4. Loading & Performance

4.1 - Loading & Performance

CERTIFIED DRONE PILOT

Structure & Formatting Reminder

This presentation is provided as a reference to help you prepare for the your exam. It seeks to go beyond memorization and provide explanation and rationale.

While this reference considers many of the points covered in the exam, given the bredth it is in no way exhaustive. It is suggested to consult a variety of resources when preparing for the exam.

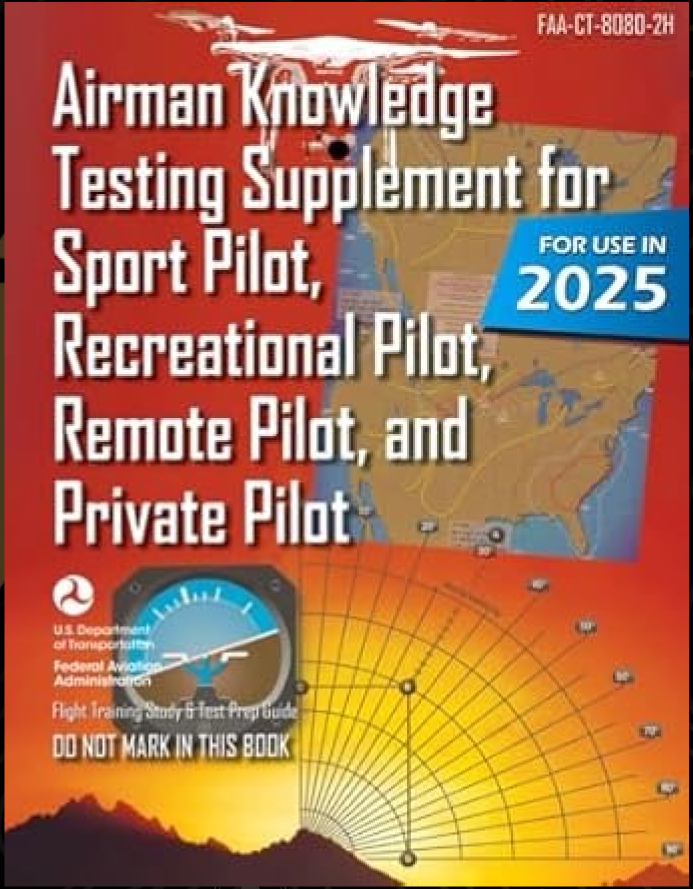
Text that is marked in YELLOW has a high probability of being referenced directly in one of the exam's nearly 400 possible questions.

Take the quiz at the end to gauge your understanding.

Airman Knowledge Testing Supplement

Many of the points covered in the slideshow and quiz reference images and concepts found in the “Airman Knowledge Testing Supplement”.

You can download the document from the FAA here. Alternatively, a hard copy can be purchased online for around $10.



4.1a - Determining Speed & Altitude

4.1 - Determining Load And Performance

Limitations Reminder

Under Part 107 pilots are limited to:

- Groundspeed of 87 knots (100mph)
- Altitude of 400’ AGL unless within a 400 foot radius of a structure (limited to 400’ AGL above structure)

4.1 - Determining Load And Performance

How can we determine Ground Speed?

- GPS reporting
- Timing between fixed points
- sUAS manufacturer limitations
- Radar gun
- Onboard sensors

4.1 - Determining Load And Performance

Terminology- Navigation & Grounspeed

- **Dead Reckoning**: navigation by computations based on time, airspeed, distance and direction (adjusted for wind speed)
- **Pilotage**: navigation by reference to landmarks or checkpoints
- **Wind Triangle**: navigation using triangulation of wind direction/velocity, true heading/true airspeed, track/true course/ground speed

4.1 - Determining Load And Performance

How do we determine altitude?

- On-board Altimeter
- GPS reporting
- Visual perspective
- Reference known terrain/structures
- Sectional charts

4.1 - Load Factor

4.1 - Load Factor

Load factor is a ratio of lift to weight. It represents a measure of stress (load) that the aircraft undergoes.

4.1 - Load Factor

Load factor is equal to lift divided by weight (again, a ratio)

n = load factor

L = lift

W = weight

$$n = \frac{L}{W}$$

4.1 - Load Factor

Load factor is expressed as “g” (gravity).

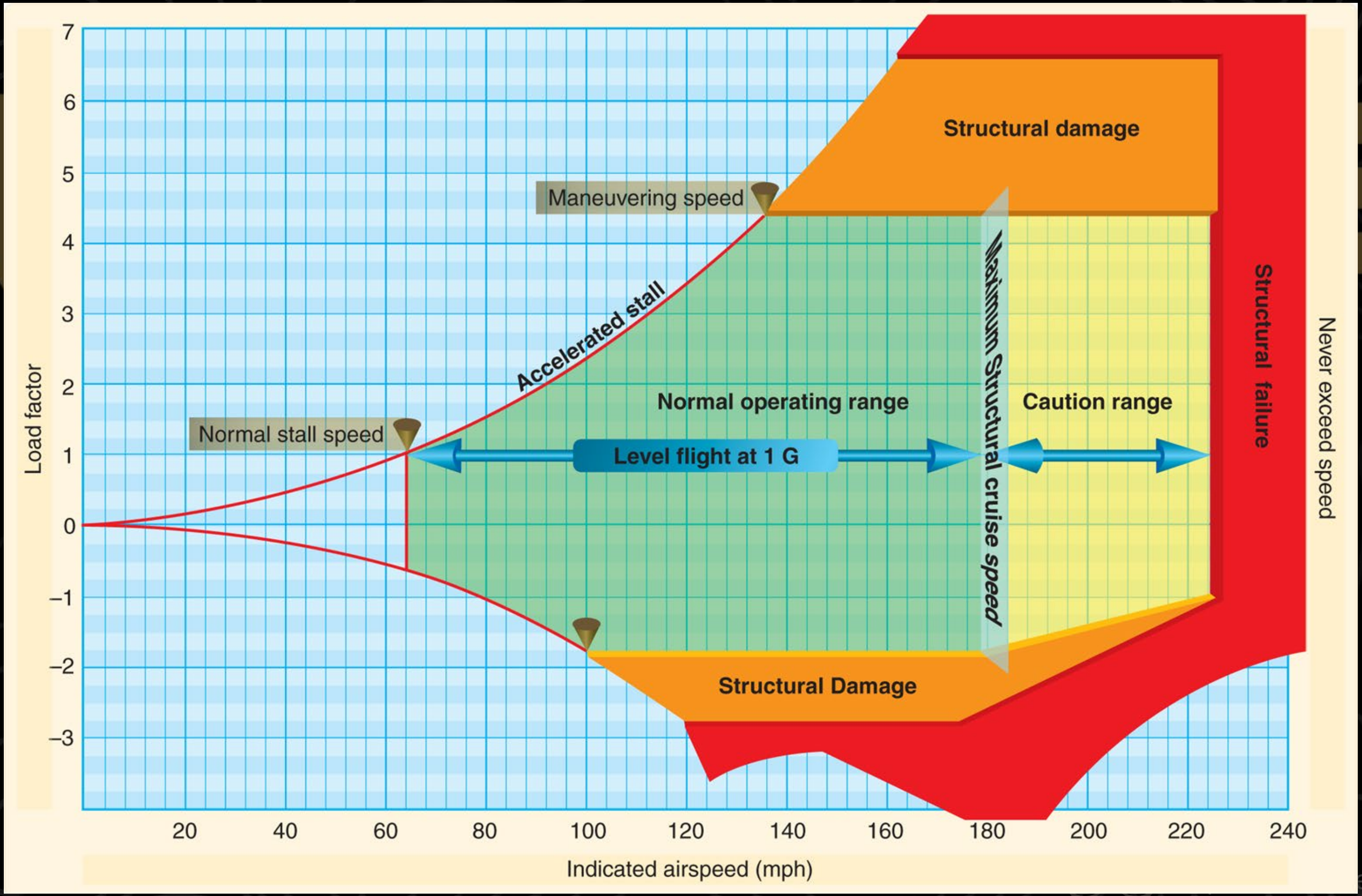
n = load factor

L = lift

W = weight

$$n = \frac{L}{W}$$

4.1 - Load Factor



4.1 - Load Factor

A Load Factor of 1 refers to level flight at a constant speed at **1g** (normal Earth gravity).

- The aircraft will remain in the air as long as lift remains the equal to gravity.

4.1 - Load Factor

A high Load Factor will increase the **Stall Speed**.

- The aircraft needs to go faster to maintain lift.

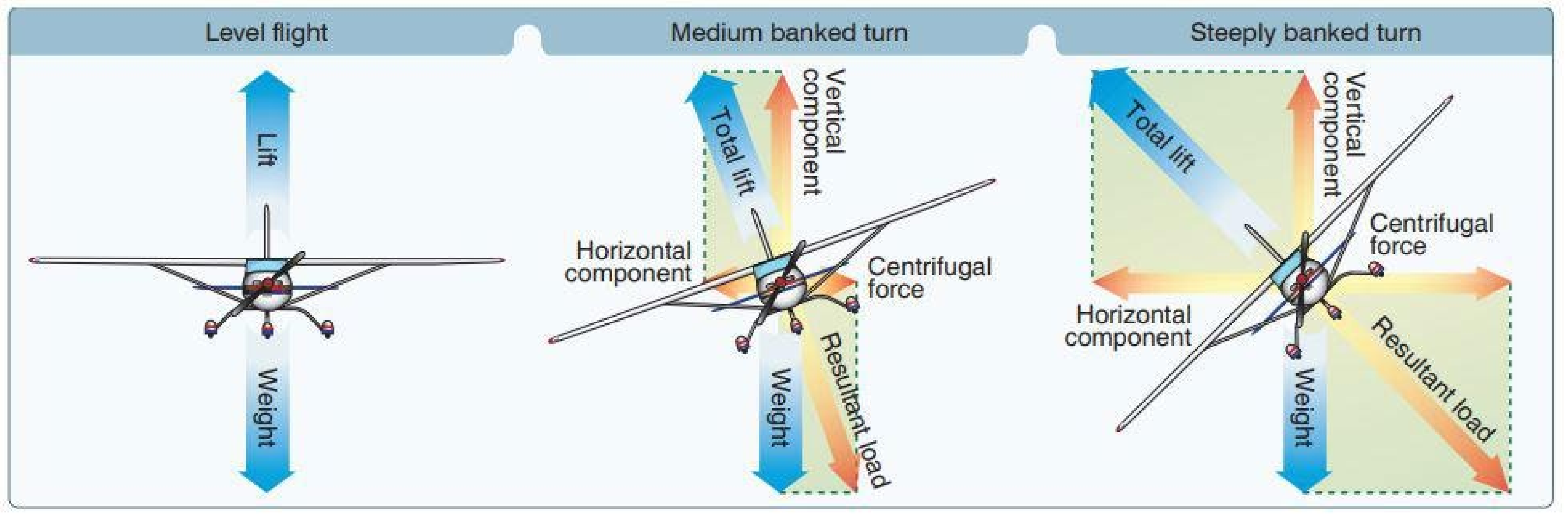
Stall speed = the speed required to stay in the air.

Why is load factor important to pilots?

4.1 - Load Factor

- When turning the load factor is increased (think pressure)
- As the degree of rotation increases the load factor increases (thereby increasing the stall speed).
  - If the turn is too sharp and the stall speed can't be maintained the aircraft can loose lift and fall.

4.1 - Load Factor



4.1 - Load Factor - *Calculation Example #1*

Possible Question:
What weight does your 47lb aircraft need to support in order to complete a 30° banked turn?

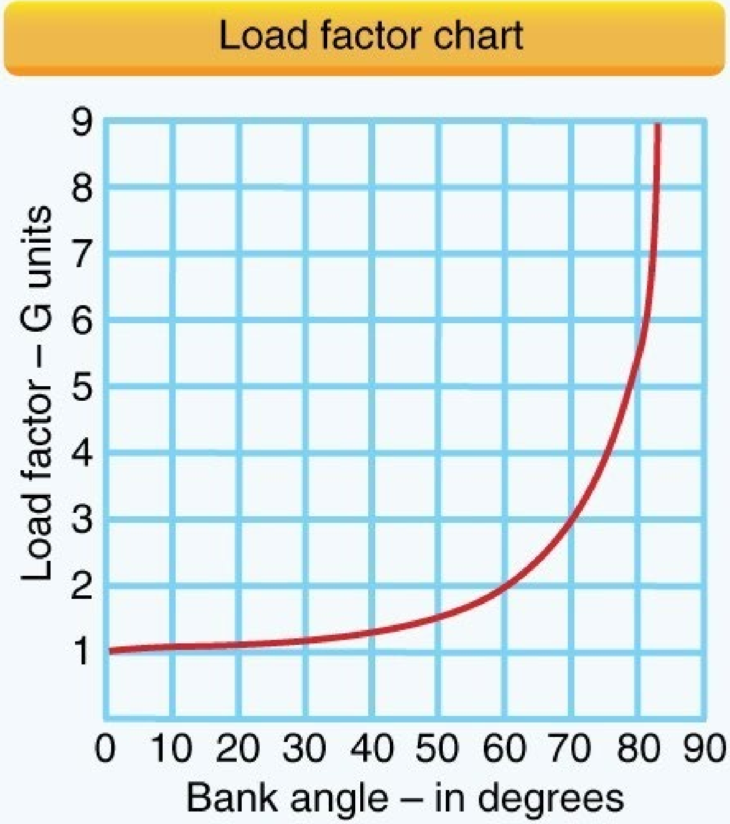
STEPS

Step 1: Find your angle of bank on the load chart. A 30 degree banked turn has a load factor of 1.154.

Step 2: Multiply the load factor (n) by the weight of your aircraft.

Load Factor x Weight = **Support**

Angle of bank Φ	Load factor n
0°	1.0
10°	1.015
30°	1.154
45°	1.414
60°	2.000
70°	2.923
80°	5.747
85°	11.473
90°	∞

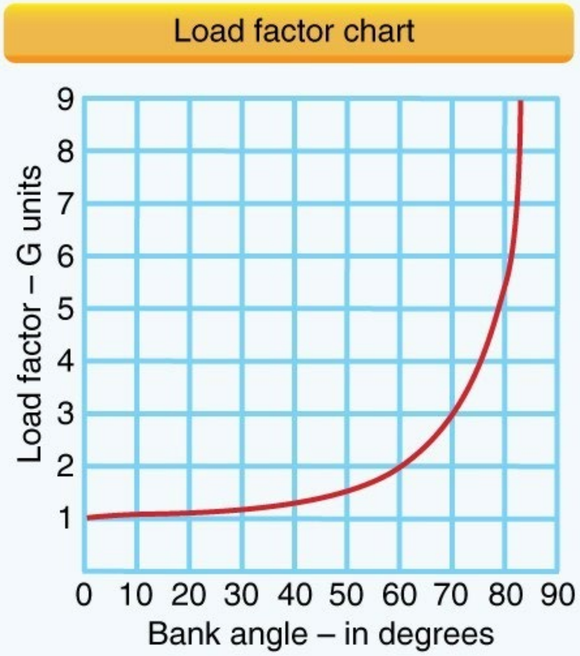


4.1 - Load Factor - *Calculation Example #2*

(Refer to figure) If an sUAS weighs 10 pounds, what approximate weight would the sUAS structure be required to support during a 60° banked turn while maintaining altitude?

A. 10.15 pounds
B. 30 pounds
C. 20 pounds

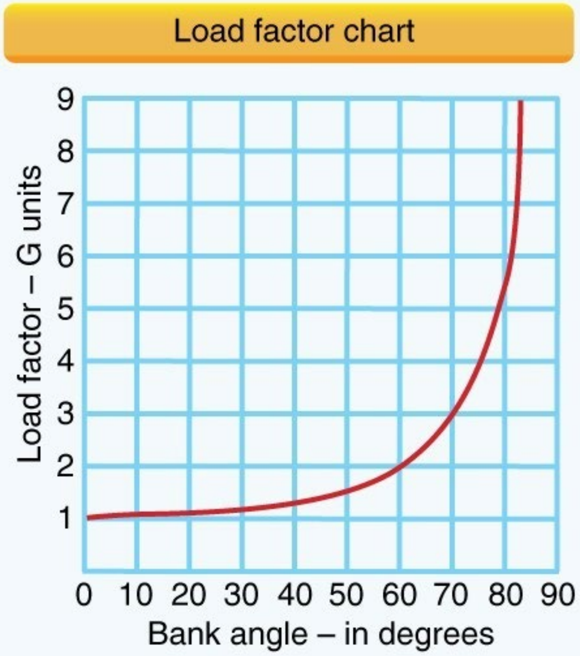
Angle of bank ϕ	Load factor n
0°	1.0
10°	1.015
30°	1.154
45°	1.414
60°	2.000
70°	2.923
80°	5.747
85°	11.473
90°	∞



4.1b - Load Factor - *Calculation Example #2*

(Refer to figure) If an sUAS weighs 10 pounds, what approximate weight would the sUAS structure be required to support during a 60° banked turn while maintaining altitude?

Angle of bank ϕ	Load factor n
0°	1.0
10°	1.015
30°	1.154
45°	1.414
60°	2.000
70°	2.923
80°	5.747
85°	11.473
90°	∞

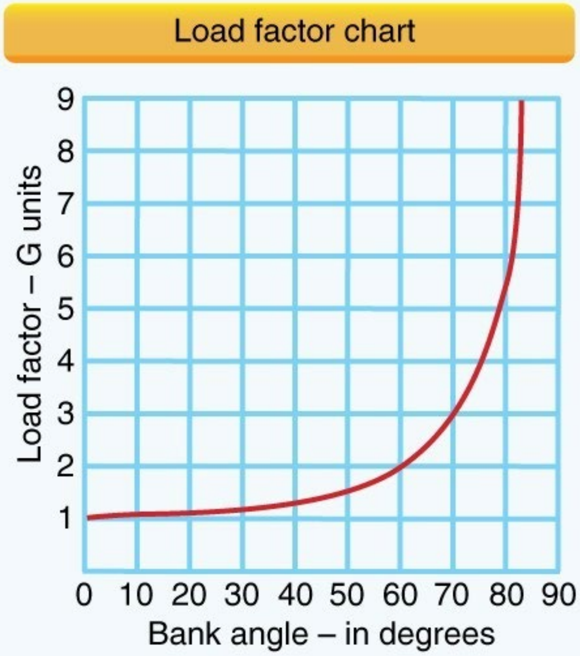


A. 10.15 pounds
B. 30 pounds
C. 20 pounds

4.1b - Load Factor - *Calculation Example #3*

(Refer to figure) If an sUAS weighs 50 pounds, what approximate weight would the sUAS structure be required to support during a 30° banked turn while maintaining altitude?

Angle of bank ϕ	Load factor n
0°	1.0
10°	1.015
30°	1.154
45°	1.414
60°	2.000
70°	2.923
80°	5.747
85°	11.473
90°	∞

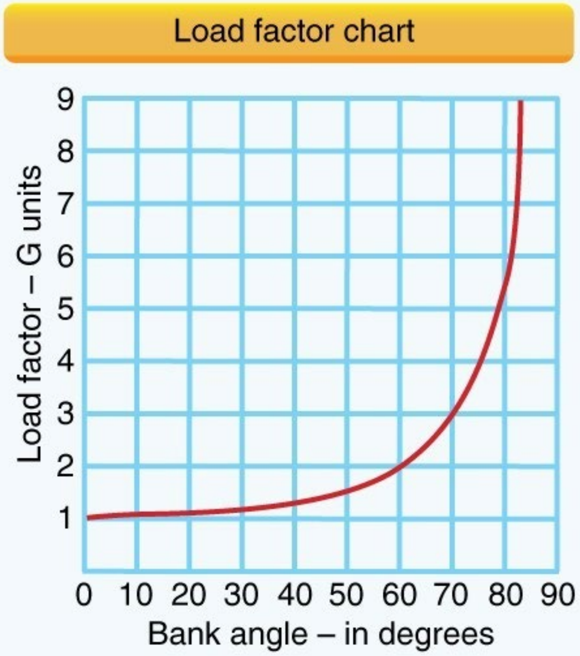


A. 60 pounds
B. 45 pounds
C. 30 pounds

4.1b - Load Factor - *Calculation Example #3*

(Refer to figure) If an sUAS weighs 50 pounds, what approximate weight would the sUAS structure be required to support during a 30° banked turn while maintaining altitude?

Angle of bank ϕ	Load factor n
0°	1.0
10°	1.015
30°	1.154
45°	1.414
60°	2.000
70°	2.923
80°	5.747
85°	11.473
90°	∞

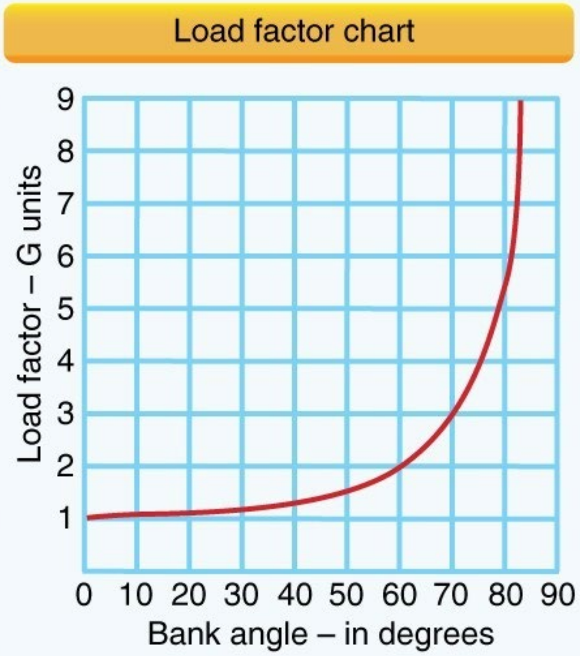


A. 60 pounds
B. 45 pounds
C. 30 pounds

4.1b - Load Factor - *Calculation Example #4*

(Refer to figure) If an sUAS weighs 33 pounds, what approximate weight would the sUAS structure be required to support during a 30° banked turn while maintaining altitude?

Angle of bank ϕ	Load factor n
0°	1.0
10°	1.015
30°	1.154
45°	1.414
60°	2.000
70°	2.923
80°	5.747
85°	11.473
90°	∞

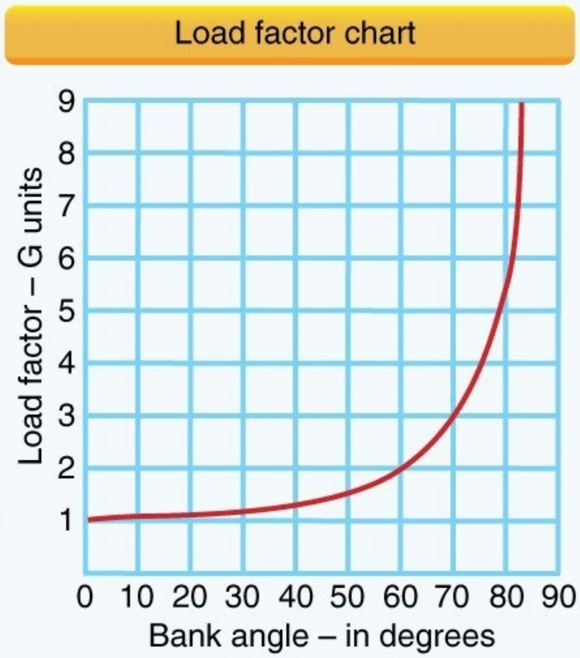


A. 34 pounds
B. 47 pounds
C. 38 pounds

4.1b - Load Factor - *Calculation Example #4*

(Refer to figure) If an sUAS weighs 33 pounds, what approximate weight would the sUAS structure be required to support during a 30° banked turn while maintaining altitude?

Angle of bank ϕ	Load factor n
0°	1.0
10°	1.015
30°	1.154
45°	1.414
60°	2.000
70°	2.923
80°	5.747
85°	11.473
90°	∞



A. 34 pounds
B. 47 pounds
C. 38 pounds

Why is it possible to use the same load factor chart for all aircraft?

Why is it possible to use the same load factor chart for all aircraft?

Gravity is esentially a constant force. Different gravity would result in a different load chart.

4.1 - Balance, Stability, & Center of Gravity

4.1 - Balance, Stability, & Center of Gravity

Weight & Lift

Gravity counteracts lift.

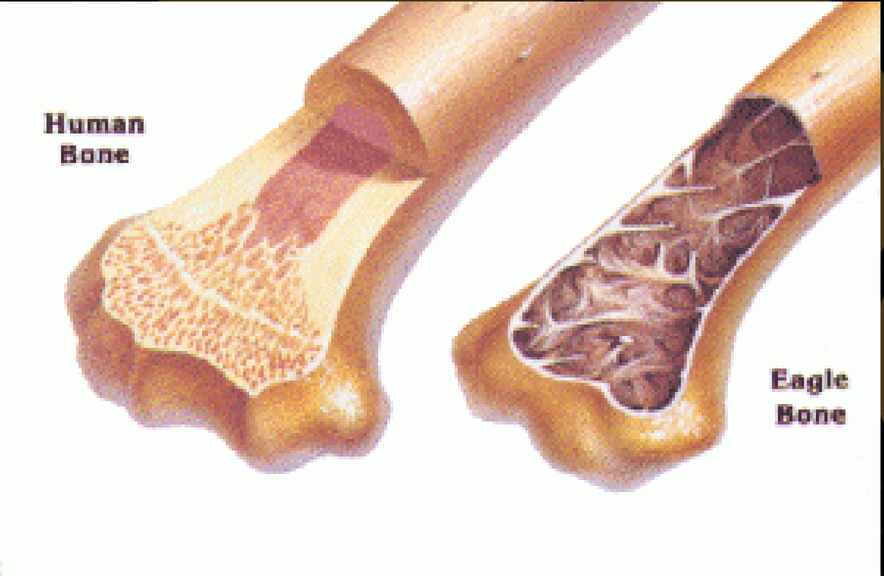
Without lift an airplane can not fly.

- Weight > Lift = Ground
- Weight < Lift = Flight

Smithsonian

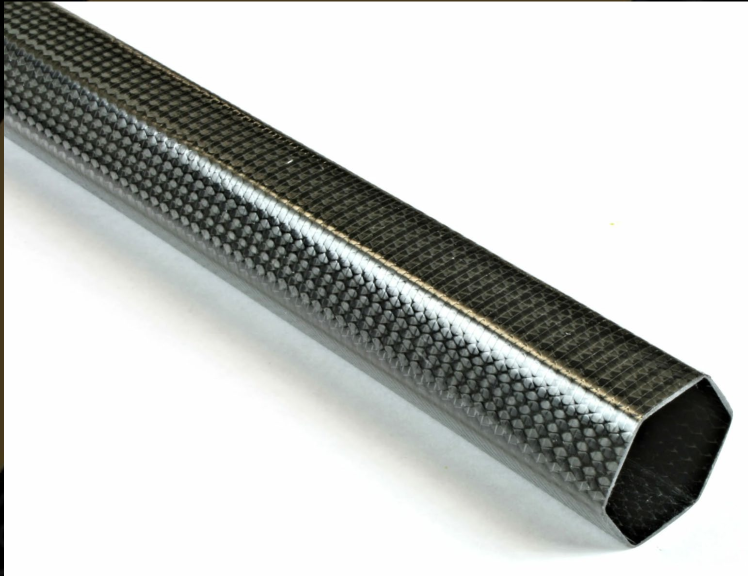
4.1 - Balance, Stability, & Center of Gravity

- It's pretty simple. Less weight requires less lift.



LREI

Bird Bones



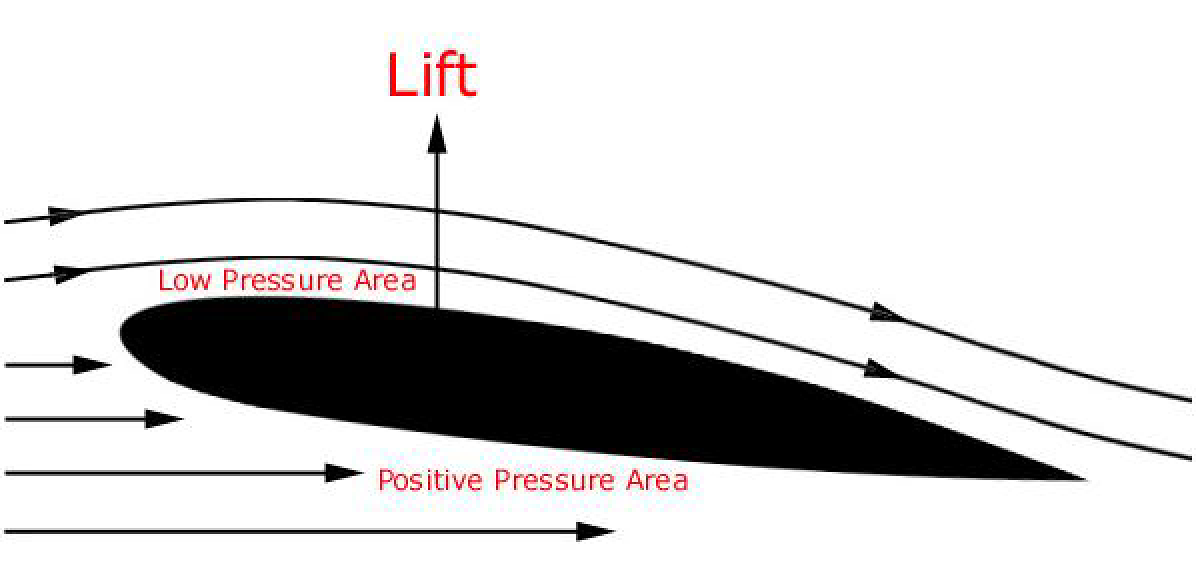
DragonPlate

Carbon Fiber

How do aircraft generate lift?

How do aircraft generate lift?

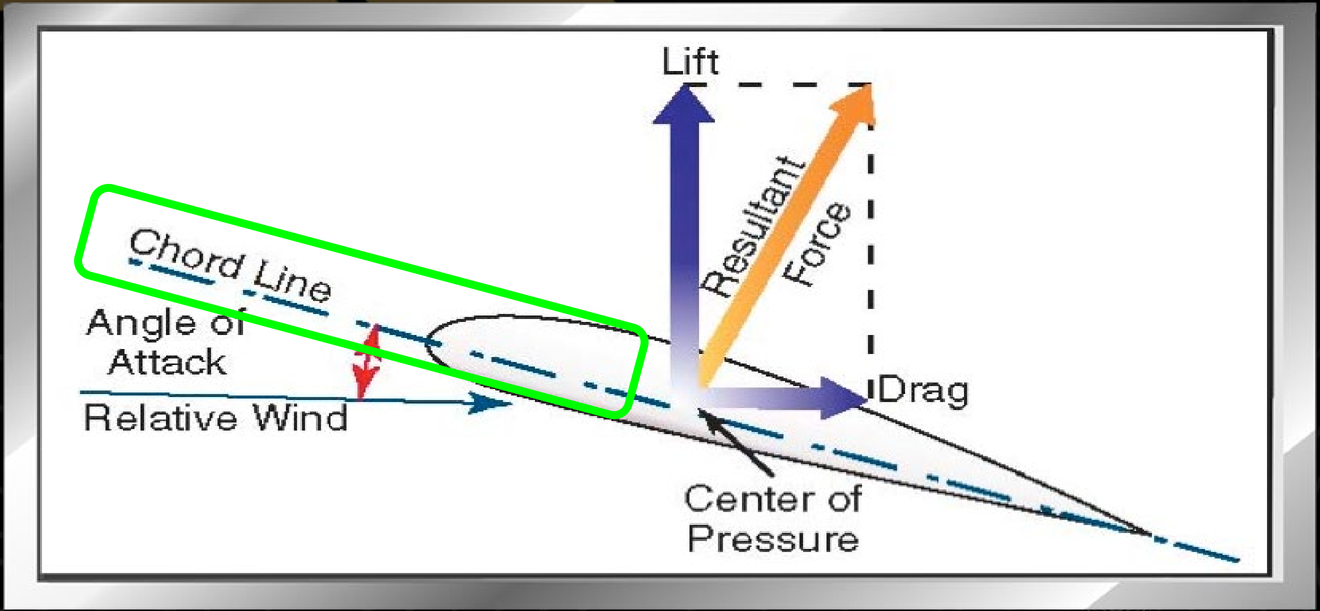
By moving air over an airfoil.



FliteTest

4.1 - Balance, Stability, & Center of Gravity

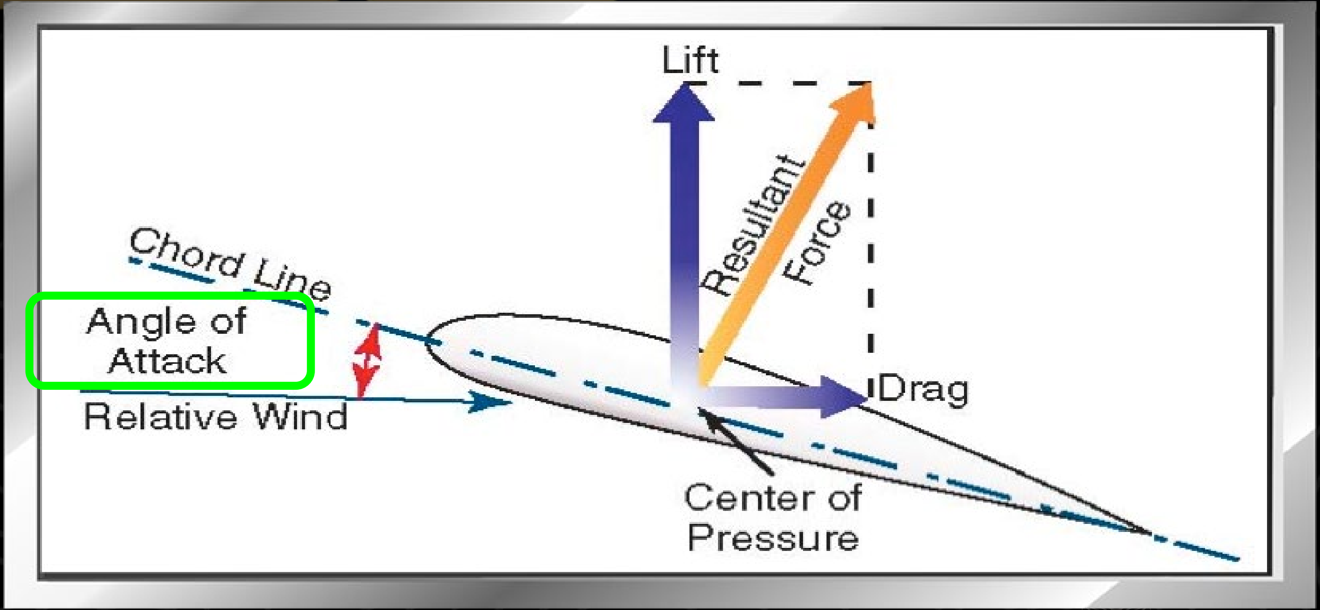
- Chord Line - an imaginary line from the leading edge of an airfoil to the trailing edge. Used to measure the angle of attack between the airfoil and the wind.



ResearchGate

4.1 - Balance, Stability, & Center of Gravity

- Angle Of Attack - the angle between the direction of the wind and the chord of an airfoil.



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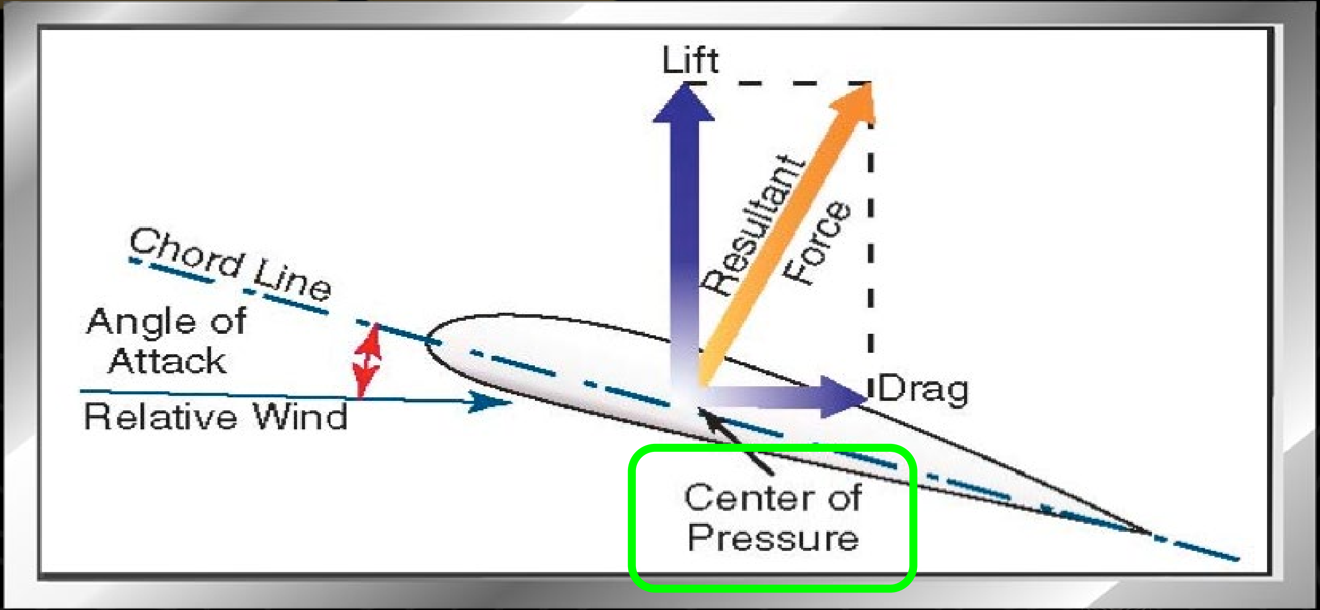
4.1 - Balance, Stability, & Center of Gravity

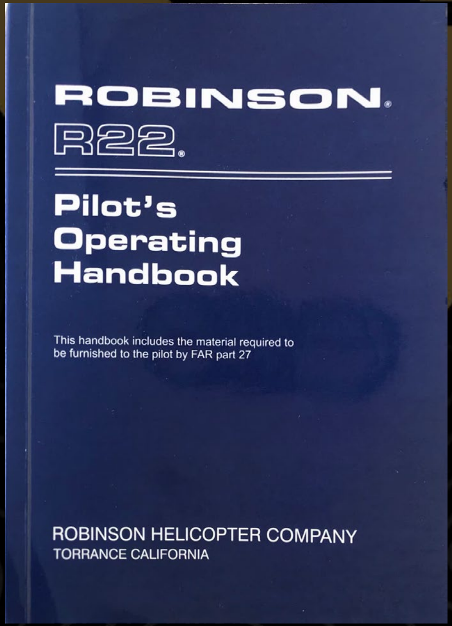
- Center of Pressure - The focal point of the lift force. The center of pressure changes depending on the angle of attack.



ResearchGate

4.1 - Balance, Stability, & Center of Gravity

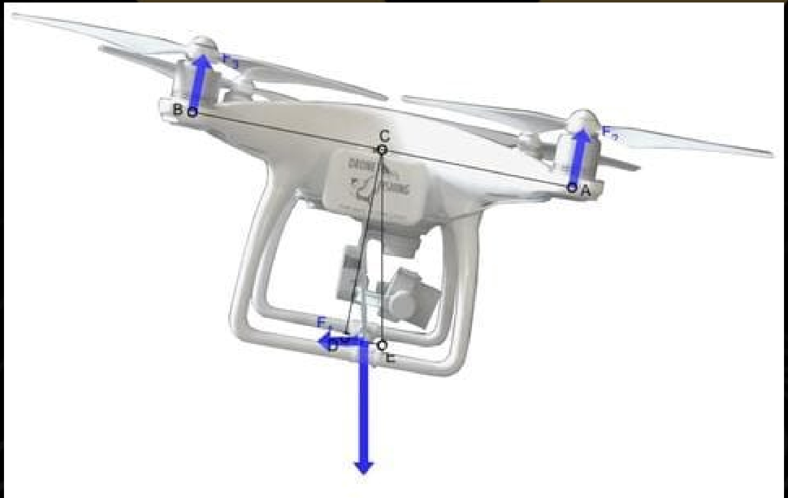
To make sure that your CG limits are not exceeded you need to follow the aircraft loading instructions in the Pilot's Operating Handbook or UAS Flight Manual.



4.1 - Balance, Stability, & Center of Gravity

Balance - refers to the location of the center of gravity.

The CG is determined by balancing the weight in the fore and aft locations along the longitudinal axis.



Drone Fishing

What might happen if the center of gravity is not even?

What might happen if the center of gravity is not even?

If the CG of an aircraft is not properly balanced, it can lead to significant flight performance and safety issues. Here's what might happen:

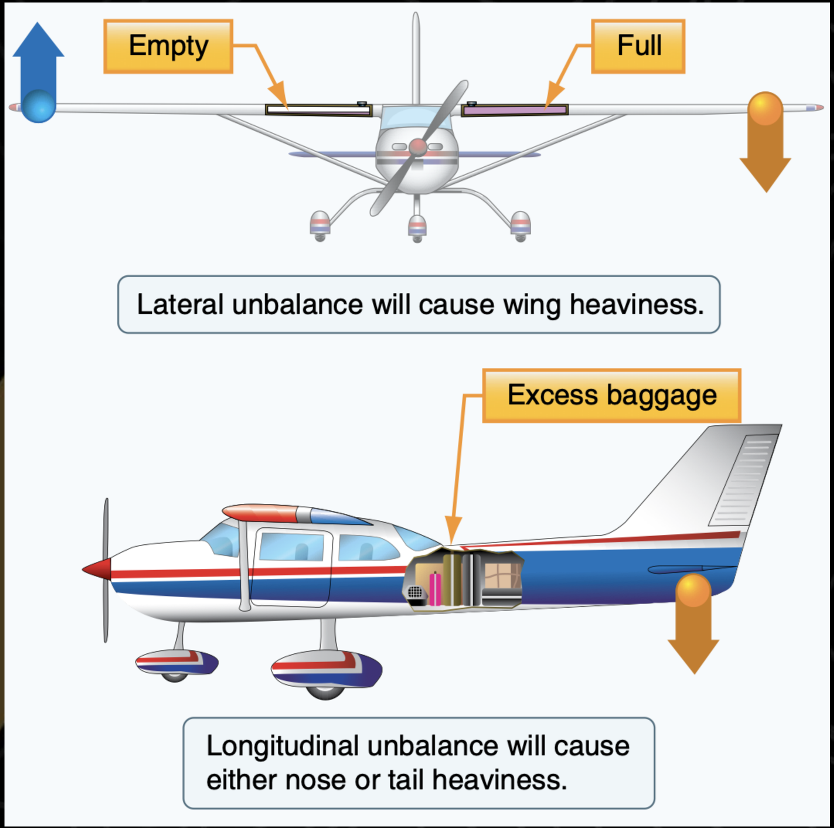
Welcome to Physics 101

Datum, Arm, Station, & Moment

4.1 - Balance, Stability, & Center of Gravity

The CG is not always a fixed point. The CG can change based on payload and fuel considerations.

If the CG is outside of manufacturer recommendations poor performance will occur.



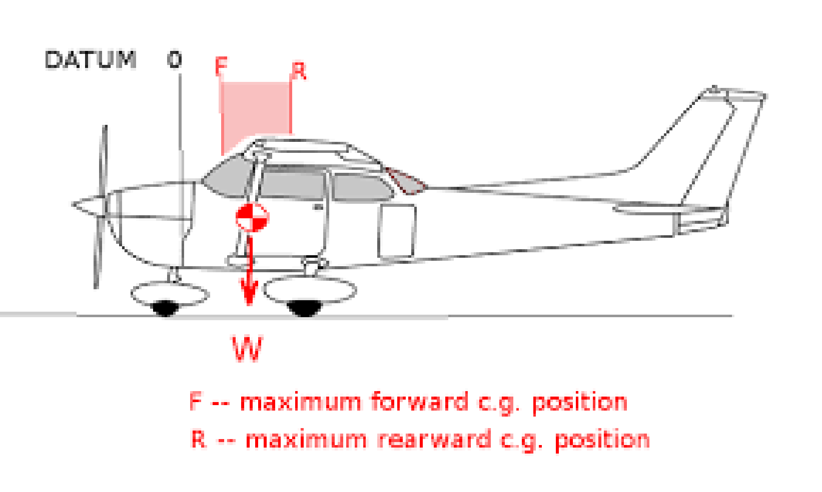
4.1 - Determining The Center of Gravity

- When adding or removing weigh the UAVs flight characteristics will be impacted.
- Determining weight is simple, all you need is a scale.
- Weight must be distributed as to keep the CG inside of manufacturer recommendations.

4.1 - Determining The Center of Gravity

CG Range & Datum

- The safe zone within which the balance point (CG) must fall is called the **CG Range**.
- The center of the CG range is known as a **datum reference**.

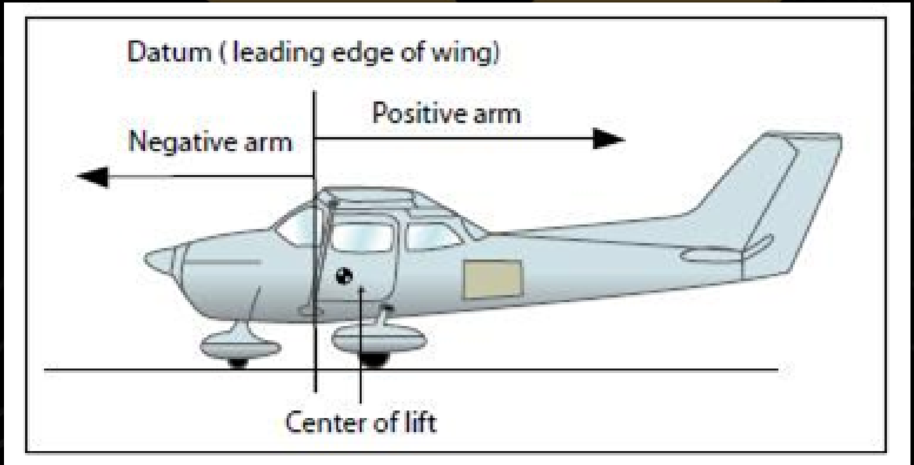


FAA

4.1 - Determining The Center of Gravity

Arm

- The distance from the datum to an object with mass is called an **arm**.
- The **arm** is measured as either positive (+) or negative (-) from the datum.



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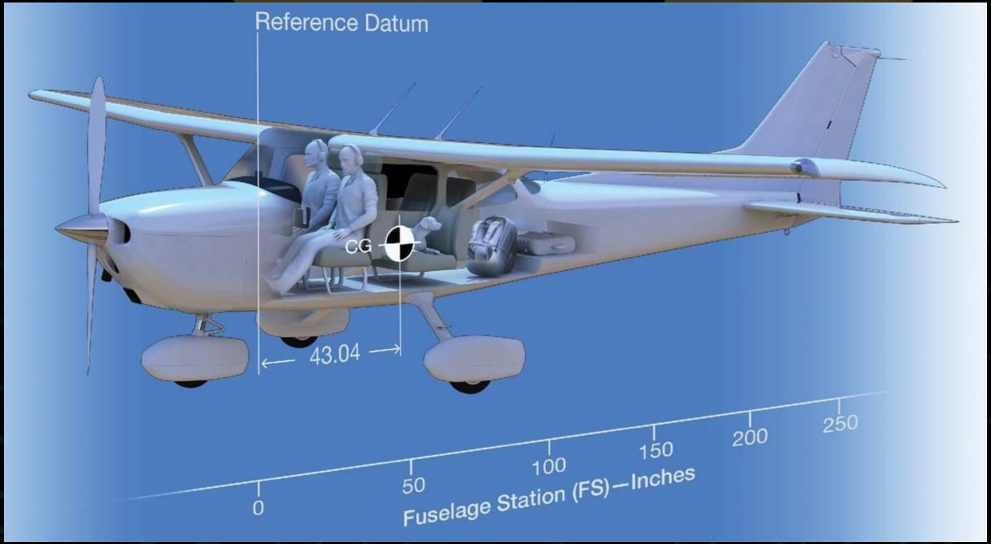
4.1 - Determining The Center of Gravity

Station

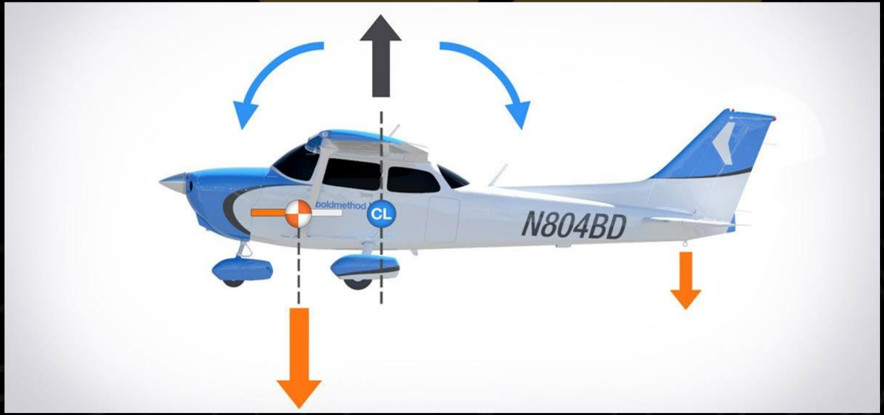
- The location of an object (positive or negative) from the datum is known as the **station**.



Globalair

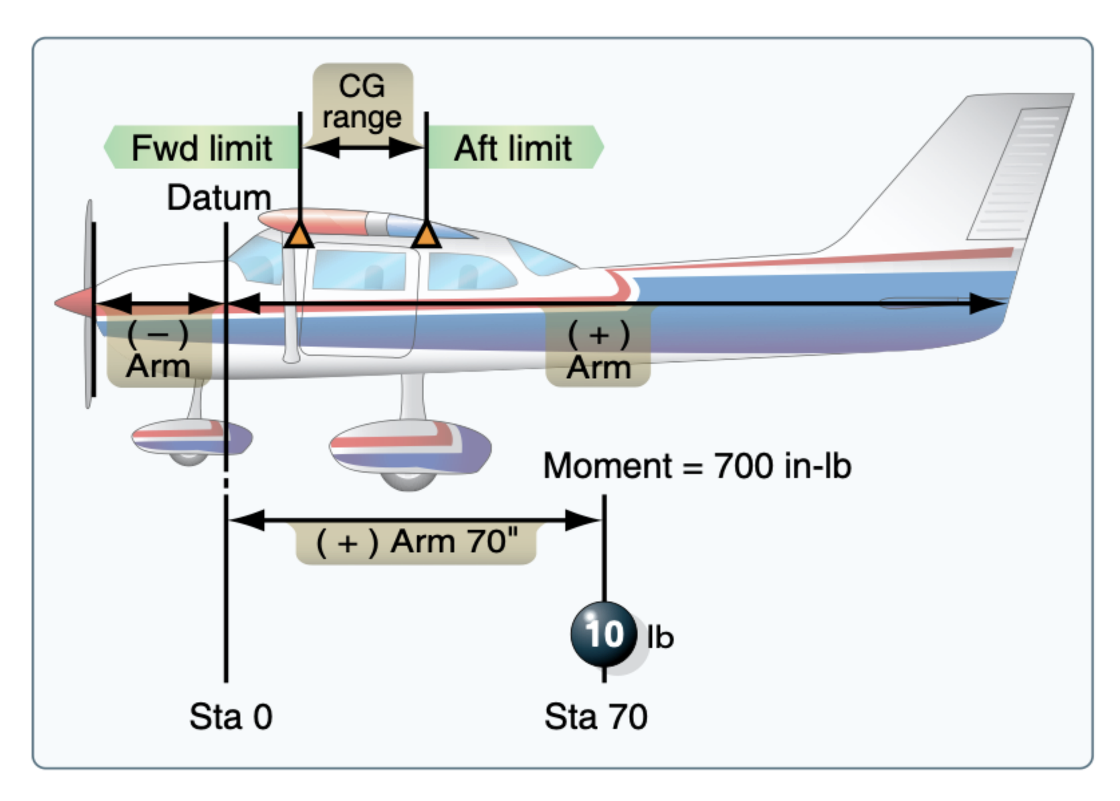
4.1 - Determining The Moment

- By multiplying the weight of an object by the arm (distance from the datum) you will find the **moment**.
- The moment is a measure of gravitational force that causes a weight to rotate on an axis.
- Moment is expressed in inch-pounds (in-lb).



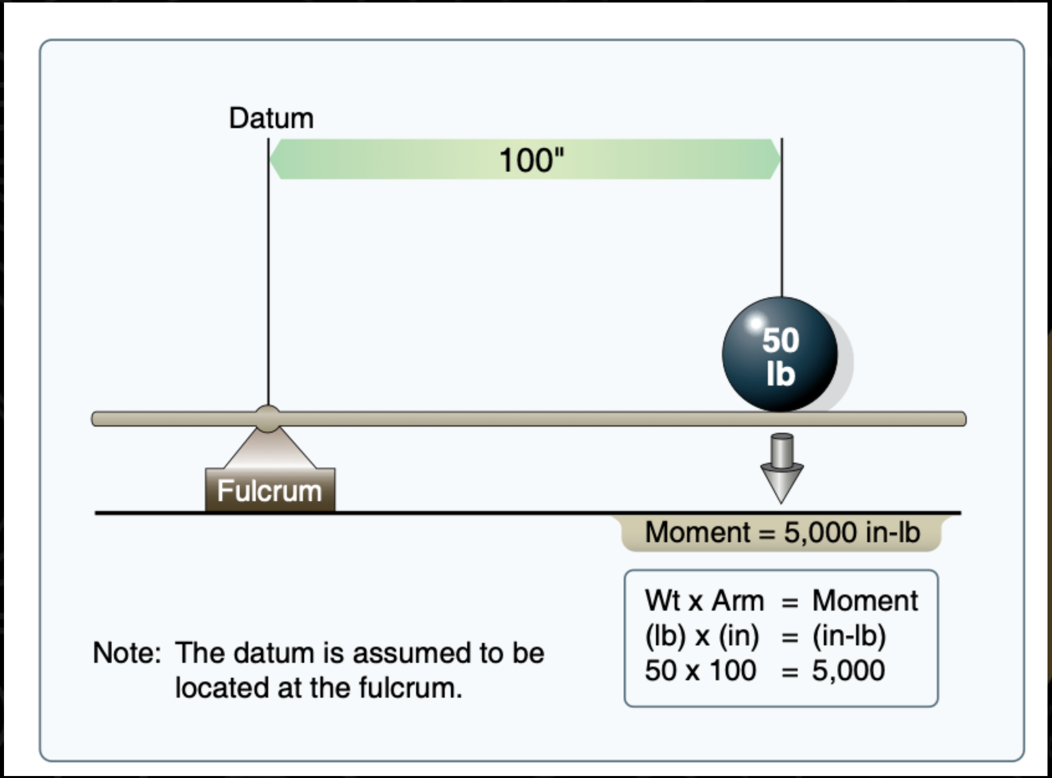
Boldmethod

4.1 - Determining The Moment



FAA

4.1 - Determining The Moment



FAA

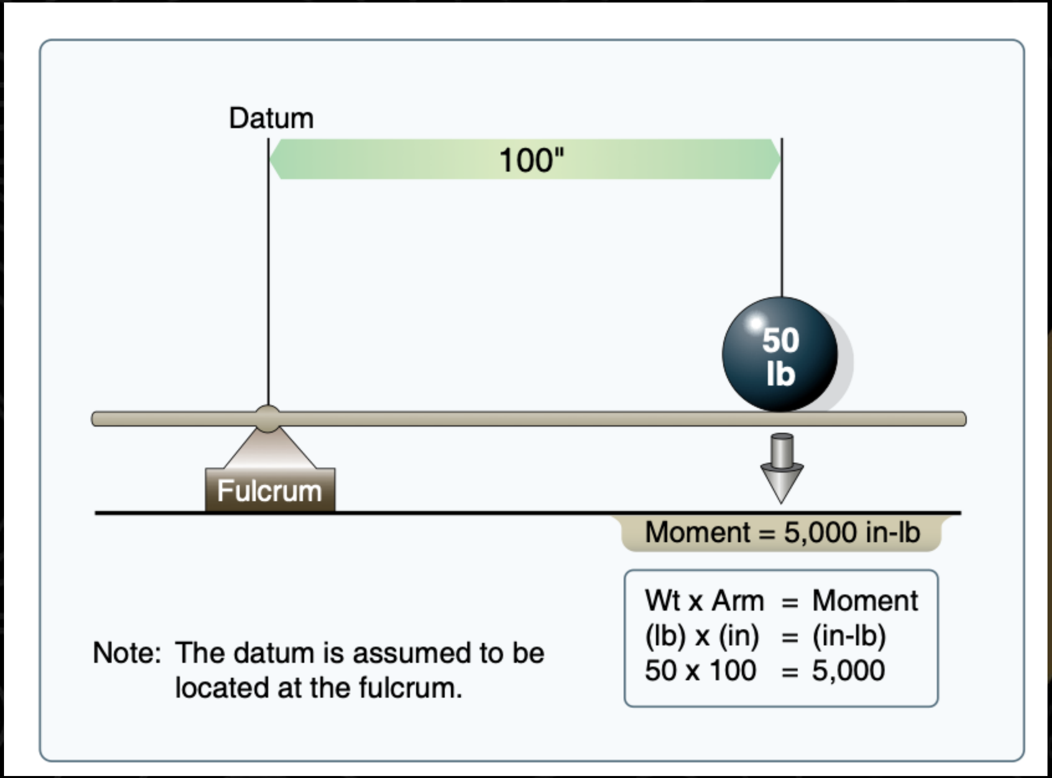
Weight x arm = moment
(lb) (in) (in-lb)

What is the weight?

What is the arm?

What is the moment?

4.1 - Determining The Moment



FAA

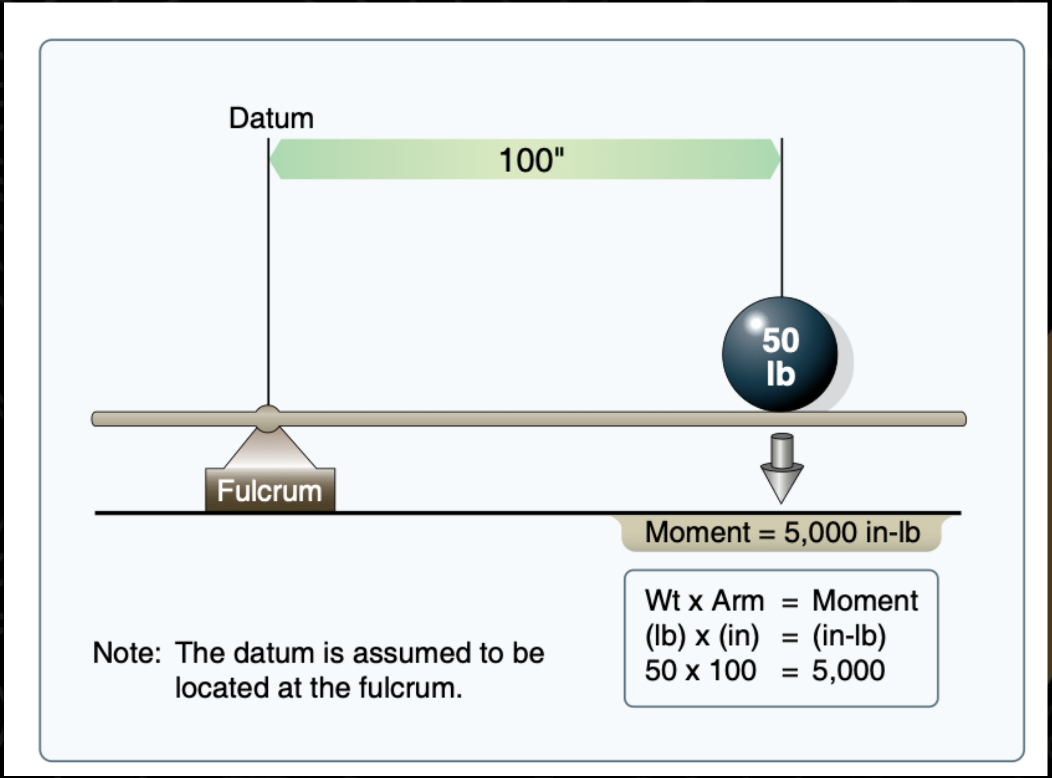
Weight x arm = moment
(lb) (in) (in-lb)

What is the weight?
50lb

What is the arm?
100in

What is the moment?
50 x 100 = 5,000 in-lb

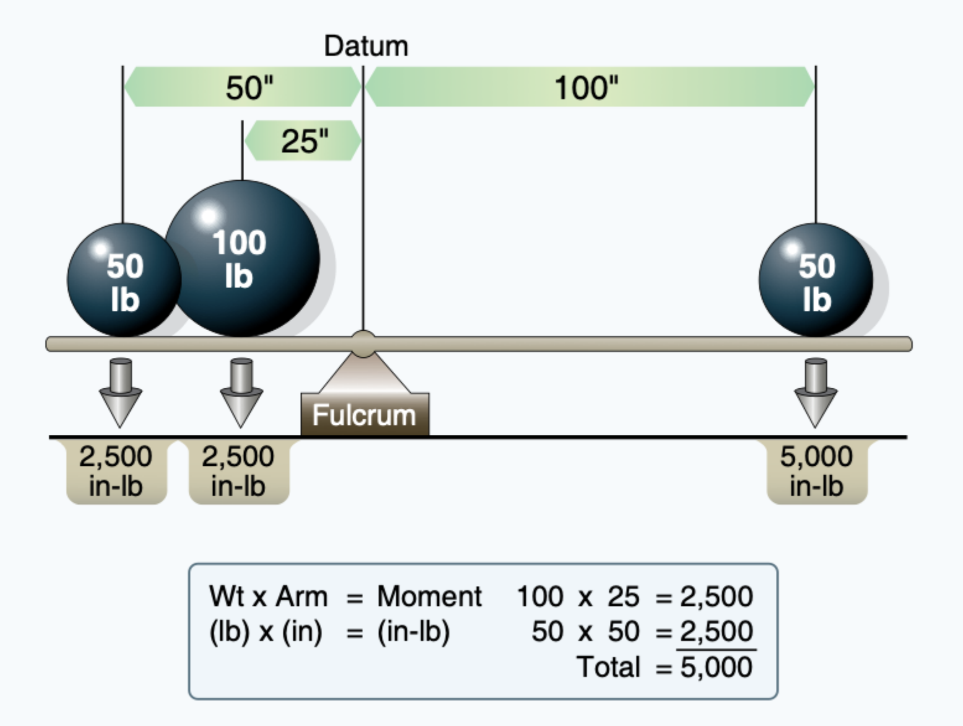
4.1 - Determining The Moment



FAA

Q: How would we establish balance with a moment of 5,000 in-lb on one side of the aircraft?

4.1 - Determining The Moment



FAA

Q: How would we establish balance with a moment of 5,000 in-lb on one side of the aircraft?

A: Add 5,000 in-lb on the opposite side of the datum.

What might happen if the moment of one arm is different from the other?

What might happen if the moment of one arm is different from the other?

Unbalanced CG can result in:

- Erratic flight behavior (drifting, oscillations).
- Overcompensation by flight controller, reducing efficiency.
- Increased battery usage due to motor imbalance.
- Difficulty holding altitude or position in GPS or ATTI mode.

4.2 - Effects of Loading On Performance

4.2 - Effects of Loading on Performance

Loading is simply the amount and distribution of weight carried by an aircraft, including its own structure and any additional payload.

4.2 - Effects of Loading on Performance

Improper loading can result in the following issues:

- Structural integrity
- Unstable flight
- Loss of control
- Lowered stall speed
- Difficulty landing

4.2 - Effects of Loading on Performance

Weight & Lift

- Manufacturers set weight and balance limits of UAVs.
- If you exceed maximum weight limits compromise structural integrity.
- If your center of gravity is outside of approved weight limits the UAV will be difficult to control.

4.2 - Effects of Loading on Performance

Balance & Stability

Some of the effects of adverse balance are:

- Poor Stability - increased stress of frame and inability to recover from stalls and spins.
- Poor Control - difficult landings, unstable flight characteristics.

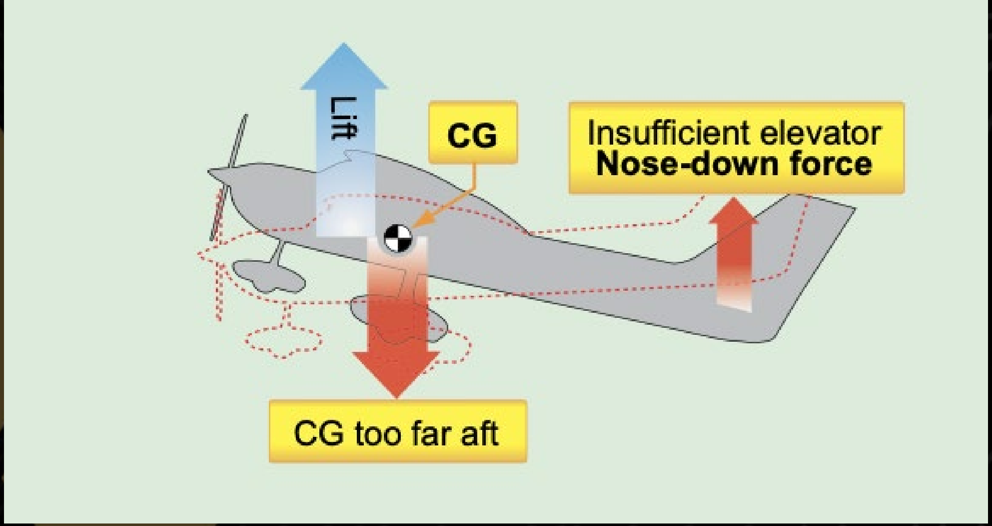
Business Insider

4.2 - Effects of Loading on Performance

Center of Gravity

If the CG is too far aft (towards the back) it can be hard to move the nose down.

This configuration can result in insufficient lift and a higher stall speed.



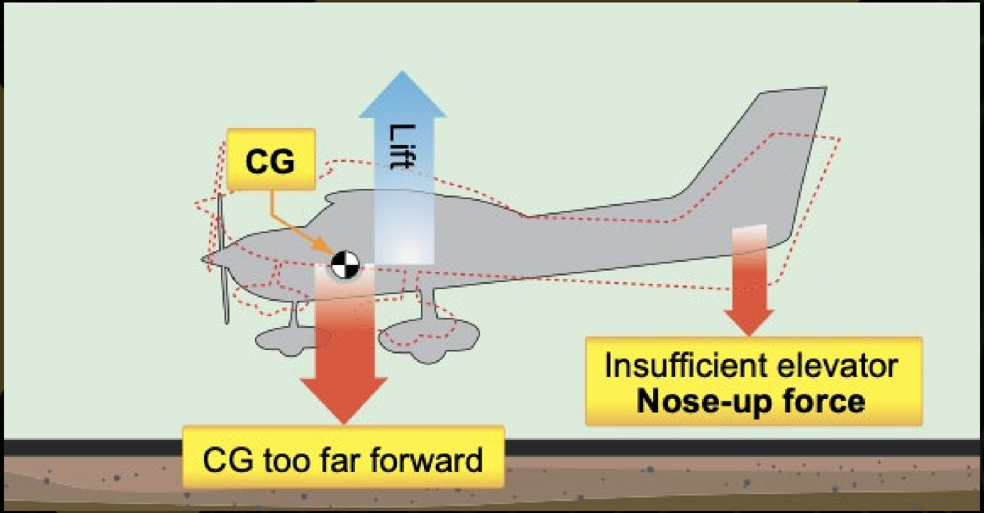
Aviation Law Monitor

4.2 - Effects of Loading on Performance

Center of Gravity

If the CG is to far forward it can be hard to move the nose up.

This configuration can result in improper angles at landing.



Aviation Law Monitor

4.2 - Effects of Loading on Performance

- It’s important to remember that being within limits doesn’t necessary mean it is safe to fly.
- Other factors that need to be considered before takeoff are:
    - Elevation
    - Temperature
    - Humidity / Density Altitude
    - Wind
    - Obstacles

What are some potential problems with weight and balance issues?

What are some potential problems with weight and balance issues?

- Loss of Stability or Control
- Motor Overload or Uneven Propulsion
- Decreased Flight Time
- Sensor or Camera Inaccuracy
- Increased Risk of Crash
- Regulatory Violations

Unit 4 Loading & Performance – 4.1 Review Quiz

- 4.1 - Loading & Performance – QUIZ
- This quiz contains 39 questions.
  - You may take it as many times as you like.
  - The order of questions are randomized each time.
  - The large majority of the questions are worded exactly as they appear on the exam.