Dynamics of a car/airplane and fuel economy: Part II

Q1

A car moving with 80km/hr on a highway; the work done by thrust force is mainly to

1) fight against the rolling-friction force;
2) against the air drag;
3) against both;
4) acquire additional kinetic energy.

Q2

A car is accelerated to 50km/hr within 5s; the work done by thrust force is mainly to

1) fight against rolling-friction forces;
2) against the air drag;
3) against both;
4) Acquire desired kinetic energy.

Q3

At 80km/hr, the rolling-friction force and air drag are about equal. And a car consumes 6L/100km at this speed. How much it consumes per 100km if its speed is 120km/hr. (Engine efficiency is assumed to be independent of speed.)

1) 10L;
2) 14L;
3) 18L;
4) 20L.

Summary of dynamics of a car

$W(net)=W\ (thrust) - W(friction, Drag) = \Delta K$

$W(thrust) = W(friction, Drag) + \Delta K$

1) During cruising at constant speed, $\Delta K=0$;

2) Acceleration costs extra energy!!

3) Fuel economy/100km:

Efficiency X (# of L) X (32MJ/L) =Work (thrust)

Hybrid Cars

- Why are hybrid cars more energy efficient?

- Efficiency of combustion engines depends on rpm. Most efficient at relative high speeds ~ 90 km/h.
- Electric motor very efficient at all speeds.

Energy needed to climb up to an altitude of 10.5km

The mass of the plane is 390 000 kg at take-off.
$V = m\, g\, h = 4 \times 10^{10}$ J

Kinetic energy at the cruising speed of 915 km/h (254 m/s). $K = \frac{1}{2} m v^2 = 1.26 \times 10^{10}$ J

- How much fuel is needed for this? The energy efficiency of the jet engines is ~25% (estimated)

Energy in jet fuel: 37.6 MJ/L.

- So we need 1400 L/0.25 = 5600L of jet fuel to accelerate to 915 km/h and go up to 10500 m.

Fuel Economy of Airplanes

A Boing 747 has a maximum range of 13,450 km and a maximum fuel capacity of 216,840 L.

We can calculate the fuel economy from this:
16L/km or 1600 L per 100 km.

The number of passengers is ~500, so each passenger uses 3.2L per 100 km when the plane is full.

This is similar to the fuel economy of a car!

Energy for cruising

- The rest of the fuel (~210,000L) is used to maintain “terminal” speed against air drag.

- Let’s estimate the drag force: A 747 has a fuel capacity of 216,840 L and a max. range of 13450km. So 210,000 L are used to counter air drag. W = F d, so F = 147 kN. (Engines have max thrust of 4 x 282 kN). It is less than the air drag on the ground (see Q4).

Flying at a high altitude reduces the air drag because of a lower air density !! That’s why planes fly relatively high although further going high results in a lower upward lifting force.

Q4

Estimate of air drag of Boeing jets
(speed about 915km/hr; cross-sectional area about 8mX3m)

1) 150kN;
2) 360kN;
3) 800kN;
4) 60kN.

Summary

Use the work-energy relations to understand/ estimate

1) the work done by thrust force for cruising or acceleration;

2) Estimate fuel economy of a car /air plane;

3) Understand the advantage of flying high.