INTRODUCTION TO AIRCRAFT STRUCTURES

Prof. Ian Lane
Senior Structures Expert, Airbus

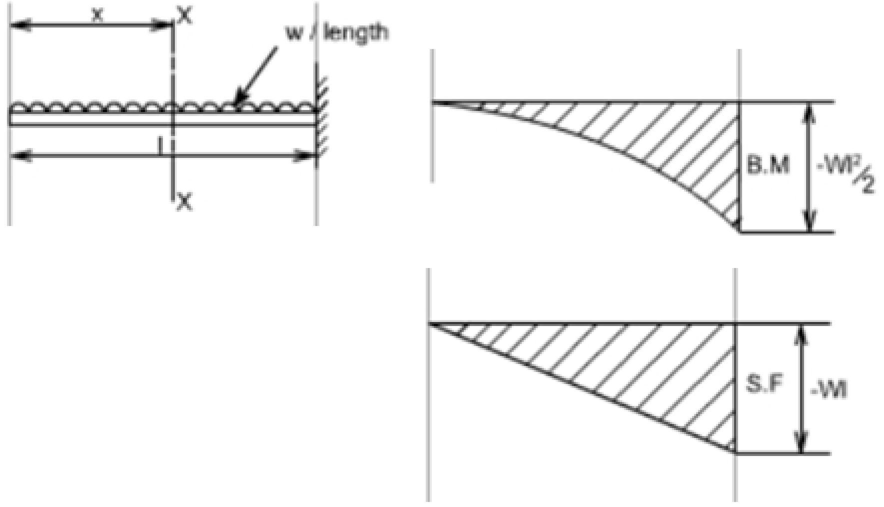
il14001@Bristol.ac.uk

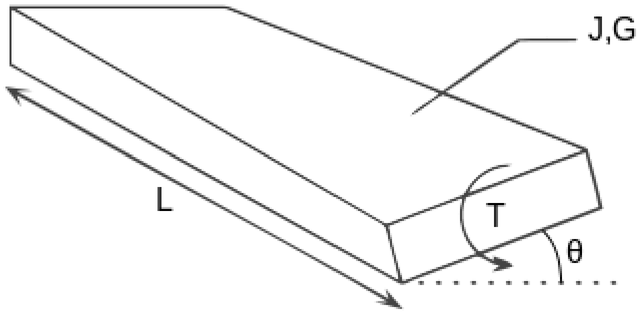
INTRODUCTION TO AIRCRAFT STRUCTURES : WING STRUCTURES

Or ‘So we need some structure to give us some lift – amongst other things’

WING STRUCTURES

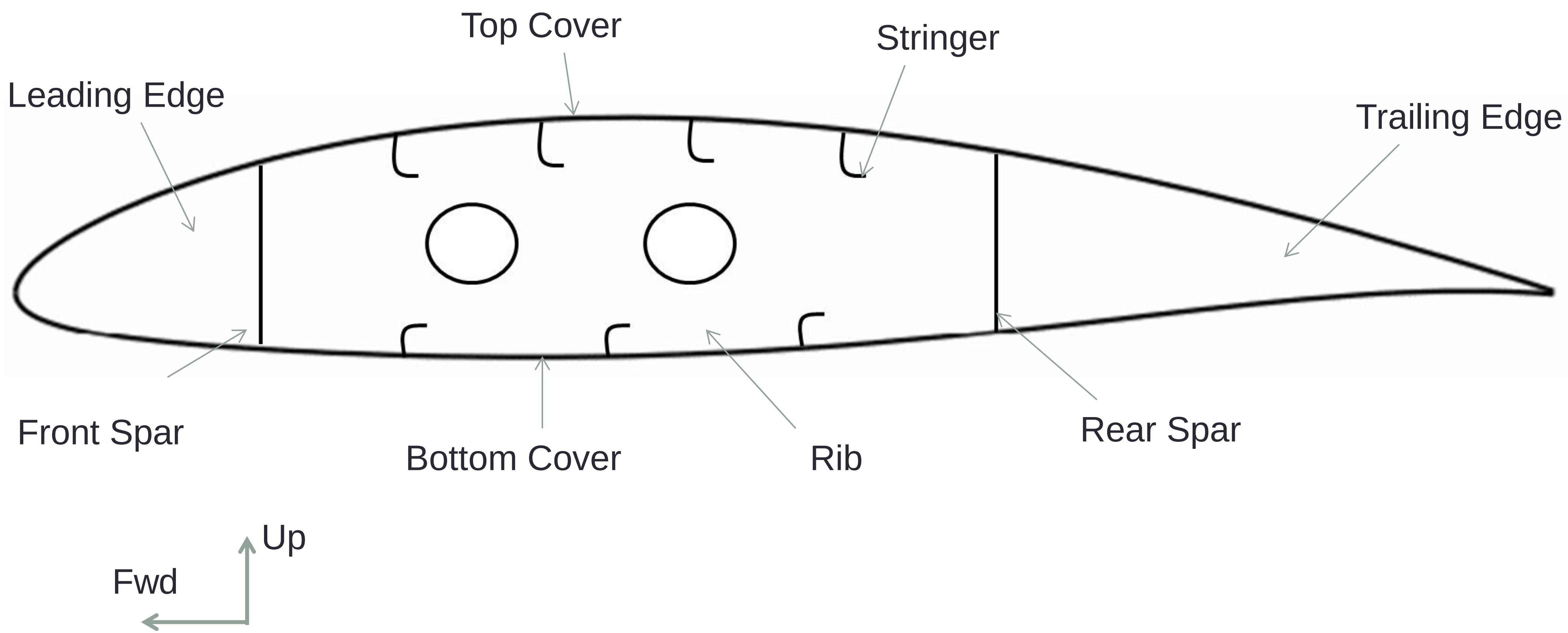
- **What does a wing need to be – structurally ?**
- A beam that can carry bending
- A beam that can carry vertical shear
- A section that can carry a torsional load
- Basic resistance to SMT (Shear, Moment & Torque)





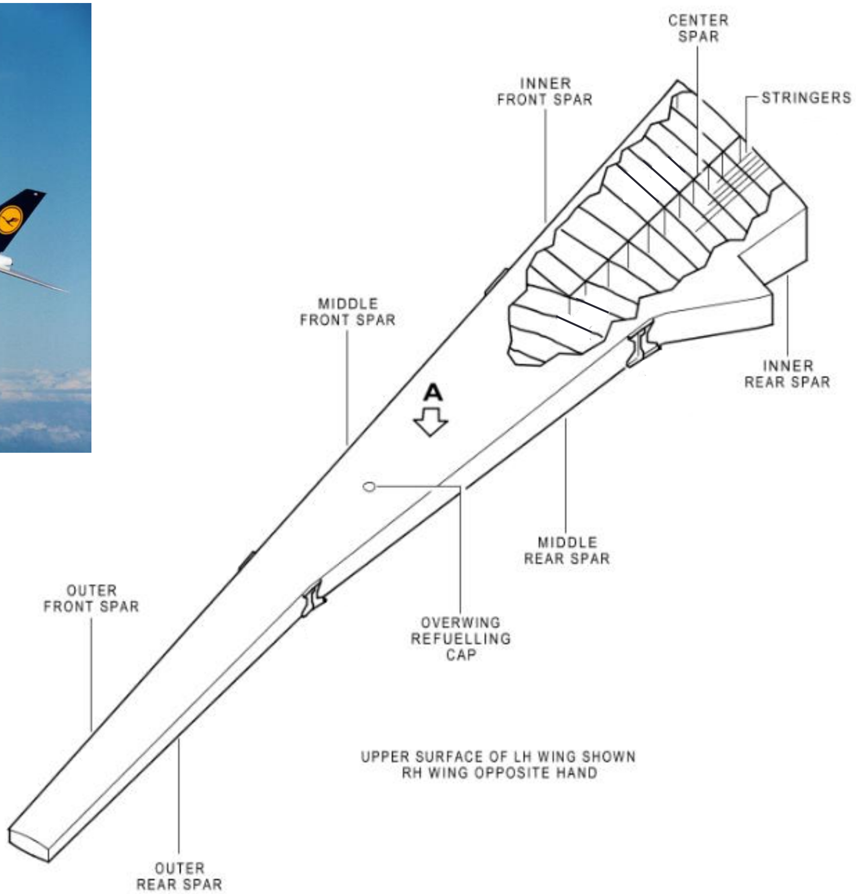
WING STRUCTURES

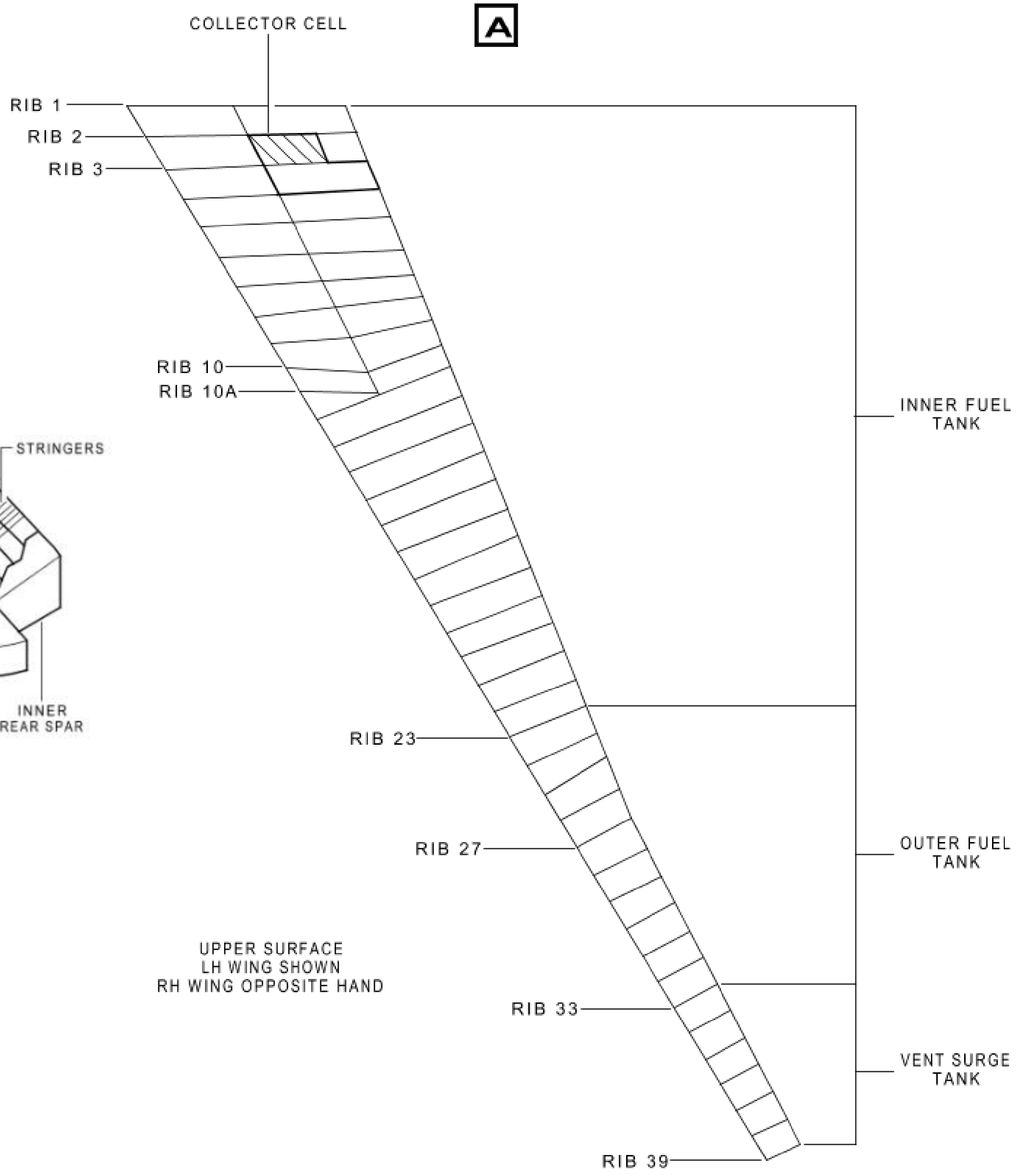
- **Typical Commercial Wing Torsion Box Layout**



WING STRUCTURES

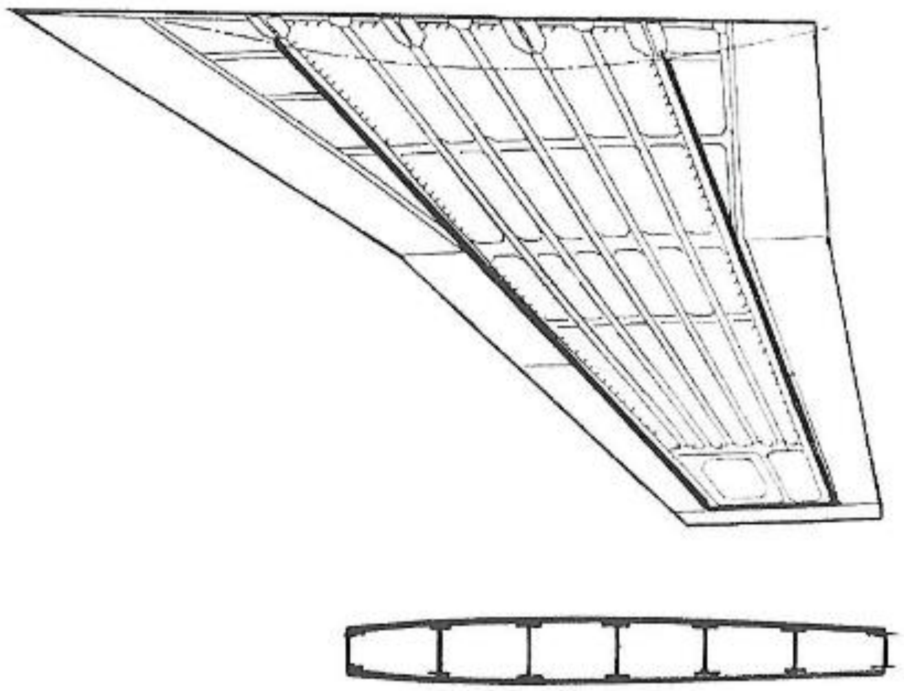
- **Typical Commercial Aircraft Wing Box**





WING STRUCTURES

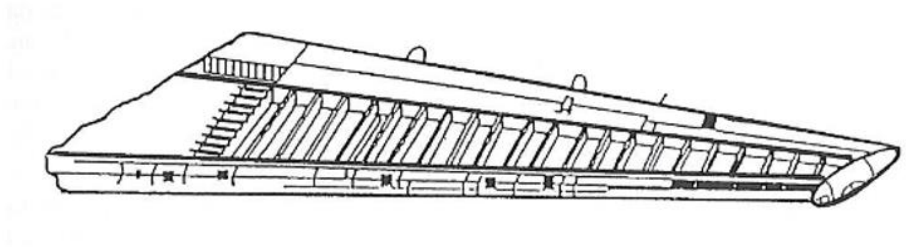
- **Typical Fighter Aircraft Multi-spar Wing Box**



WING STRUCTURES

- Rotor Blade – It's a Wing too !

WING STRUCTURES



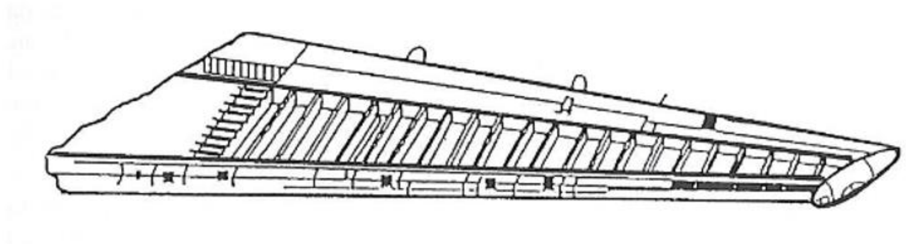
- **Wing Design Considerations**

- Leading and trailing edges often not considered part of main wing-box structure – just required to transfer loads chordwise into box, rather than spanwise along wing.

- Leading edge may contribute significantly to overall torsional stiffness – provided it can carry the loads without shear buckling.

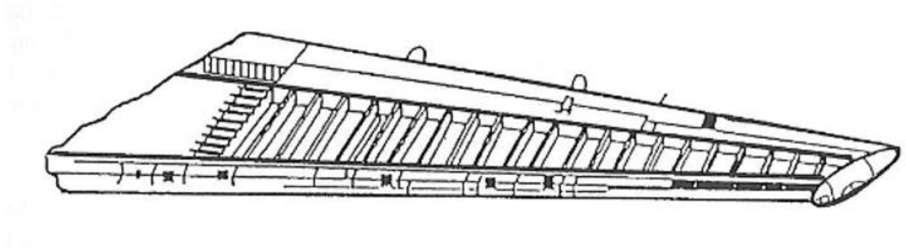
- The leading and trailing edge also need to accommodate control and high lift devices – slats, flaps, ailerons – not shown on schematics for simplicity.

WING STRUCTURES



- **Wing Design Considerations**
- A single spar may be able to carry loads adequately on a small aircraft. An I section spar will be poor in torsion, and the closed section formed by the skin will need to carry these loads
- In a box formed by two spars the bending can be carried by the spars strengthened with additional material in the flanges to increase second moment of area. Torsion will be carried around the closed box section. The skin will probably need to be stiffened depending on how high the loads are.
- For large aircraft with high wing loading the whole wing box needs to carry bending as well as torsional loads, and so skins are highly stiffened.

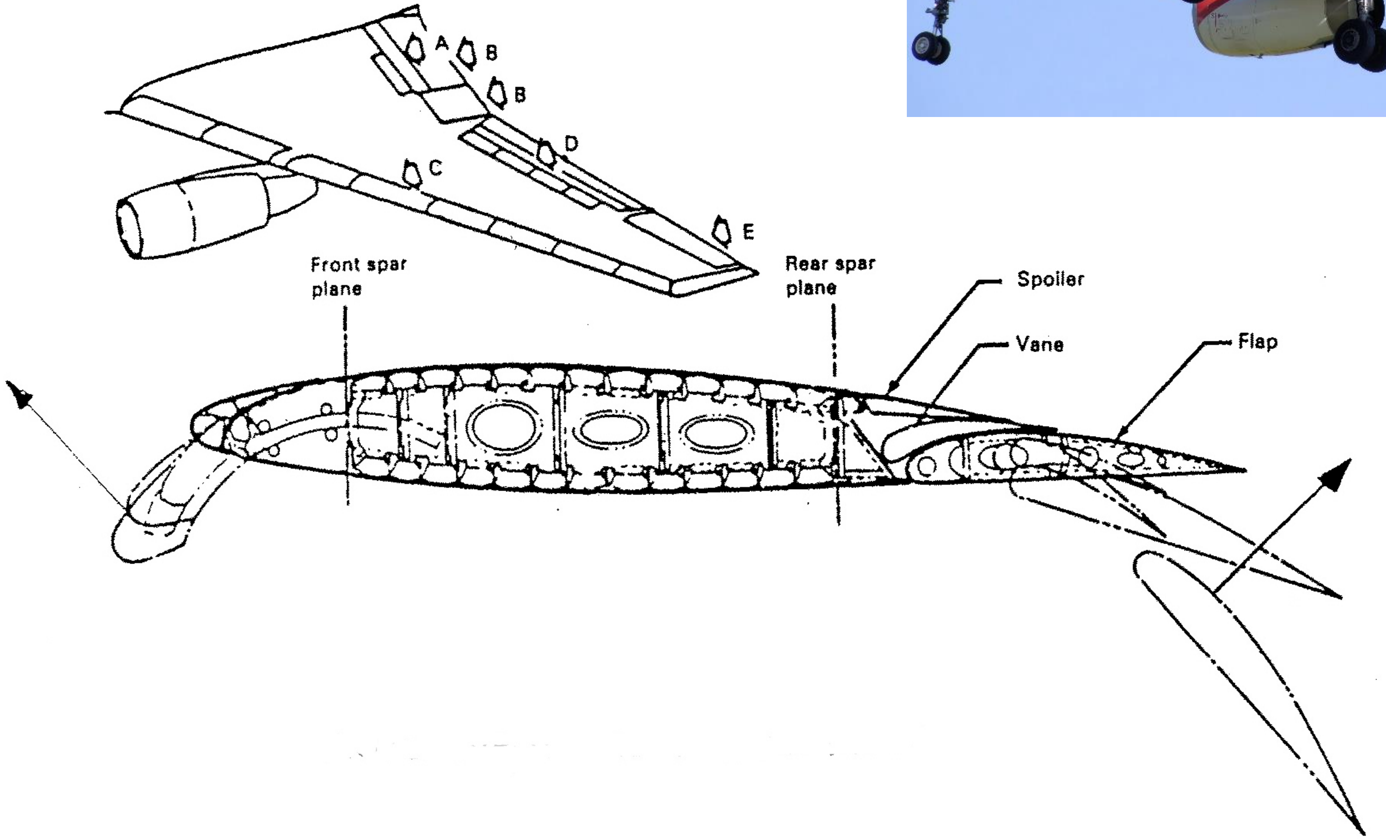
WING STRUCTURES

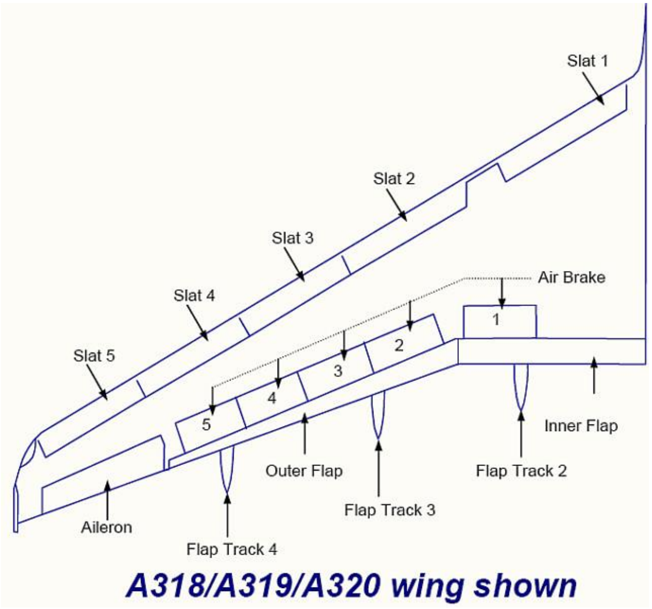


- **Wing Design Considerations**
- Most wing boxes have two main spars. Multi spar designs are occasionally used, but are generally less efficient except for delta wing aircraft.
- Honeycomb may be used to stabilise wing skins instead of stiffeners. It is very efficient, especially for lightly loaded structures, but is more susceptible to damage.
- Full depth honeycomb is sometimes used on control surfaces, or on very thin supersonic wing sections.

WING STRUCTURES

- **High Lift Inputs – Slats& Flaps**
- **All these point input loads have to be carried into the main wingbox**



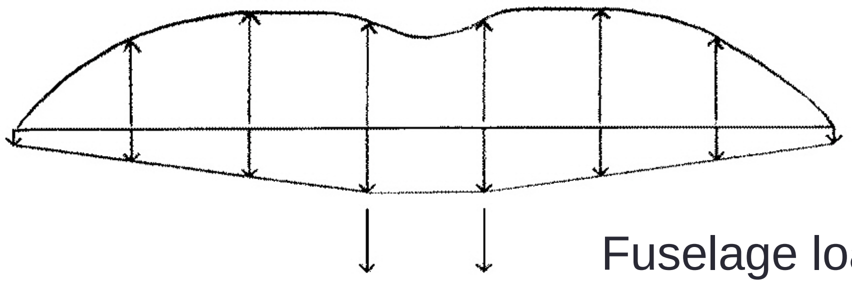


INTRODUCTION TO AIRCRAFT STRUCTURES : WING STRUCTURES LOADING

Or ‘So we need to work out some wing loading’

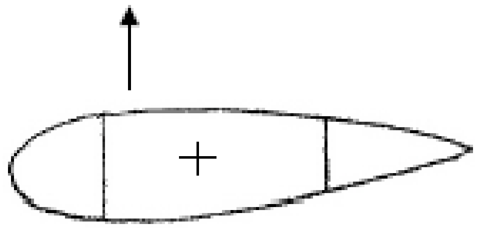
WING STRUCTURES

- **Wing Loading in Flight**



- Lift
- Inertia
- Fuselage Loads

- Torsion due to offset between lift and shear centres



WING STRUCTURES

- Numerical example

- A business aircraft with fuselage mounted engines has a wingspan of 15 m. The mass of the wing structure is 500 kg, and the wing also carries 1000 kg of fuel. The all-up mass of the aircraft is 4500 kg.

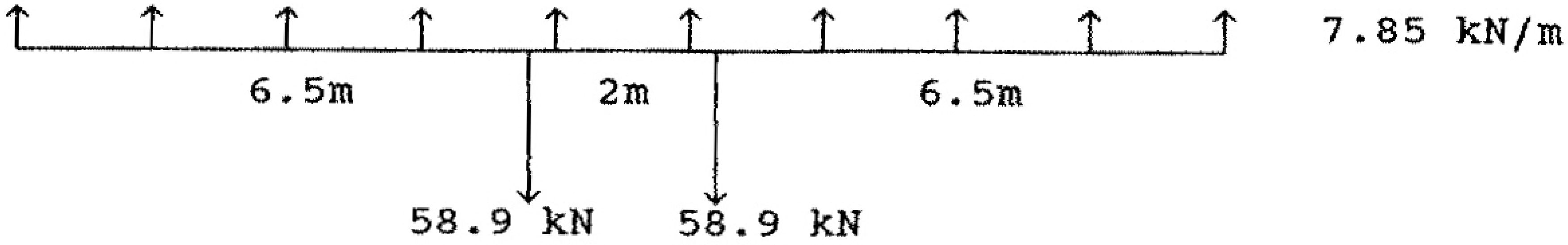
- For simplicity the distributions of structural mass, fuel mass and lift may all be assumed to be uniform across the span. Loads from the fuselage may be assumed to be transmitted at two points at 1m either side of the midspan position. Calculate the shear force and bending moment distributions for a symmetric gust case with a load factor of 4.

WING STRUCTURES

- Overall lift loading = 4500 x 9.81 x 4 = 176.6 kN
- Wing + fuel inertia loading = (1000 + 500) x 9.81 x 4 = 58.9 kN
- Net load from fuselage = 176.6 – 58.9 =117.7 kN
- i.e. 58.9 kN each side
- Net distributed load on wing = 117.7 / 15 = 7.85 kN/m

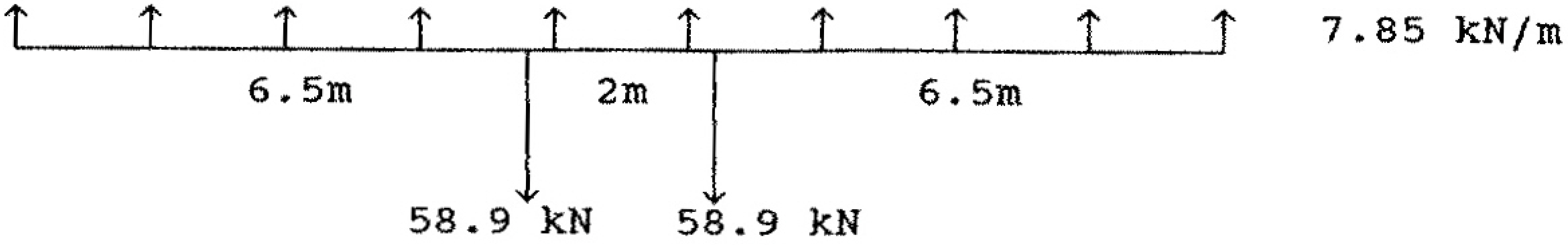
WING STRUCTURES

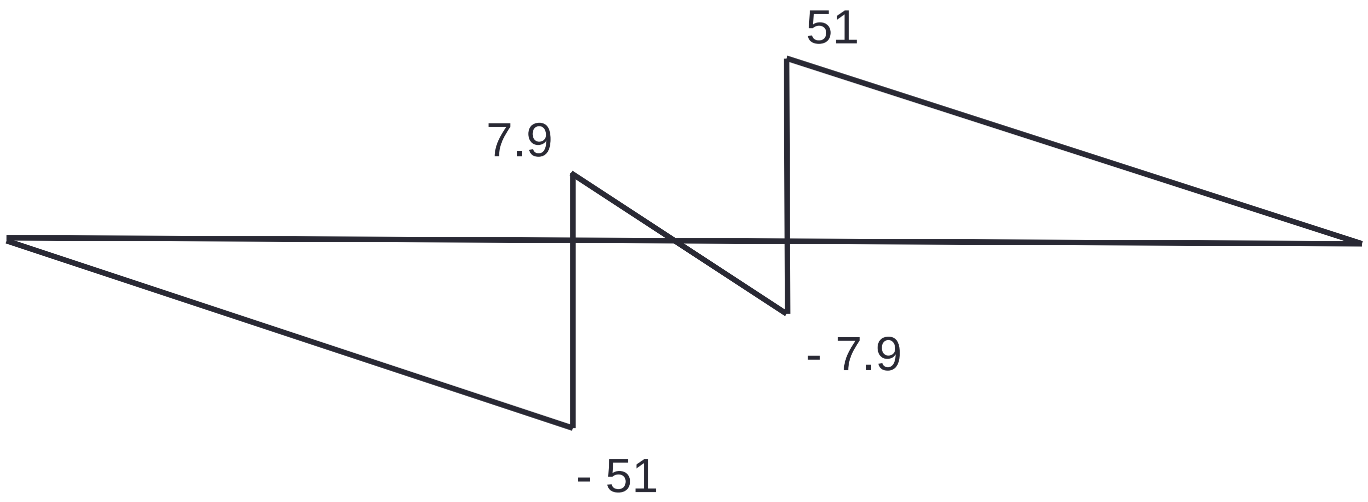
- Wing loading diagram becomes :



WING STRUCTURES

- Shear force diagram with principal values:

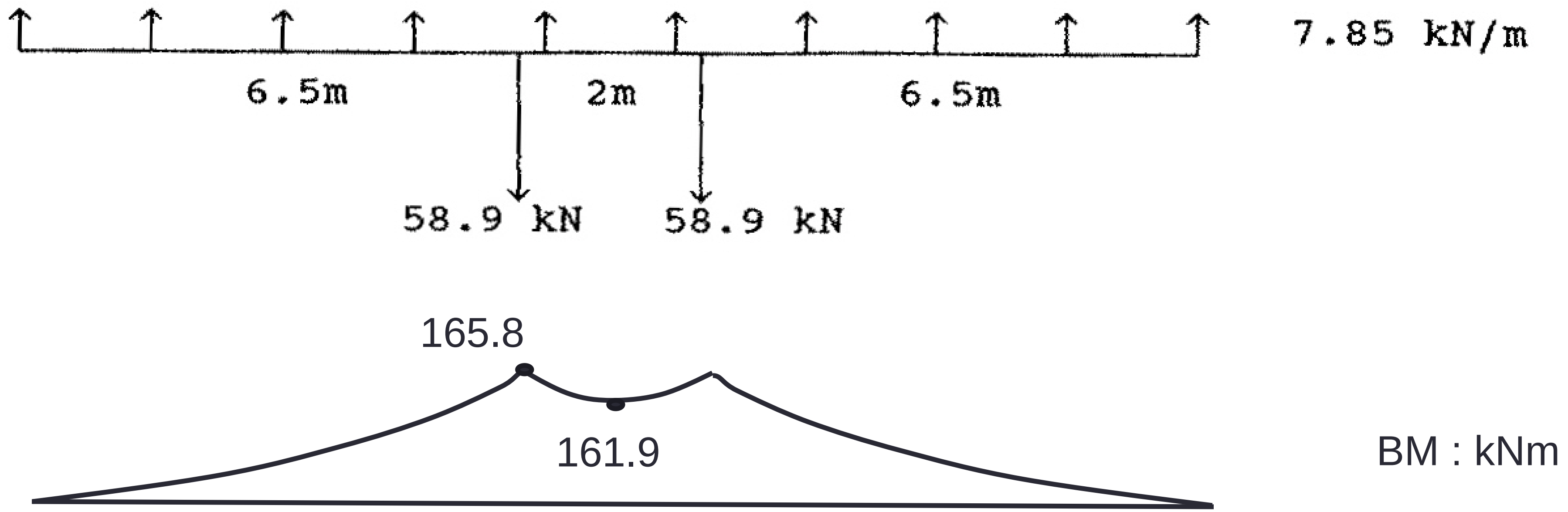




Shear Force : kN

WING STRUCTURES

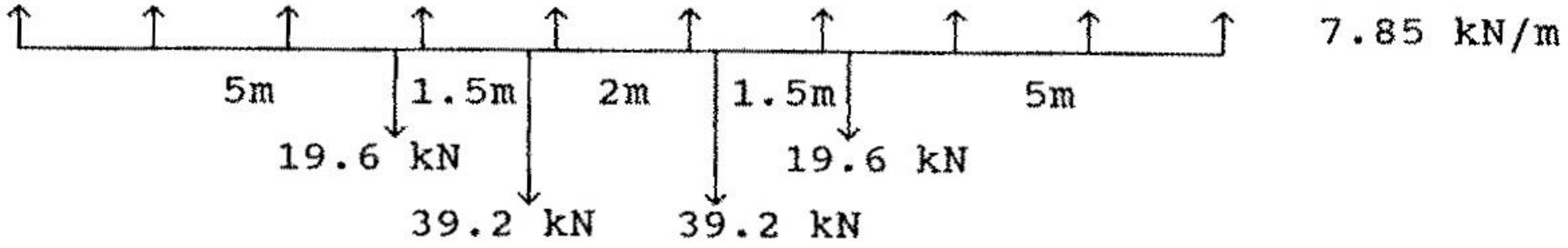
- Bending moment diagram with principal values:



WING STRUCTURES

- The two engines each have a mass of 500 kg.

- What is the effect on the shear force and bending moment for the same flight condition if the engines are mounted on the wing at points 2.5m from the midspan?



WING STRUCTURES

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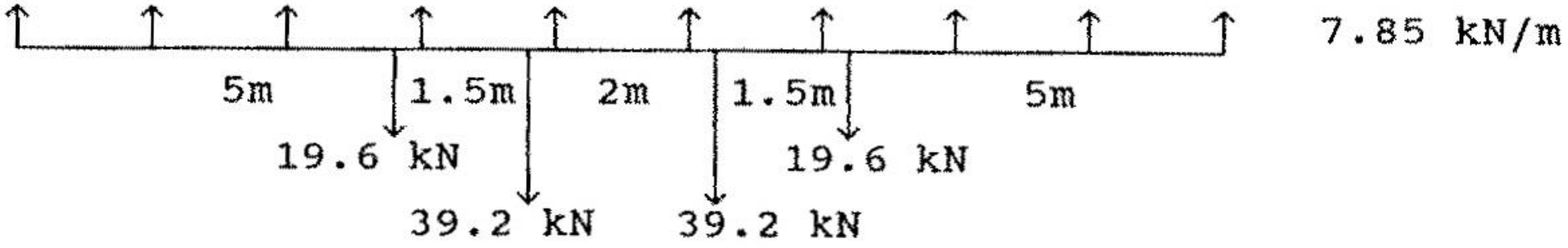

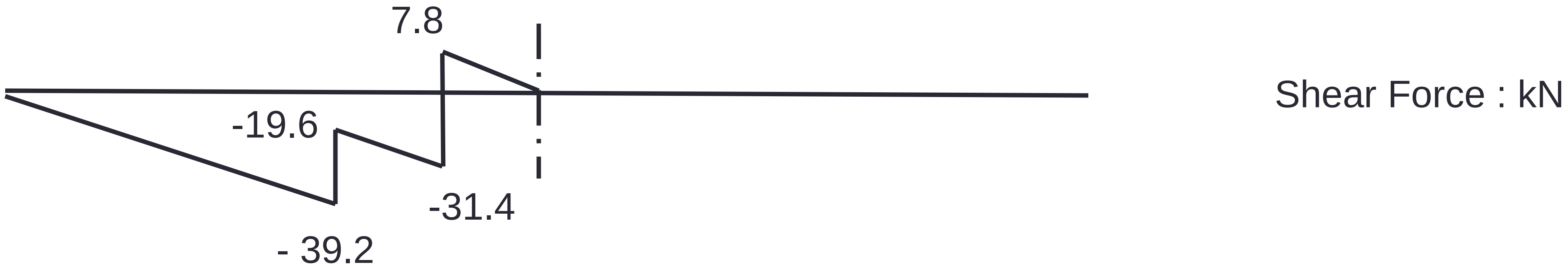

WING STRUCTURES

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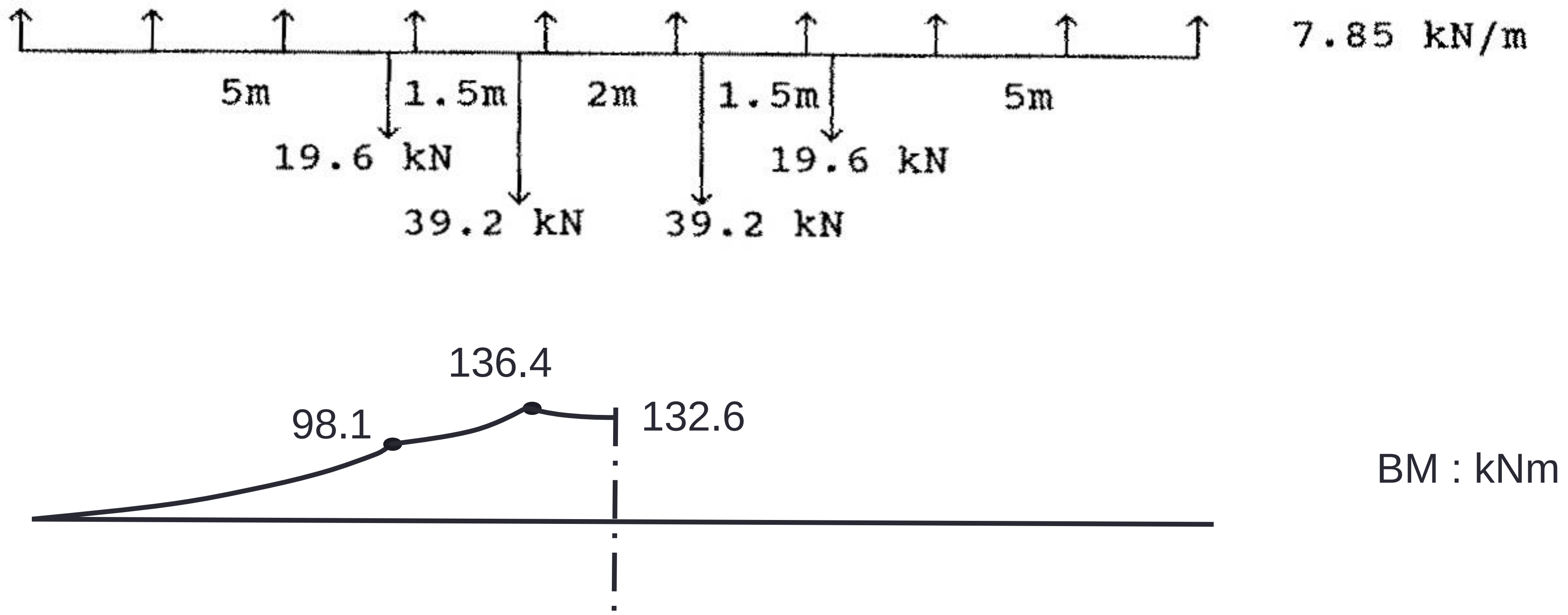


WING STRUCTURES

- **Wing Loading in Landing**

- Consider the previous case with fuselage mounted engines, and the undercarriage attaching at points 2.5 m from the centre.

- In a two point landing a load factor of 3.5 applies.

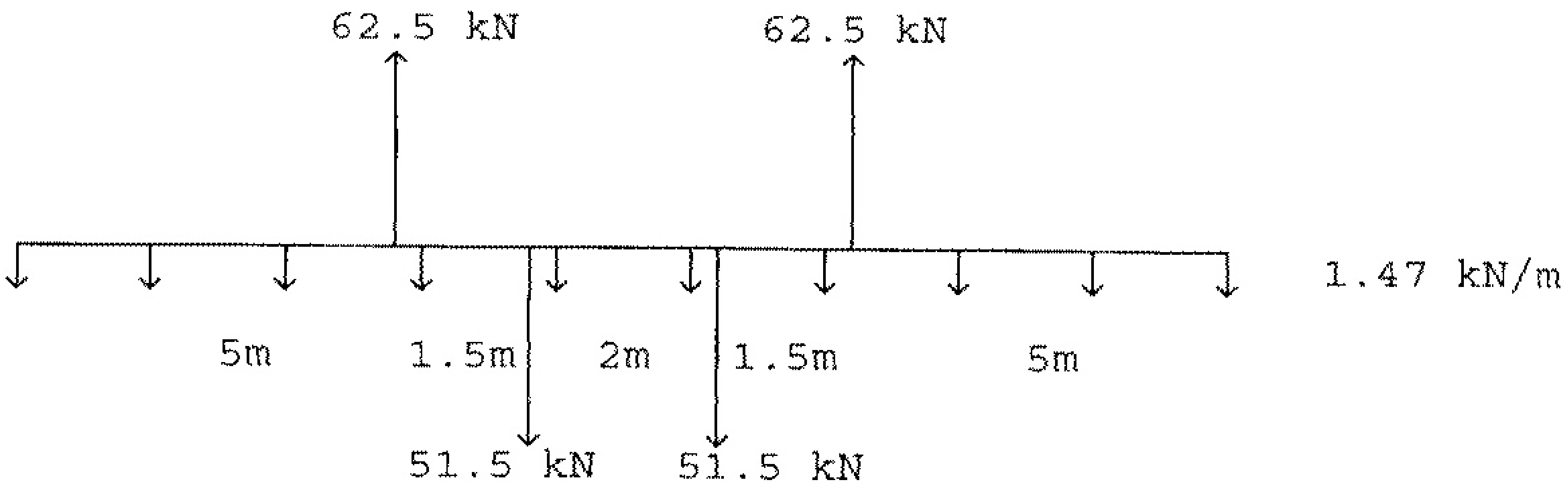
- There is residual lift loading of 0.667g. I.e. the aircraft is not in equilibrium.

WING STRUCTURES

- **Wing Loading in Landing**
- Overall inertia loading = 4500 x 9.81 x 3.5 = 154.5 kN
- Residual wing lift loading = 4500 x 9.81 x 0.667 = 29.5 kN
- Therefore undercarriage load = 154.5 – 29.5 = 125 kN
- Wing + fuel inertia loading = 1500 x 9.81 x 3.5 = 51.5 kN
- Therefore net distributed load on wing = (51.5 – 29.5) / 15 = 1.47 kN/m
- Fuselage inertia loading = (2000 + (2 * 500)) x 9.81 x 3.5 = 103 kN

WING STRUCTURES

- Wing loading diagram becomes :



WING STRUCTURES

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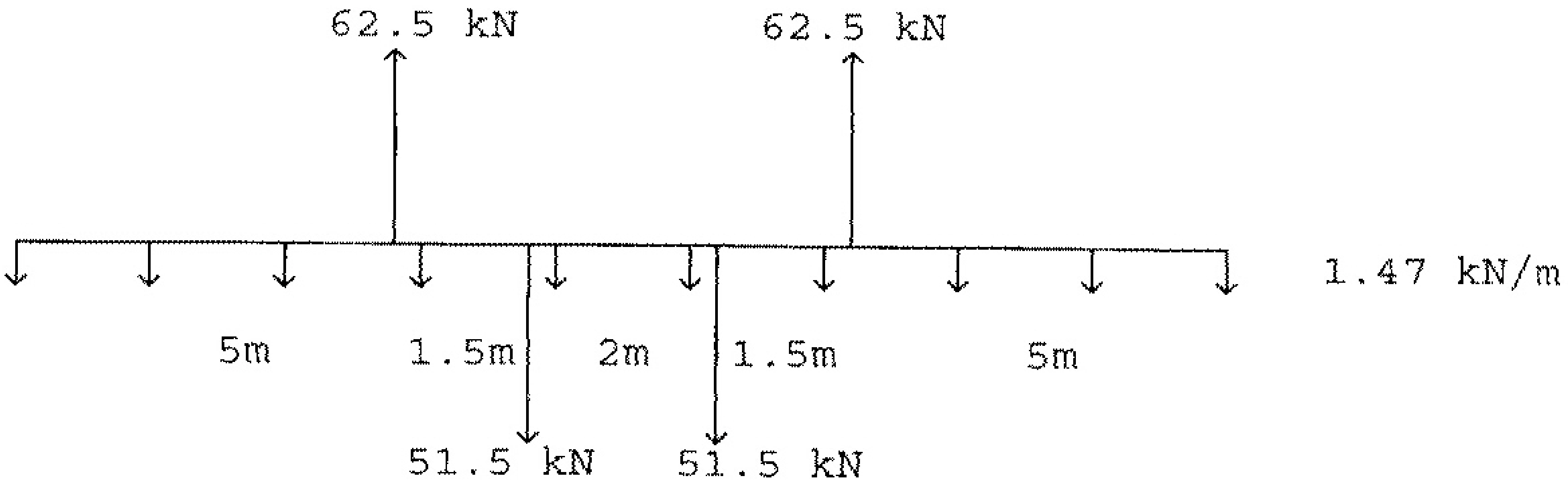

WING STRUCTURES

- Bending moment diagram with principal values: