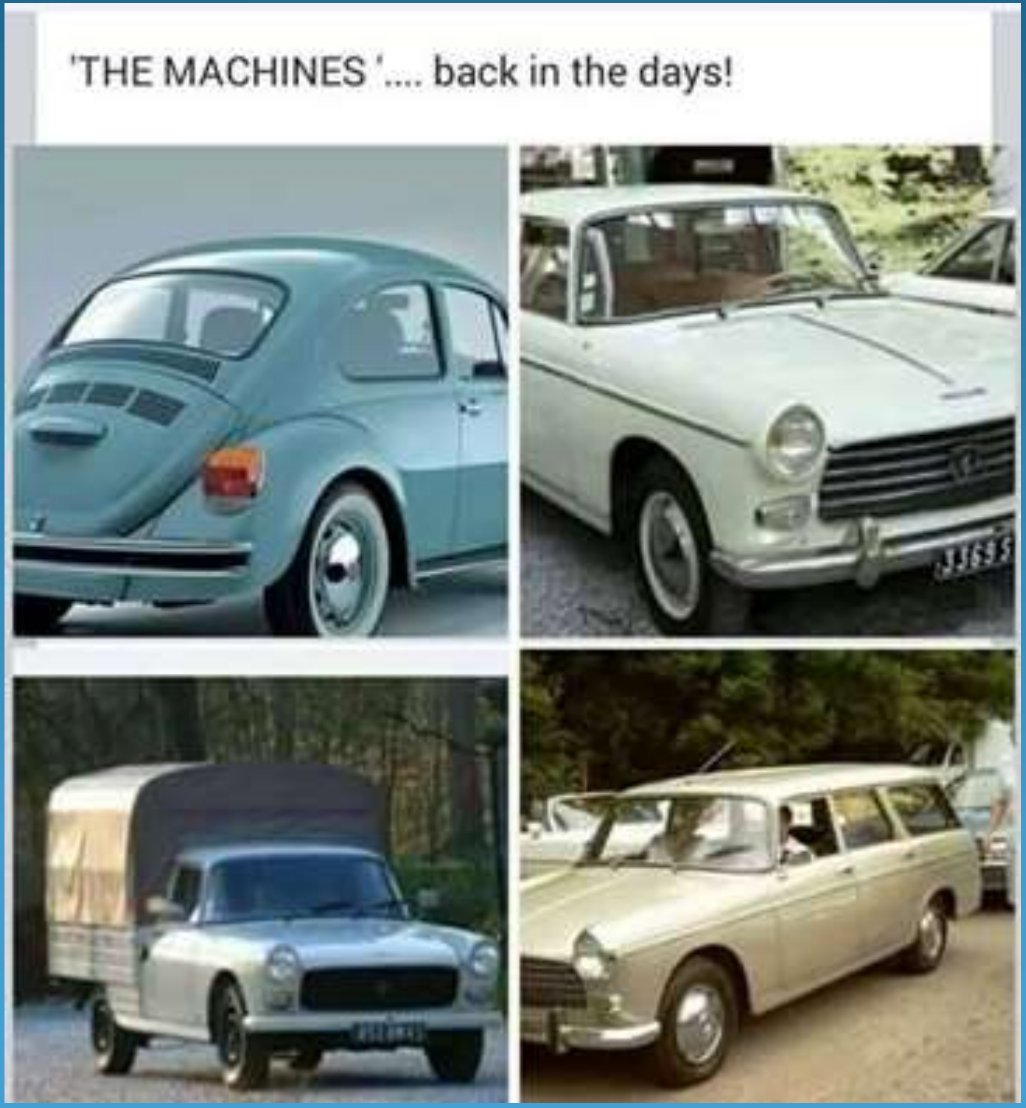
Terminal Velocity & Car Design

The top speed of a vehicle is governed by its terminal velocity.

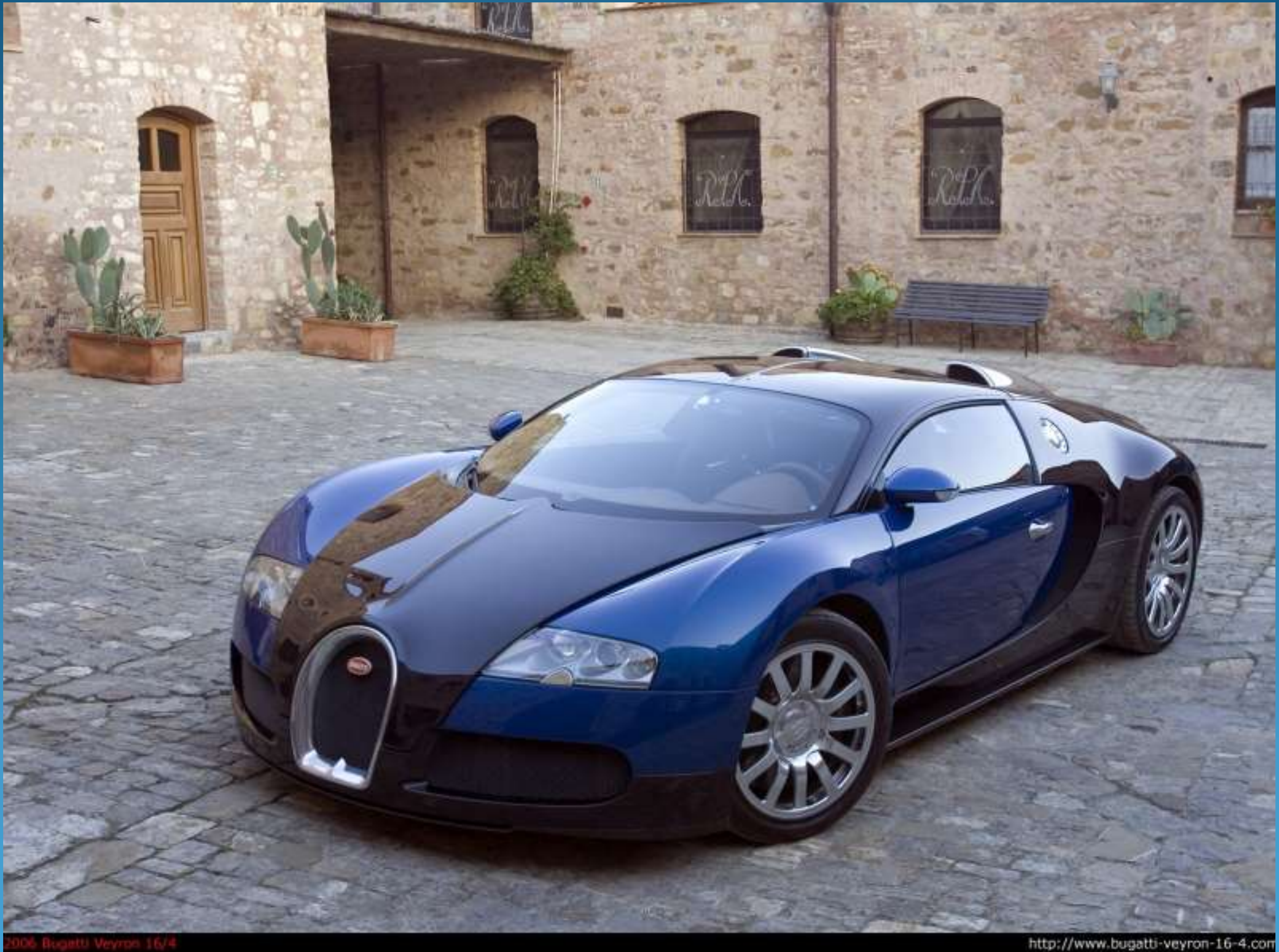
<u>For a given power of engine, a streamlined car will have a higher top speed than a non-streamlined one</u>.

At the top end of the speed range, the engine must produce increasing large amounts of power for relatively small gains in top speed.

The "Machines" back in the 60s and 70s!



Very streamlined car



Formula 1 Racing car

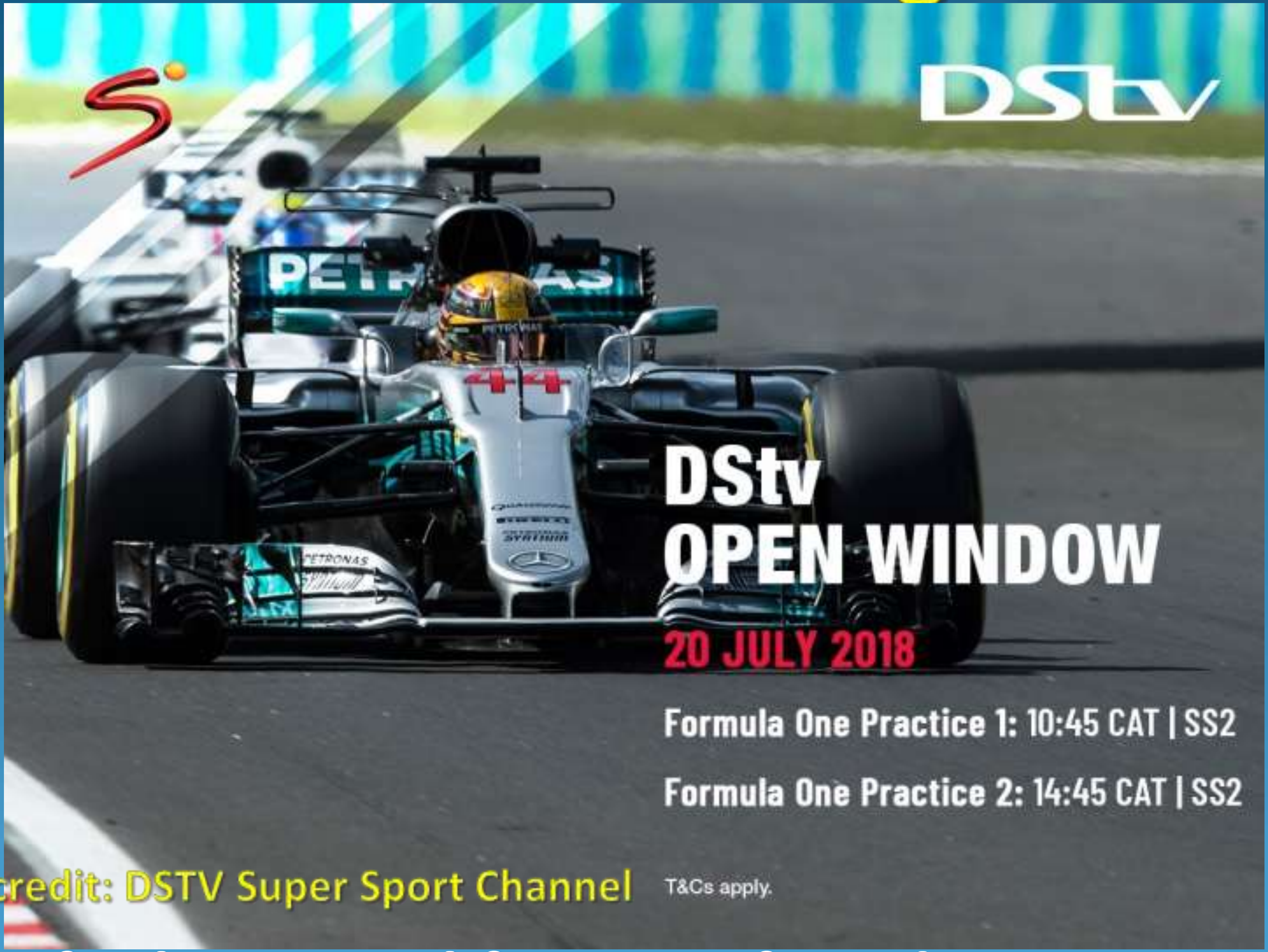


Photo credit: DSTV Super Sport Channel

Identify the special features for adaptation to attain very high speed.

Top speed of some cars …

Bugatti Veyron (2004) 252.2 MPH, 1001 BHP

Koenigsegg CCX (2006) 250 MPH, 900 BHP

Saleen S7 (2005) 248 MPH, 750 BHP

McLaren F1 (1994) 240.14 MPH, 620 BHP

Ferrari Enzo (2002) 217 MPH, 657 BHP

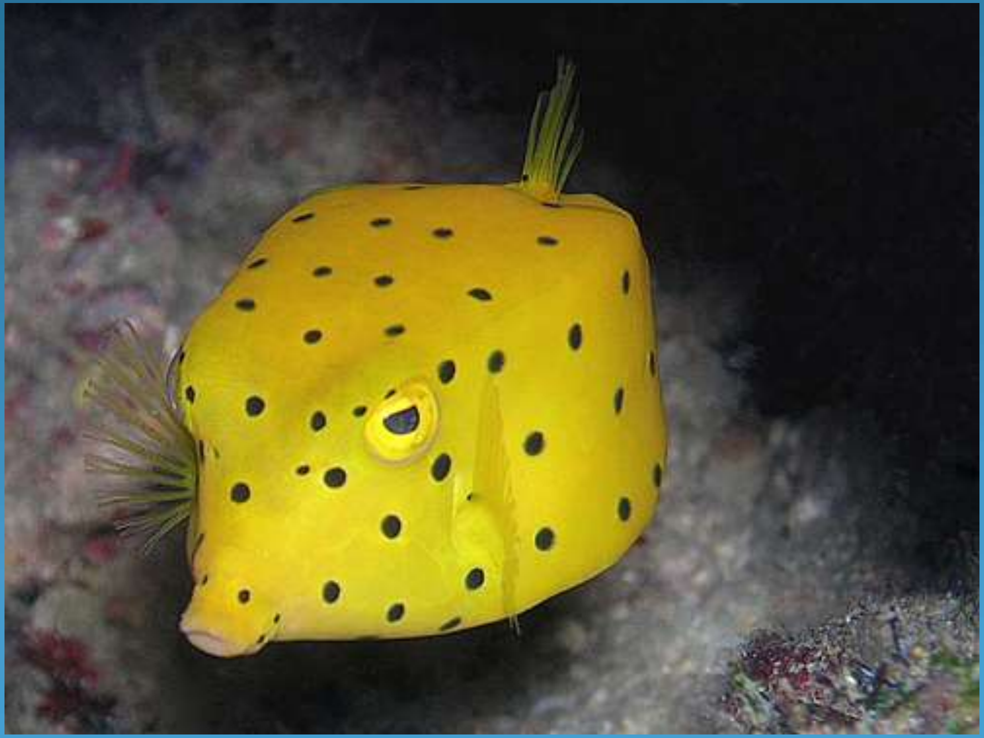
Jaguar XJ220 (1992) 217 MPH, 549 BHP

Pagani Zonda F (1999) 215 MPH, 602 BHP

Lamborghini Murcielago (2003) 213 MPH, 633 BHP

But it's not only top speed....

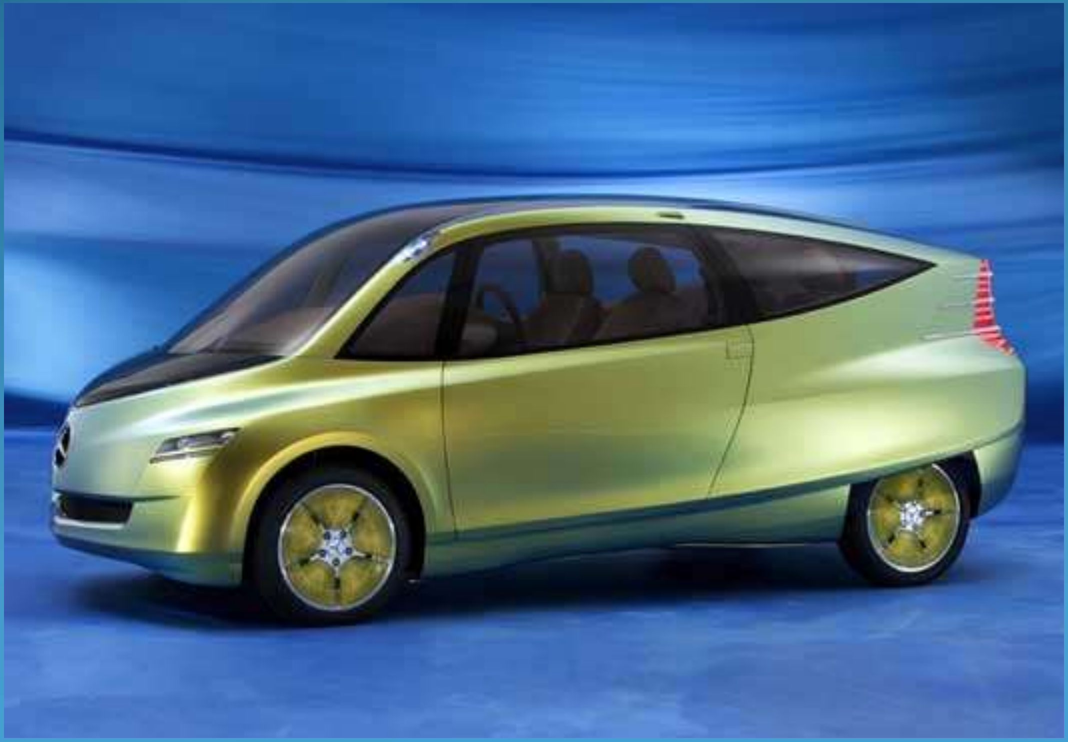
When I'm cruising at a constant speed of 70mph down the motorway... I'm not accelerating so why do I even need to have the engine switched on?



A yellow boxfish

Fuel Efficiency....

At a constant speed on level ground, the power produced by the engine is only working against resistance... Air resistance and friction from the tyres.



Mercedes Bionic

(Concept Car)

Around 70 mpg

(miles per gallon)

Drag Force & Streamlining

Drag force - A force opposing the motion of an object due to fluid (e.g. air) flowing past the object as it moves.

Streamline - design or build something with a smooth shape so that it moves with minimum resistance through fluid (e.g. air or water).

Drag Force & Stoke's Equation/Law

Objects moving through a fluid experiences a drag force due to the viscosity of the fluid and also, at high speeds, to turbulence behind the object.

The viscous (drag) force F_D is directly proportional to the speed v of the object.

$$F_D = kv$$

Drag Force & Stoke's Equation/Law

<u>The magnitude of the constant k depends on the size and shape of the object and on the viscosity ή of the fluid</u>. For a sphere of radius r, k has been calculated to be

$$k = 6\pi r\eta \text{ (Sphere)}$$

Therefore the drag force on a small sphere, when the flow is laminar, is given by an equation known as Stoke's equation

$$F_D = kv = 6\pi r\eta v \text{ (Sphere)}$$

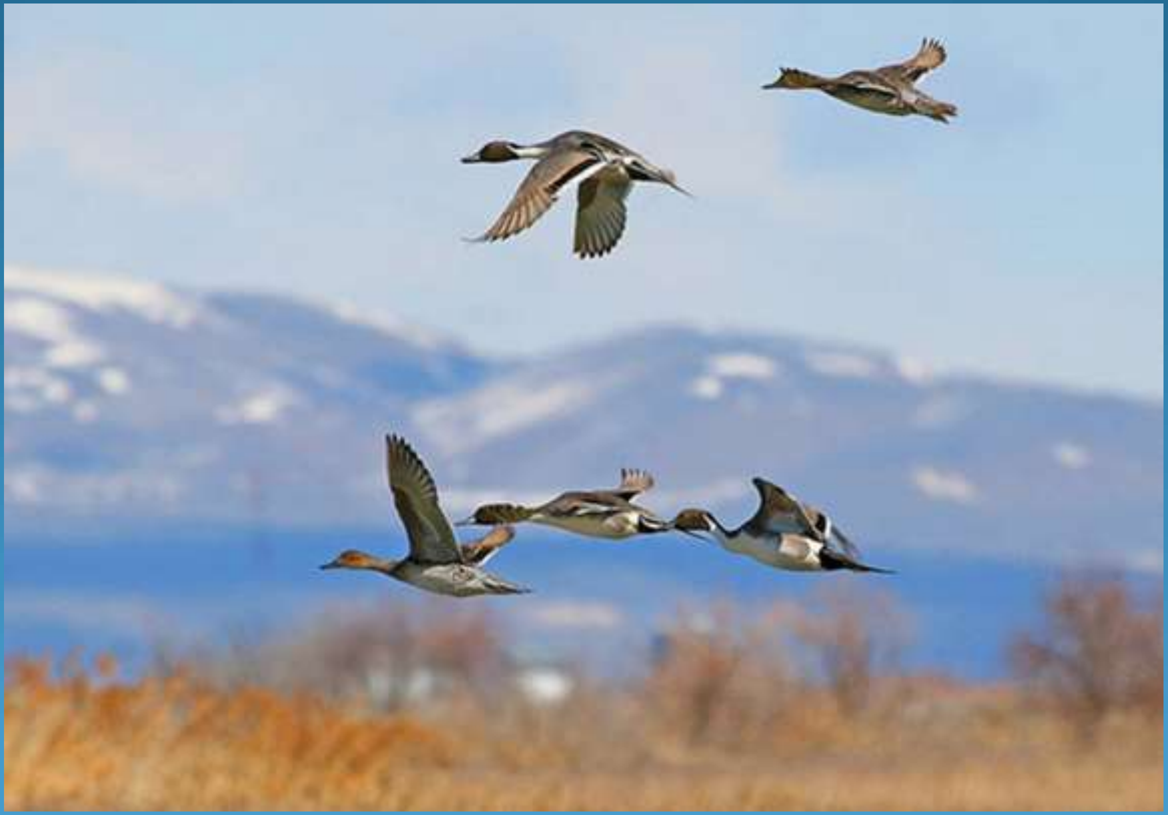
Recap

So fluid friction also known as drag depends on:

- how thick the fluid is (its "viscosity")
- the shape of the object
- the speed of the object

Recap Streamlined shape

Recap Streamlined shape



Northern pintails in flight Credit: J. Kelly/USFWS

Recap

Streamlined shape - design to minimize total surface area so that bodies (such as cars, boats & airplanes) moves with minimum resistance through fluid (air or water)

Aircraft and car designers want to reduce drag, so that the vehicle can go fast without having to waste too much fuel.


Any
questions?

References

Dr Poulton and Mr Moore
Ranelagh A level Physics Wikispace