

AIRCRAFT WEIGHT AND BALANCE**WEIGHTY CONCEPTS AND CALCULATIONS**

Working individually, complete the following activities to demonstrate your understanding of these concepts from the lesson:

- The relationship between weight and balance
- How weight and balance are determined on an aircraft
- The effects on an aircraft when operating outside of weight and balance limitations

FUNDAMENTALS

1. Define the following terms.

Weight - *the force exerted on an aircraft by gravity*

Datum - *an arbitrarily chosen point from which all other locations are measured in inches fore (forward) or aft (behind); considered "station zero"*

Arm - *the distance from the reference datum to any aircraft component or loaded station*

Moment - *the product of the weight of an item multiplied by its arm.*

Center of gravity (CG) - *the point at which an airplane would balance if it were possible to suspend it at that point. Theoretical point at which entire weight of the aircraft is assumed to be concentrated.*

2. Describe the concept of "CG range" on an aircraft.

Most aircraft are designed so that the CG can shift aft or forward within a limited range and still permit the airplane to safely fly. The CG range is the distance between the forward and aft limits for the allowable center of gravity. A CG range is determined for each aircraft by the manufacturer. An aircraft must be operated within the CG range and at or under the maximum allowable weight for safe flight. Operation outside the CG range will result in control difficulty.

3. Why is it important for an aircraft to have an acceptable range of CG?

If an aircraft could fly safely with only one CG location, it would severely limit the utility of the aircraft. Engineers take this need into account when designing aircraft to ensure they are safe to operate in a variety of loading configurations. A CG range allows an aircraft to be operated with various passenger, fuel, and baggage configurations.

4. Does the CG of an aircraft change if the passenger in the front seat moves to the back seat? Why or why not?

Yes. The weight has shifted to the back seat, so the arm for that weight is now longer; therefore the load moment is larger. Since CG is a function of both weight and load moment, the CG will change when the moment changes.



CALCULATIONS

Refer to the graphs in **Aircraft Weight and Balance Student Notes 1** to complete the scenario below.

Consider the following loading scenario for the Cessna 172S, which has a maximum gross weight of 2,550 lbs:

Aircraft empty weight	1,547 lbs
Empty load moment	58,331 in-lbs
Weight of pilot	184 lbs
Weight of front-seat passenger	215 lbs
Weight of backseat passenger 1	96 lbs
Weight of backseat passenger 2	174 lbs
Weight of cargo in baggage area A	55 lbs
Gallons of fuel	53 gallons

5. Is the aircraft legal and safe to fly, based on your weight and balance calculations? Why or why not?

No, the total takeoff weight of 2,581 pounds is above that airplane’s maximum gross weight of 2,550 lbs.

ITEM	WEIGHT	MOMENT
Basic Empty Weight	1547	58.33
Usable Fuel	318	15.5
Pilot and Front Passenger	399	15
Rear Passengers	270	20
Baggage Area A	55	5.5
Baggage Area B	0	0
RAMP WEIGHT & MOMENTS	2589	114.3

Fuel allowance for start, taxi, runup	- 8	- .4
TAKEOFF WEIGHT & MOMENT	2581	113.93
CG = 44.14 inches		



6. If the configuration is not within limits, what actions could you take to bring it into compliance?

The problem is weight, so the most likely solution here is to reduce total weight. Theoretically, you could offload some gas, but most airports won't allow you do that for safety reasons. Alternatively, a pilot could remove baggage or leave a passenger behind. In this scenario, the airplane would just be under the maximum allowable gross takeoff weight if the baggage is removed.

7. If no changes were made, what effect would this loading scenario have on the aircraft's takeoff performance?

The airplane is heavy, so it will need more speed and therefore a longer runway for takeoff. After liftoff, the airplane may not climb as well so there should be concern about clearing obstacles like trees or power lines. The airplane may also not climb as well

APPLICATIONS

Answer the questions below the following scenarios.

SCENARIO 1

- An aircraft is loaded to maximum gross takeoff weight.
- It's CG is 2 inches in front of its forward CG limit.

Is this aircraft safe and legal to fly?

No. Aircraft should never be flown outside of their published CG limits.

What effect does a forward CG have on:

- Aircraft handling during takeoff and landing?

Forward CGs are dangerous—especially during landings—because they may result in nose heaviness, making it difficult or impossible to flare for landing. A forward CG can also make it difficult to lift the nose on takeoff.

- Stall speed and recovery factors?

The aircraft will stall at a higher-than-normal airspeed, which could mean a faster landing approach and longer landing roll. On the other hand, a forward CG can enhance stall recovery, since the technique to recover from a stall is to lower the nose (angle of attack) to gain better airflow over the wings. Since the CG is forward, the nose will be easier to push down, making it easier to recover from a stalled condition.



SCENARIO 2

- An aircraft is loaded 50 pounds below gross weight.
- It's CG is 3 inches aft of its rear CG limit.

Is this aircraft safe and legal to fly?

No. Aircraft should never be flown outside of their published CG limits.

What effect does an aft CG have on:

- Aircraft handling during takeoff and landing?

With an aft CG, there is a danger of "over-rotating" during takeoff, creating the possibility of excessive nose-up pitch and a stall close to the ground.

- Stall speed and recovery factors?

Stall speed decreases with an aft CG (a good thing); however, should a stall occur, recovery could be difficult or even impossible. The result could be an aerodynamic spin, a flat spin, or an uncontrolled impact with the ground in the stalled condition.