

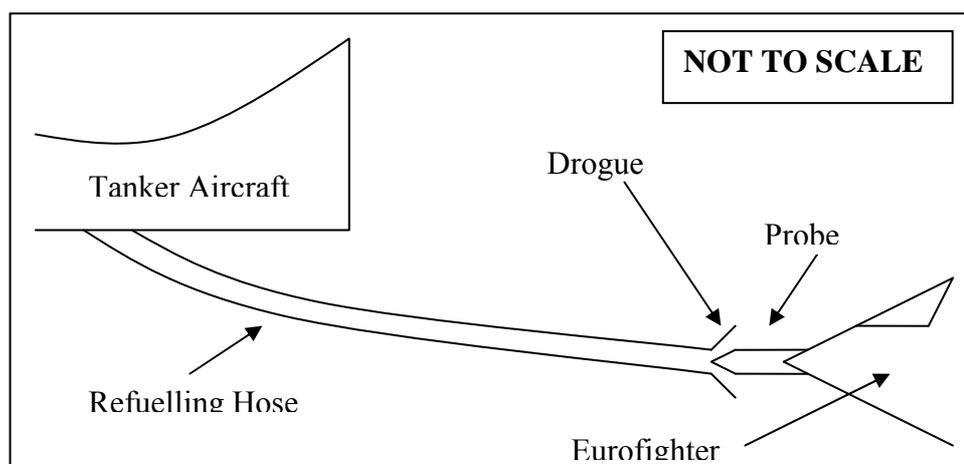
In-flight refuelling

I work for Cobham Mission Equipment, a company at the forefront of weapons carriage and release, and Air-to-Air refuelling. We have a 98% market share of drogue based Air-to-Air refuelling among NATO countries, and have been supplying these systems to air forces worldwide for over 75 years.

Other divisions of Cobham produce a huge scope of product, including life support systems for astronauts, communication devices for army vehicles, and locator beacons for round the world yachts.

The Problem – this could be made more complex by using a differential equation for fuel flow rate.

A Eurofighter aircraft back from a mission in the Middle East doesn't have enough fuel to get back to London, and hence has to refuel in mid-air. It is 2800 miles from London, with just 150 litres of fuel left in its tanks. The aircraft's average fuel economy is 2 miles per litre of kerosene, but this reduces to 1 mile per litre for the final 50 miles of approach for landing. The RAF specifies that a minimum of 100 litres of fuel is kept in the aircraft as reserve fuel (i.e. 100 litres of fuel must be left when the aircraft has landed). During in-flight refuelling, the tanker and receiver aircraft want to remain connected for the minimum possible period of time in order to reduce the risk of a collision. Given that a refuelling hose has a diameter of 11.2cm, and that the fuel flows through this hose at a velocity of 3.6m/s, model the fuel as a solid object to calculate the minimum amount of time (to the nearest second) that the hose must be connected to get the Eurofighter back to London.



Answer:

$$\begin{aligned}\text{Fuel needed for journey} &= 2750 \div 2 + 50 \\ &= 1375 + 50 \\ &= 1425 \text{ litres}\end{aligned}$$

However, the Eurofighter already has 50 litres of fuel above the reserve fuel threshold, so the Eurofighter needs a further $1425 - 50 = 1375$ litres of fuel.

$$\begin{aligned}\text{Fuel flow rate} = \pi r^2 v &= \pi \times 0.056^2 \times 3.6 &= 0.03547 \text{ m}^3 \text{ of fuel per second} \\ & &= 35.5 \text{ litres per second}\end{aligned}$$

$$\begin{aligned}\text{The minimum time} &= 1375 \div 35.5 &= 38.7 \text{ seconds} \\ & &= \mathbf{39 \text{ seconds}}\end{aligned}$$

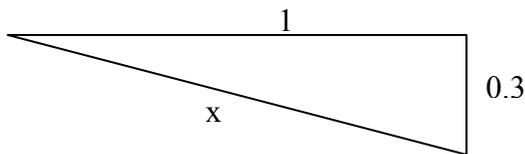
A Further Problem

a) A refuelling hose is 32m long. To air the fuel flow, the tanker aircraft must be above the receiver aircraft whilst refuelling, with the average gradient of the hose at maximum value of -0.3. Calculate the maximum possible horizontal length of the hose during refuelling.

b) The maximum angle that the hose can form with the horizontal for safe refuelling is 40° . Give limits for the minimum and maximum vertical distance between the two aircraft for safe refuelling.

Solution

a) If the gradient is at -0.3, you can use the following triangle:



By Pythagoras Theorem, $x = \sqrt{1^2 + 0.3^2} = \sqrt{1.09} = 1.044\text{m}$

To scale this triangle up, you do $32\text{m} \div 1.044\text{m} = 30.65$

So $1 \times 30.65 = \underline{\underline{30.65\text{m}}}$ is the minimum horizontal distance.

This problem can also be solved using trigonometry.

b) For the minimum distance, use the above scale factor of 30.65, to get

$30.65 \times 0.3 = \underline{\underline{9.20\text{m}}}$.

The maximum distance = $32\sin 40 = \underline{\underline{20.57\text{m}}}$