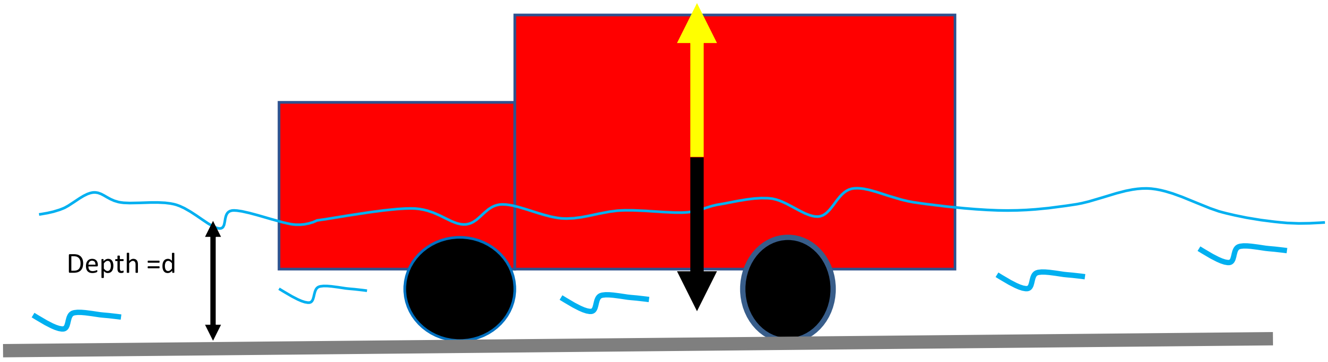
What depth of water is needed to float your car?

Whilst lying in bed listening to heavy rain pouring down I began wonder how much water it would take to make my car float: as you do!

I had to get up straight away and start doodling around with some figures and before you say it: I know; I need to get out more!

The calculation is simple enough although some assumptions have been made to avoid tedious, precise mini-calculations that make little difference to the result.



The vehicle will float when the **Upthrust** (shown by the yellow arrow) is equal to the **Weight** of the car (shown by the black arrow)

Archimedes told us that the Upthrust is equal to the weight of fluid (that's a gas or a liquid) displaced by the body: in this case, the weight of water displaced by the car.

At the point at which the car floats: **Upthrust (U) = Weight of car (W)**

$\mathbf{U = m_{car}\, g}$ (Where 'm_{car}' is the mass of the car and 'g' is the Acceleration of Gravity)

Upthrust is simply the weight of the displaced water, which is the mass of displaced water times g.

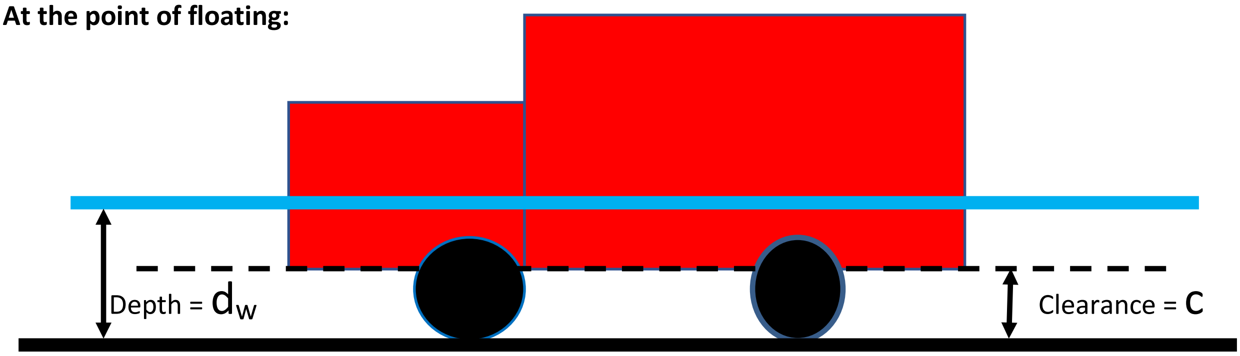
The mass of the displaced water is found by multiplying its **Density** (d) by its **Volume** (V)

Or: $\mathbf{d\, V\, g = m_{car}\, g}$

$\mathbf{V = m_{car} / d}$ Where the density of water (d) is 1Kg/litre or 1000Kg / cubic metre.

This is where I am going to simplify the calculation by assuming the wheels are cylinders standing on edge and that they only displace water up to the height of the sills; furthermore, I will assume that the body of the car is essentially a box!

At the point of floating:



Volume of displaced water (V) = Volume displaced by the wheels + Volume displaced by the body.

If the volume displaced by one wheel is V_W and the volume displaced by the body is V_B

Then: $V = 4\,V_w + V_B$

Assuming the wheel is a cylinder: $V_w = [(\pi D^2)\,W_t / 4]\,C/D$

Where **D** is the diameter of the tyre and W_t is the width of the tyre and the ratio **C/D** is the portion of the wheel that is submerged, where **C/D** has a maximum value of 1.

Therefore, the volume displaced by all 4 wheels is: $4\,V_w = (\pi D^2)\,W_t\,C/D$

Or: $4\,V_w = \pi\,D\,W_t\,C$

Now for the volume of the submerged part of the vehicle at the point at which it floats V_B

V_B = Length of the car (L_{car}) times the width of the car (W_{car}) times the depth of water above the sills, which from the diagram above can be expressed as $(d_w - C)$

$$V_B = L_{car}\,W_{car}\,(d_w - C)$$

$$V = 4\,V_w + V_B$$

$$V = [\pi\,D\,W_t\,C] + [L_{car}\,W_{car}\,(d_w - C)]$$

This is the volume of water displaced by the car at the point at which it will float.

But on page 3 we derived a different equation for volume of displaced water at the point of float:

$$V = m_{car} / d$$

These two equations are therefore equal:

$$[\pi\, D\, W_t\, C] + [L_{car}\, W_{car}\, (d_w - C)] = m_{car} / d$$

The only factor in this equation we don't know is d_w, the depth at which the car will float, so let's make this the subject of the equation:

$$dw = \{[(m_{car} / d) - \pi\, D\, W_t\, C] / [L_{car}\, W_{car}]\} + C$$

At this point the equation looks a bit cumbersome so I'm going to add some numerical values for my Range Rover Vogue:

Mass of car = m_{car} = **3200kg**

Density of water d = **1000kg / m^3**

Diameter of tyre = D = **0.5m**

Width of tyre = W_t = **0.28m**

Length of car = L_{car} = **4.97m**

Width of car = W_{car} = **2.22m**

Clearance to sills = C = **0.3m** (suspension on lowest setting)

Therefore: $$d_w = \left[\frac{(3200 / 1000) - 3.142 \times 0.5 \times 0.28 \times 0.3}{(4.97 \times 2.22)}\right] + 0.3$$

d_w = 0.58 metres **or 1.9 feet**

Wow; that's not much for a car with a formidable off-road capability, although it is on the lowest suspension setting. If I recalculate raising the level of the car body to its highest off-road setting, d_w becomes 2.13 feet of water.

How much water would it take to float a Citroen C3; surprisingly, it would take 1.2 feet of water; which is not that much different from the Vogue on low suspension (1.9 feet). This is at first a bit surprising, but the longer, wider Vogue with its big wide wheels, all help to displace more water, giving more Upthrust, which compensates for the fact that the Vogue is more than twice the mass of the C3. So the real advantage in any car to increase the depth at which it will float is most definitely its ground clearance: hence why the Vogue with its ability to lift its entire body work by 3 suspension settings is a very capable off road vehicle.

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