AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

YOU must be able to predict the performance of your aircraft to operate safely in and out of airports, and understand its climb and cruise performance. You must also be able to safely load your aircraft, know when you are overloaded and weather the center of gravity is too far forward or aft.

Pilot’s Operating Handbook (POH) specific to THAT airplane contains:

Airspeed Calibration for Normal and Alternate Static Sources)  
Stall Speeds (Fore-Aft CG)  
Take Off Distances  
Rate of Climb  
Time, Fuel, and Distance to Climb  
Cruise Performance  
Range Profile  
Endurance Profile  
Landing Distance  
and much, much more…
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

FACTORS INFLUENCING PERFORMANCE

Pressure Altitude. Understand that engineer’s create performance charts and tables based on a sea level pressure and altitude. Pressure altitude is that altitude which is indicated on your altimeter when you select 29.92 in the Kollsman window.

Looking at the sample takeoff chart, you can see that the given pressure altitude of 1,500 feet falls between the 1,000- and 2,000-foot pressure altitude values.

This means if the outside air temperature is 30°C, your ground roll distance will fall between 1,090 and 1,200 feet.

To solve for ground roll, interpolation is necessary. You must first compute the differences between the known values.

The 1,500-foot airport pressure is 50% of the way between 1,000 and 2,000 feet. Therefore, the ground roll also is 50% of the way between 1,090 and 1,200 feet. The answer then, is 1,145 (110-foot difference x .5 + 1,090 feet = 1,145).

Difference in PA changes takeoff Roll.
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

How do you determine Pressure Altitude from Indicated Altitude?

1. Note Kollsman Window, write pressure, set to 29.92. Altimeter now indicates Pressure Altitude. REMEMBER TO RESET.

2. Head work, determine difference of pressure set in Kollsman window and 29.92. If greater than 29.92, you multiply by 1000 and REDUCE from Indicated altitude. If less than 29.92, you multiply by 1000 and ADD to the Indicated altitude.

INDICATED ALT = 2500

<table>
<thead>
<tr>
<th>Kollsman</th>
<th>30.42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference = -0.50 x1000 = -500 ft</td>
<td></td>
</tr>
<tr>
<td>29.92</td>
<td></td>
</tr>
</tbody>
</table>

PRESSURE ALTITUDE = 2000 FT

INDICATED ALT = 3300 FT

| Difference = -0.80 x1000 = +800 ft |
| 29.12 |

PRESSURE ALTITUDE = 3300 FT
Density Altitude: Non-standard TEMPERATURE effects on the airplane. We calculated using E6B, but can use POH performance charts.
DENSITY ALTITUDE

What is it?

Why is it important?

Effect on performance

There are many graphic charts which can be used to determine density altitude.
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

DENSITY ALTITUDE CHARTS come in many flavors, you could see any of these on your FAA exam. All basically the same. Find the intersect of the Pressure Altitude and Temperature, then follow to read Density Altitude.

Example: +16 C  Press. Alt=4000
Density Altitude = 5000
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE
DENSITY ALTITUDE

Practice Problems:

Pressure Alt. = 8000
Temperature = 16 C
Density Altitude = 10,000

Indicated Alt. = 3500
Altimeter setting = 29.42
Temperature = 30 F
Density Altitude = 3,000

30 F = -1 C
29.92
29.42
+.50 x 1000
Diff = + 500
Press. Alt = 3500 + 500 = 4000
GA manufacturers recommend not exceeding **20% VS0** C182 56 kts mx=12 kts

Take Off RWY 04 Winds 070@30

Wind speed (Bottom follow blue circle) Intersect Wind difference 70-40=30 (follow pink)

Has same effect as a direct headwind of 26 and 90 degree crosswind =15

Wind 350@15 for runway 04
Is it recommended by Cessna to takeoff in the C182?

**50 degree runway/wind difference**
H/W COMPONENT = 9
X/W COMPONENT = 11-12
RECOMMENDED? Yes, but if gusting higher NO
X-Wind Component - MENTALLY

**You can do this in your head – easily 😊**

1. Take the difference in your Runway / TC and the wind direction (i.e. 30 degrees)
2. Add 20 to it and use that as a percentage i.e. $(30+20)=50\% \ (0.50 \text{ decimal})$
3. Multiply that by the wind speed.

**Examples** (Rwy 09, winds 050@10)
- Difference $= 40+20 = 0.6*10 = 6$
- Rwy 360, winds 310@30
  - Difference $= 50+20 = 0.7*30 = 21$: X/W component $= 21$

If tailwind such as 200 at 20, landing runway 30 (bad idea)
we use the reciprocal of heading $30+180=210$, and $210-200$=difference of $10+20=30$, covert to $0.3$ multiply wind speed $20= X/W$ component of $7$
Figure your Headwind Component MENTALLY if you know square roots

\[ a^2 + b^2 = c^2 \]
\[ HW^2 + XW^2 = WV^2 \]
\[ HW^2 = WV^2 - XW^2 \]

\[ HW = \text{Square Root} \left( \text{Wind Velocity}^2 - X\text{Wind Component}^2 \right) \]

\[ \text{WHY would I ever want to do such a thing? Safety and precision.} \]

Example Taking off runway 040 with winds of 080 at 10
1. X-Wind Component is 40+20=-.6*10=6
2. \[ HW = \text{SQR}(100-36)=\text{SQR}(64)=8 \]

Example Flying 90 KTs on a TC of 180 with winds of 210 at 12
X-Wind Component is 30+20=-.5*12=6
\[ HW = \text{SQR}(144-36)=\text{SQR}(108)=\text{approximate 10.4} \]

Ground speed is the TAS +/- HW: \[ GS = 90-10=80 \]
Let’s take it up a notch 😊

We can mentally determine WCA, to get our TH, and also determine GS in our head! Prerequisite: know your speed in miles / minute - and it’s reciprocal (1/x)

<table>
<thead>
<tr>
<th>TAS</th>
<th>Nm/Min</th>
<th>XW Mult</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>75</td>
<td>1.25</td>
<td>0.80</td>
</tr>
<tr>
<td>90</td>
<td>1.50</td>
<td>0.67</td>
</tr>
<tr>
<td>120</td>
<td>2</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Step 1. Determine your XWind component as described in previous slide.
Step 2. WCA = Multiply the XWind component by XW-Mult (give you WCA)
Step 3. TC +/- WCA = TH
Step 4. Use X/W component and wind speed for H/W component to get GS.

Flying 090 at 120 KTS, Wind 120 at 10 What is TH and GS
1. X/W component = 30+20=.5 * 10 = 5
2. Wind correction angle is 5 * .5 = 2.5 (round to 3)
3. TH = 090 + 3 = 093
4. HW = SQRT(100-25)=8.7 round to 9 … GS=120-9=111
# AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

## TAKEOFF DISTANCE

**CONDITIONS:**
- Flaps 10°
- Full Throttle Prior to Brake Release
- Paved, Level, Dry Runway
- Zero Wind

**NOTES:**
1. Short field technique as specified in Section 4.
2. Prior to takeoff from fields above 3000 feet elevation, the mixture should be leaned to give maximum RPM in a full throttle, static runup.
3. Decrease distances 10% for each 9 knots headwind. For operation with tailwinds up to 10 knots, increase distances by 10% for each 2 knots.
4. For operation on a dry, grass runway, increase distances by 15% of the "ground roll" figure.

### FACTORS
- Weight
- Temperature
- Pressure Altitude
- Head/Tailwind
- Non-std runway

<table>
<thead>
<tr>
<th>WEIGHT (LBS)</th>
<th>TAKEOFF SPEED (KIAS)</th>
<th>PRESS ALT (FT)</th>
<th>0°C</th>
<th>10°C</th>
<th>20°C</th>
<th>30°C</th>
<th>40°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIFT OFF</td>
<td>AT 50</td>
<td>TOTAL FT</td>
<td>ROLL</td>
<td>TO CLEAR</td>
<td>ROLL</td>
<td>TO CLEAR</td>
</tr>
<tr>
<td>2400</td>
<td>51</td>
<td>56</td>
<td>S. L</td>
<td>795</td>
<td>1460</td>
<td>800</td>
<td>1570</td>
</tr>
<tr>
<td>2200</td>
<td>49</td>
<td>54</td>
<td>S. L</td>
<td>650</td>
<td>1195</td>
<td>700</td>
<td>1280</td>
</tr>
<tr>
<td>2000</td>
<td>46</td>
<td>51</td>
<td>S. L</td>
<td>525</td>
<td>970</td>
<td>565</td>
<td>1035</td>
</tr>
</tbody>
</table>

*Ground School 2015*
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

Runway Surface: Many POHs only add distance for sod. Different runway surfaces can add from 5% up to 18% of ground roll to your calculations.

Runway Gradient (SLOPE): Check the Airport/Facility Directory to see if the runway has a +(upward) or -(downward) slope. Effects: takes longer to takeoff uphill than no slope or downhill.

Runway Conditions (Moisture, Snow, Ice) Even rain can extend landing and takeoff distances because of hydroplaning and braking effectiveness. Snow and ice, as in a car, can effect controllability and definitely braking. HYDROPLANING !!!
Minimum dynamic hydroplaning speed (rounded off) =

$9 \times \sqrt{\text{Tire pressure (in psi)}}$

$\sqrt{36} = 6$

$9 \times 6 = 54$ knots
How does hydroplaning effect an airplane?

**LOSS OF CONTROL** during Take Off and Landings

Here is a hydroplaning formula for determining the speed at which hydroplaning will be experienced by any aircraft.

Speed at which Hydroplaning begins = 9 x sqrt(main gear tire pressure)

Example: 25 lbs in tires. 9 * Sqrt 25 = 5, which is 9*5=45 mph

**Landings**: Dynamic/Viscous/Rubber-reverted Hydroplaning: LITTLE OR NO BRAKING with as little as 1/10th inch of water. “Cornering Force” – side forces are the square of the X-Wind Component (15 KT X-W you have 9 times less control than 5 KT X-W component)

**WHAT TO DO**: EVALUATE CONDITIONS AND RUNWAYS. CHECK TREAD that you have at least 20% original tread (after 80% wear-you have serious hydroplaning). Grooved runways help.
True Airspeed Table

We know how to do it on the E6B, but there is also a graphic to determine.
1. Identify the pressure altitude for field elevation: Kollsman window to 29.92.

2. Read column to closest temperature. (2,000@20°C) Ground roll is 1,000 feet, and distance to clear a 50 foot obstacle is 1,790 feet with an aircraft weight of 2,300 pounds.
Practice Problem: weight 2,200, PA 3000, Temp 10 C, 50-Ft Obs. Distance= 1705
Practice Problem: weight 2,200, PA 4000, Temp 10 C, 50-Ft Obs. Distance= 1890
Practice Problem: weight 2,200, PA 3500, Temp 10 C, 50-Ft Obs. Distance= **1797.5**
**REAL WORLD**: WEIGHT 2300 [BETWEEN 2200 & 2400], TEMP 5C [0C &10C], TAKE OFF PRESSURE ALTITUDE = 5500 [5000 & 6000], 18 KT HEADWIND. GROUND ROLL ON DRY GRASS RUNWAY?

---

### Table: Ground Roll on Dry Grass Runway

<table>
<thead>
<tr>
<th>WEIGHT LBS</th>
<th>TAKEOFF SPEED KIAS</th>
<th>PRESS ALT FT</th>
<th>0°C</th>
<th>10°C</th>
<th>20°C</th>
<th>30°C</th>
<th>40°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>GND</td>
<td>ROLL</td>
<td>GND</td>
<td>ROLL</td>
<td>GND</td>
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<tr>
<td>2400</td>
<td>1000</td>
<td>51</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>796</td>
<td>1460</td>
<td>601</td>
<td>1570</td>
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<td>2200</td>
<td>1000</td>
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<td>54</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
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<td></td>
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<td>650</td>
<td>1195</td>
<td>700</td>
<td>1280</td>
<td>750</td>
</tr>
<tr>
<td>2000</td>
<td>1000</td>
<td>46</td>
<td>51</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>525</td>
<td>970</td>
<td>565</td>
<td>1035</td>
<td>605</td>
</tr>
</tbody>
</table>

---

Decrease distances 10% for each 9 knots headwind. For operation with tailwinds up to 10 knots, increase distances by 10% for each 2 knots.

For operation on a dry, grass runway, increase distances by 15% of the “ground roll” figure.
WEIGHT 2300 [BETWEEN 2200 & 2400], TEMP 5C [0C & 10C], TAKE OFF PRESSURE ALTITUDE = 5500 [5000 & 6000], 18 KT HEADWIND. GROUND ROLL ON DRY GRASS RUNWAY?

THREE LEVELS OF INTERPOLATION---REDUCE 2 VALUES TO 1

1. DETERMINE PA:5500 @ 0C, 10C FOR 2400 & 2200 LBS
   *5500 is 50% > 5000
   2400 0C = (2755-2445*.5)+2445 = 2600
   2400 10C = (3015-2660*.5)+2660 = 2838
   2200 0C = (2170-1845*.5)+1845 = 2008
   2200 10C = (2355-2170*.5)+2170 = 2263

2. Determine 5C for 2200 & 2400 lbs.
   2200 5C = (2838-2600*.5)+2600 = 2719
   2400 5C = (2263-2208*.5)+2208 = 2336

3. Determine 5C for 2300 lbs.
   2300 5C = (2719-2336*.5)+2336 = 2528

4. Reduce by Headwind: 2528 – (18/9*.10) [20%]… = 2022 feet

5. Increase distance by 15% for sod. 2022 + (2022*.15 OR 303) = 2325
## LANDING DISTANCE

### SHORT FIELD

**CONDITIONS:**
- Flaps 40°
- Power Off
- Maximum Braking
- Paved, Level, Dry Runway
- Zero Wind

**NOTES:**
1. Short field technique as specified in Section 4.
2. Decrease distances 10% for each 9 knots headwind. For operation with tailwinds up to 10 knots, increase distances by 10% for each 2 knots.
3. For operation on a dry, grass runway, increase distances by 45% of the “ground roll” figure.

<table>
<thead>
<tr>
<th>WEIGHT LBS</th>
<th>SPEED AT 50 FT KIAS</th>
<th>PRESS ALT FT</th>
<th>0°C</th>
<th>10°C</th>
<th>20°C</th>
<th>30°C</th>
<th>40°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2300</td>
<td>S.L.</td>
<td></td>
<td>495</td>
<td>510</td>
<td>530</td>
<td>545</td>
<td>565</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td></td>
<td>510</td>
<td>530</td>
<td>550</td>
<td>565</td>
<td>585</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td></td>
<td>530</td>
<td>550</td>
<td>570</td>
<td>585</td>
<td>605</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td></td>
<td>550</td>
<td>570</td>
<td>590</td>
<td>605</td>
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<td></td>
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<tr>
<td></td>
<td>7000</td>
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<td></td>
<td>665</td>
<td>685</td>
<td>705</td>
<td>720</td>
<td>740</td>
</tr>
</tbody>
</table>

Figure 5-10. Landing Distance
Problem: 13C, PAIt 8000, Weight 2800, 2 Kt tailwind, takeoff over 50 ft obstacle
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

KOCH CHART – TO/CLIMB ADJUSTMENT CHART

ADD THIS PERCENTAGE TO YOUR NORMAL TAKE-OFF DISTANCE

PERCENT DECREASE IN RATE OF CLimb

AIRPORT PRESSURE ALTITUDE
(READ YOUR ALTIMETER SET TO 29.92 INCHES)

AIRPORT TEMPERATURE
DEGREES FAHRENHEIT
**AIRPLANE PERFORMANCE / WEIGHT AND BALANCE**

**DETERMINING IAS OF STALLS IN DIFFERENT CONFIGURATIONS & ATTITUDES**

### AIRSPEED CALIBRATION — NORMAL SYSTEM

<table>
<thead>
<tr>
<th>Flaps 0°</th>
<th>Flaps 15°</th>
<th>Flaps 45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>KIAS</td>
<td>KCAS</td>
<td>KIAS</td>
</tr>
<tr>
<td>80</td>
<td>84</td>
<td>70</td>
</tr>
<tr>
<td>100</td>
<td>102</td>
<td>90</td>
</tr>
<tr>
<td>120</td>
<td>122</td>
<td>100</td>
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<td>140</td>
<td>141</td>
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<td>160</td>
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<td>130</td>
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<td>200</td>
<td>201</td>
<td>140</td>
</tr>
<tr>
<td>220</td>
<td>221</td>
<td>150</td>
</tr>
</tbody>
</table>

**KIAS — INDICATED AIRSPEED IN KNOTS**

**KCAS — CALIBRATED AIRSPEED IN KNOTS**

### STALL SPEEDS — KCAS

4600 LB GROSS WEIGHT

<table>
<thead>
<tr>
<th>CONFIGURATION</th>
<th>ANGLE OF BANK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0°</td>
</tr>
<tr>
<td>Gear and Flaps Up</td>
<td>84</td>
</tr>
<tr>
<td>Gear Down and Flaps 15°</td>
<td>80</td>
</tr>
<tr>
<td>Gear Down and Flaps 45°</td>
<td>76</td>
</tr>
</tbody>
</table>

**What would be the indicated stall speed in a 30° banked turn with the gear down and flaps set at 15°?**

A ← 77 KIAS.
B ← 82 KIAS.
C ← 88 KIAS.

1. Bank 30 = (83 + 92) / 2 = 87.5 [88]

2. Difference = 6  
   Apply 88 - 6 = 82  
   Answer B - 82 KIAS

**What would be the indicated stall speed in a 40° banked turn with the gear down and flaps set at 45°?**

A ← 81 KIAS.
B ← 83 KIAS.
C ← 89 KIAS.

1. KCAS = 87

2. Difference = 4  
   Apply 87 - 4 = 83  

Answer B - 83 KIAS
# CLIMB DATA

### Conditions
- Flaps up
- Gear up
- 2,500 RPM
- 30° Hg
- 120 PPH fuel flow
- Cowl flaps open
- Standard temperature

### Notes
1. Add 16 pounds of fuel for engine start, taxi, and takeoff allowance.
2. Increase time, fuel, and distance by 10% for each 7°C above standard temperature.
3. Distances shown are based on zero wind.

<table>
<thead>
<tr>
<th>Weight (pounds)</th>
<th>Press ALT (feet)</th>
<th>Rate of climb FPM</th>
<th>From sea level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time (minutes)</td>
</tr>
<tr>
<td>4,000</td>
<td>S.L.</td>
<td>605</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4,000</td>
<td>570</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>8,000</td>
<td>530</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>12,000</td>
<td>485</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>16,000</td>
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<td>365</td>
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<td>S.L.</td>
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<td>0</td>
</tr>
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<td>4,000</td>
<td>665</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>8,000</td>
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<td></td>
<td>12,000</td>
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<td></td>
<td>16,000</td>
<td>525</td>
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<td></td>
<td>20,000</td>
<td>460</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>S.L.</td>
<td>810</td>
<td>0</td>
</tr>
<tr>
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<td>4,000</td>
<td>775</td>
<td>5</td>
</tr>
<tr>
<td>3,400</td>
<td>8,000</td>
<td>735</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>12,000</td>
<td>690</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>16,000</td>
<td>635</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>20,000</td>
<td>565</td>
<td>29</td>
</tr>
</tbody>
</table>
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE
CLIMB PERFORMANCE

Use Vx for obstacle clearance

Vy is greater than Vx but less than “cruise climb” speed.
“Normal” pattern climb speed, but after leaving pattern, use “climb cruise speed.

V-SPEEDS SPECIFIC TO YOUR AIRCRAFT AND FOUND IN THE AIRCRAFT PILOT OPERATING HANDBOOK (POH)

MEMORIZE
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

HOW HIGH WILL YOUR AIRCRAFT CLIMB? **ABSOLUTE CEILING: ROC = 0**

SERVICE CEILING is another reference altitude that the airplane will yield a rate of climb of only 100 fpm

IAS increase with $V_x$, decreases with $V_y$ at higher altitudes.
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

POH Data saves time in determining Time, Fuel, Distance.

What if you don’t TO at SL? Climbing 2000-8000? (Subtract base values)

8000=17 Min, 3.1 Gals., 22 Miles. Subtract 2000 values (3, .6, 4) Yields 14 Min., 2.5 Gals., 18 Miles
Fuel Efficiency: **SPECIFIC RANGE**

Most cars are compared on fuel efficiency by using miles per gallon. Airplane fuel efficiency is often given as “Specific Range.” It is a value derived by dividing the range in nautical miles by the pounds of fuel burned. Instead of miles per gallon, it represents miles per pound of fuel. It is a good method for comparing performance between different aircraft.

As an example, a piston airplane with a true airspeed of 150 knots while burning 12 gallons per hour (72 pounds) would have a very good specific range of 2.08. A business jet cruising at 440 knots true burning 1,200 pounds per hour (pph) has a specific range of 0.37, good for a jet.

In general, LSA’s are more efficient than other general aviation aircraft except for motor-gliders. **LSA’s have specific ranges in the 4-5 as compared to 1-2’s for many single engine general aviation aircraft.** General aviation aircraft can get much better specific ranges by **reducing power to 55-65% and only sacrificing a small airspeed loss** but getting much higher specific range and also total available range. For example a twin-engine Baron flying 170Kts burns 30 GPH, but reducing power to maintain 120Kts only burns 16 GPH. The specific range increases from .94 to 1.2 which is a 26% increase in range with only a 30% decrease in airspeed. The same holds true for all classes of aircraft.

Another thing to remember that airlines practice to the extreme is that **a lighter aircraft has to use less power and therefore is more fuel efficient.**
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

CLIMB CHARTS

TEMP 18C
Pr. Alt. = 4000
INTERSECT(3)
DOWN TO
FIND ROC
= 335-340 FPM
### Rate of Climb Charts – Interpellation required – watch fine print!

#### NORMAL CLimb - 100 KIAS

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<tr>
<th>CONDITIONS:</th>
<th>PRESS ALT</th>
<th>Mixture Setting</th>
<th>PPH</th>
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</table>

**NOTES:**
1. Add 12 pounds of fuel for engine start, taxi and takeoff allowance.
2. Increase time, fuel and distance by 10% for each 10°C above standard temperature.
3. Distances shown are based on zero wind.

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<thead>
<tr>
<th>WEIGHT LBS</th>
<th>PRESS ALT FT</th>
<th>RATE OF CLimb FPM</th>
<th>FROM SEA LEVEL</th>
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**CONDITIONS:**
- Flaps Up
- Gear Up
- 2500 RPM
- 25 Inches MP or Full Throttle
- Cowl Flaps Open
- Standard Temperature

**WEIGHT LBS | PRESS ALT FT | CLimb SPEED KIAS | RATE OF CLimb - FPM**

- **4000**
  - S.L. 100 1170 1035 895 755
  - 8000 100 1080 940 800 655
  - 12,000 100 980 840 695 555
  - 16,000 100 870 730 590 ---
  - 20,000 99 485 355 --- ---
  - 24,000 97 190 70 --- ---

- **3700**
  - S.L. 99 1310 1165 1020 875
  - 4000 99 1215 1070 925 775
  - 8000 99 1115 965 815 670
  - 12,000 99 1000 855 710 ---
  - 16,000 99 865 730 590 ---
  - 20,000 97 600 470 --- ---
  - 24,000 95 295 170 --- ---

- **3400**
  - S.L. 97 1465 1320 1165 1015
  - 4000 97 1370 1220 1065 910
  - 8000 97 1265 1110 955 795
  - 12,000 97 1150 995 845 ---
  - 16,000 97 1010 865 725 ---
  - 20,000 96 730 595 --- ---
  - 24,000 94 405 275 --- ---

**Figure 9.** – Fuel, Time, and Distance to Climb.

**Figure 33.** – Maximum Rate-of-Climb Chart.
Figure 15. – Fuel, Time, and Distance to Climb.
45 minutes reserve at 55% power best economy mixture

Range may be reduced by up to 7% if wheel fairings are not installed

Add 0.6 NM for each degree Celsius above standard temperature and subtract 1 NM for each degree Celsius below standard temperature.

Associated conditions:
- Mixture: Leaned per section 4
- Weight: 2,300 lb.
- Wings: No
- Fuel: 48 gal usable
- Wheel Fairings installed
- Cruise: Mid cruise
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

CRUISE PERFORMANCE

DISCUSSION:
WHAT BESIDE “MAXIMUM AVAILABLE POWER” LIMITS THE MAXIMUM FLIGHT AIRSPEED?

POWER/AIRSPEED RELATIONSHIP
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

CRUISE POWER SETTINGS
65% MAXIMUM CONTINUOUS POWER (OR FULL THROTTLE)
2800 POUNDS

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<th>IOAT</th>
<th>ENGINE SPEED</th>
<th>MAN PRESS</th>
<th>FUEL FLOW PER ENGINE</th>
<th>TAS</th>
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<th>MAN PRESS</th>
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<td>°C</td>
<td>RPM</td>
<td>IN HG</td>
<td>GPH</td>
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NOTES: 1. Full throttle manifold pressure settings are approximate.  2. Shaded area represents operation with full throttle.

1. Find the pressure altitude
2. Use the table for the appropriate temperature. (If the temperature is between the given values, use interpolation.)
3. Read the true airspeed and fuel consumption for your chosen power setting.

Power settings not only consideration: Range and Endurance also have tables.
Interpolation required: notice specific altitudes, weights, and temperatures.
Combined Endurance and Range Chart

Associated conditions:
- Maximum continuous power*
- 3,600 lb gross weight
- Flaps up
- 90 KIAS
- No wind

* 2,700 rpm & 38 in M.P. (3-blade prop)
  2,575 rpm & 36 in M.P. (2-blade prop)
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

1. Find the pressure altitude and correct for nonstandard temperature. In this example, the temperature is standard, so the correction factors in the note are not used.

2. Look horizontally to the appropriate power line.

3. Follow vertically to read the range at the bottom of the chart.

4. For the range with no reserve, use the second set of power lines.

Note: Range may be reduced by up to 7% if wheel fairings are not installed.

Best Power Mixture Range
Associated Conditions:
Mixture leaned per Section 4
Mid cruise weight 2300 lbs., no wind
48 gal. usable fuel, wheel fairings installed

- 45 min. reserve @ 55% power
- Best economy mixture

Range - Nautical Miles
(Includes distance to climb and descend)
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

![Chart for engine performance with instructions: 1. Enter the chart at the correct outside air temperature. 2. Go up to the appropriate pressure altitude line. 3. Go across to the line for the power you have chosen. 4. Go down to obtain the r.p.m. setting for that rated power.]

ENGINE PERFORMANCE
ASSOCIATED CONDITIONS
BEST POWER MIXTURE PER SECTION 4
INSTRUCTIONS
WHEEL FAIRINGS INSTALLED

FUEL FLOW GALLON PER HOUR
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- **ENGINE SPEED - RPM**
- **OUTSIDE AIR TEMPERATURE - °C**
- **PRESURE ALTITUDE - FT**
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<th>TAS MPH</th>
<th>GAL/HOUR</th>
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Figure 11. – Cruise and Range Performance.
Last performance Chart: Cruise... at last 😊

### CRUISE POWER SETTING
65% MAXIMUM CONTINUOUS POWER (OR FULL THROTTLE)
2,800 POUNDS

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<td>16,000</td>
<td>-29</td>
<td>-34</td>
<td>2,450</td>
<td>16.1</td>
<td>5.3</td>
<td>9.7</td>
<td>156</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Full throttle manifold pressure settings are approximate.
2. Shaded area represents operation with full throttle.

Ground School 2015
WEIGHT AND BALANCE

WHY SHOULD YOU CARE?

A small mistake in CG can lead to much bigger problem. Picture courtesy of CASA
WEIGHT AND BALANCE

WEIGHTS

Empty Weight = Empty airplane with unusable fuel, and full oil
Ramp Weight = Maximum weight permitted before starting engine (higher than TO)
Takeoff Weight = Ramp weight less fuel burned to start, taxi, runup prior to TO.
Landing Weight = Takeoff weight less the fuel burned enroute.
Gross Weight = Maximum airborne weight.

Useful Load = What the airplane with carry (Gross Weight – Empty Weight) NOT how much passenger/baggage because it does not include fuel (6 LBS / GAL).

Payload (Useful load – fuel) is the maximum passengers, baggage and cargo.

Maximum Take Off Weight = Maximum permitted for takeoff.

Maximum Landing Weight = Maximum permitted for the landing.

If my C182 has a Gross (takeoff) weight of 2950, an empty weight of 1842, and is loaded with 75G of fuel, WHAT IS MY PAYLOAD? 658

--450--
WEIGHT AND BALANCE

Your scheduled for a flight and know now that your maximum payload capability on the Cessna 182 is 658 (with full fuel).

You and 3 friends want to fly to Miami this weekend. You graciously ask them their weight and the weight of their baggage.

You weight 170 and bring 15 lbs of luggage
Passenger 1 weights 190 and brought 30 lbs of luggage.
Passenger 2 weights 188 and brought 25 lbs of luggage
Passenger 3 weights 122 and brought 35 lbs of luggage

Given the aircraft center of gravity is in balance,

IS IT OK TO TAKE OFF WITH PASSENGERS AND LUGGAGE?

Total passenger weight = 670 lbs
Total luggage weight = 105 lbs
Total passenger/cargo = 775 lbs

DISCUSSION: What are the RISKS? What are the options in this situation?

NEVER TAKE OFF EXCEEDING MAX TO / GROSS WEIGHT
END OF STORY
WEIGHT AND BALANCE

Flying Too Heavy (Over Gross)

• Reduced structural load safety factor
• Reduced acceleration, higher take-off speed and longer take-off distance
• Reduced rate and angle of climb
• Reduced cruising speed and range
• Higher stalling speed and reduced maneuverability
• Higher landing speed and extended landing distance
• or maybe the aircraft won't even leave the ground – which can be a bit expensive if you end up in the barbed wire fence at the end of the strip. Much worse if it does get airborne but you trip over the fence; or if you can't establish a climb rate greater than the vertical velocity of down-flowing air at the end of the runway.
"CENTER OF GRAVITY" (CG)
IMAGINARY POINT OF BALANCE FOR THE AIRCRAFT
WEIGHT AND BALANCE

BALANCE BOTTOM LINE

- High control forces
- Higher stalling speeds
- Longer takeoff and landing distances
- Harder to raise the nose during takeoff and landing

- Unstable flight characteristics
- Aircraft structure is easily overstressed
- Violent stalls
- Aircraft may not recover from a spin
Center of gravity has limits of how far forward or rearward CG can be to safely fly the airplane.

**WEIGHT AND BALANCE**

**MANEUVER LIMITS**

**NORMAL CATEGORY**

This airplane is certificated in both the normal and utility category. The normal category is applicable to aircraft intended for non-aerobatic operations. These include any maneuvers incidental to normal flying, stalls (except whip stalls), lazy eights, chandelles, and turns in which the angle of bank is not more than 60°. Aerobatic maneuvers, including spins, are not approved.

**UTILITY CATEGORY**

This airplane is not designed for purely aerobatic flight. However, in the acquisition of various certificates such as commercial pilot, instrument pilot and flight instructor, certain maneuvers are required by the FAA. All of these maneuvers are permitted in this airplane when operated in the utility category.

**FAR, Part 23.337**

<table>
<thead>
<tr>
<th>Category</th>
<th>Max. G</th>
<th>Min. G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>+3.8G</td>
<td>-1.52G</td>
</tr>
<tr>
<td>Utility</td>
<td>+4.4G</td>
<td>-1.76G</td>
</tr>
<tr>
<td>Acrobat</td>
<td>+6.0G</td>
<td>-3.00G</td>
</tr>
</tbody>
</table>
WEIGHT AND BALANCE

CG LIMITS SPECIFIED AS # IF INCHES FROM THE “REFERENCE DATUM” WHICH IS DIFFERENT ON DIFFERENT TYPES AND MODELS OF AIRCRAFT.
WEIGHT AND BALANCE

BALANCE

Left = Right

5 pounds x 10 inches = 50 inch/pounds

5 pounds x 10 inches = 50 inch/pounds

The airplane is balanced when weight and distance is equal from the center of gravity balance point.

5 pounds x 5 inches = 25 inch/pounds

5 pounds x 10 inches = 50 inch/pounds

If one of the weights is shifted, an imbalance will also exist.

10 pounds x 10 inches = 100 inch/pounds

5 pounds x 10 inches = 50 inch/pounds

If one of the weights is increased, an imbalance occurs.

10 pounds x 5 inches = 50 inch/pounds

5 pounds x 10 inches = 50 inch/pounds

Shifting the weight will return the plane to a balanced condition.
WEIGHT AND BALANCE

Reference Datum is our fulcrum

Distance weight is from datum is called ARM

MOMENT is weight exerted at end of the arm

BALANCING ACT

LEFT=RIGHT

Moment = 5,000 pound-inches

Moment = Wt. x Arm
(lbs.) x (a.) = (lbs.-in.)
50 lbs. x 100 in. = 5,000 lbs.-in.
If 50 lbs of weight is located at point X and 100 lbs is located at point Z, how much weight must be located at point & to balance the plank?

SOLVE FOR Y
\[50 \times 50 + 25Y = 100 \times 100\]
\[2,500 + 25Y = 10,000\]
\[25Y = 10,000 - 2,500\]
\[25Y = 7,500\]
\[Y = 300 \text{ lbs}\]

How far should a 500 lb weight be shifted to balance a plank on the fulcrum?

\[500 \times 15 = 200 + 20 \times 250\]
\[500 \times X = 8,000\]
\[X = 8,000 / 500 = 16\]

Since the 500 lb wt is 15 inches and we need 16 we must move it 1 more inch to the left.
WEIGHT AND BALANCE
CG LOCATION

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>Arm</th>
<th>Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty Airplane</td>
<td>1,150</td>
<td>70</td>
<td>80,500</td>
</tr>
<tr>
<td>Pilot</td>
<td>135</td>
<td>73</td>
<td>9,855</td>
</tr>
<tr>
<td>Total</td>
<td>1,285</td>
<td>73</td>
<td>90,355</td>
</tr>
</tbody>
</table>

\[
\frac{90,355 \text{ pound-inches}}{1,285 \text{ pounds}} = 70.3 \text{ inches}
\]

\[
\text{CG Arm} = \frac{90,355 \text{ pound-inches}}{1,285 \text{ pounds}} = 70.3 \text{ inches}
\]
WEIGHT AND BALANCE COMPUTATION METHOD

CALCULATE CG AS TOTAL MOMENTS / TOTAL WEIGHT
ENTER ON GRAPH
### Weight and Balance

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WEIGHT</th>
<th>ARM</th>
<th>=</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty Weight</td>
<td>1455.6</td>
<td>x</td>
<td>=</td>
<td>56040.60</td>
</tr>
<tr>
<td>Fuel (40 G. Max)</td>
<td>120</td>
<td>x</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>Pilot/Front Seat</td>
<td>210</td>
<td>x</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>Rear Seat</td>
<td>170</td>
<td>x</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>Baggage Area 1</td>
<td>60</td>
<td>x</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>Baggage Area 2</td>
<td>0</td>
<td>x</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2015.6</td>
<td></td>
<td></td>
<td>87316.60</td>
</tr>
</tbody>
</table>

\[ CG \text{ MOM/WT}= (A) \]  
\[ CG \text{ MOM/1000}= (B) \]

### Diagrams

**A** (MOM/WT)

- Center of Gravity Limits
- Landplane

**B** (MOM/1000)

- Center of Gravity Moment Envelope
- Normal Category
- Utility Category

---

Ground School 2015
## WEIGHT AND BALANCE

### Weight and Moment Calculations

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WEIGHT</th>
<th>ARM</th>
<th>=</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMPTY WEIGHT</td>
<td>1455.6</td>
<td>x</td>
<td>38.5</td>
<td>56040.60</td>
</tr>
<tr>
<td>Fuel (40 G. Max)</td>
<td>240</td>
<td>x</td>
<td>45.3</td>
<td></td>
</tr>
<tr>
<td>Pilot/Front Seat</td>
<td>340</td>
<td>x</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Rear Seat</td>
<td>170</td>
<td>x</td>
<td>72.8</td>
<td></td>
</tr>
<tr>
<td>Baggage Area 1</td>
<td>94</td>
<td>x</td>
<td>94.9</td>
<td></td>
</tr>
<tr>
<td>Baggage Area 2</td>
<td>0</td>
<td>x</td>
<td>123</td>
<td></td>
</tr>
</tbody>
</table>

**Total Weight:** 100789.2

**Center of Gravity (CG) Weight/Moment (MOM):** 43.83

**Moment per 1000 (B):** 100.78

### CG Limit Diagrams

- **A [MOM/WT]**
  - Forward CG Limit
  - Aft CG Limit
  - Exceeds Gross

- **B [MOM/1000]**
  - Center of Gravity Moment Envelope
Automation?

- You can do W&B automagically using EXCEL but the FAA also requires you to manually calculate and document for commercial (Part 121 and 135) operations.

See Jewel box filename: wb_Excel Spreadsheet.xls as sample autocalc. WARNING: The values use in the spreadsheet are for a very specific aircraft and the Weights and Arms will not match your aircraft values, so use your POH And Weight and Balance sheets as provided by maintenance records in Your airplane.
WEIGHT AND BALANCE

TABLE METHOD

Simplified: Look up weight and total moment, removes need to multiply by arm.
### Useful Load Weights and Moments

**Occupants**

<table>
<thead>
<tr>
<th>FRONT SEATS</th>
<th>REAR SEATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARMS 85</td>
<td>ARMS 121</td>
</tr>
<tr>
<td>Weight</td>
<td>Weight</td>
</tr>
<tr>
<td>120</td>
<td>120</td>
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<tr>
<td>130</td>
<td>130</td>
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<td>140</td>
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<td>150</td>
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<td>160</td>
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<td>170</td>
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<td>180</td>
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<tr>
<td>190</td>
<td>190</td>
</tr>
<tr>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

**Usable Fuel**

<table>
<thead>
<tr>
<th>MAIN WING TANKS</th>
<th>ARM 75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons</td>
<td>Weight</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>15</td>
<td>90</td>
</tr>
<tr>
<td>20</td>
<td>120</td>
</tr>
<tr>
<td>25</td>
<td>150</td>
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<tr>
<td>30</td>
<td>180</td>
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<tr>
<td>35</td>
<td>210</td>
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<tr>
<td>40</td>
<td>240</td>
</tr>
<tr>
<td>44</td>
<td>264</td>
</tr>
</tbody>
</table>

**Auxiliary Wing Tanks**

<table>
<thead>
<tr>
<th>ARM 94</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>19</td>
</tr>
</tbody>
</table>

**Empty Weight - 2015**

MOM / 100 = 1554

**Moment Limits vs Weight**

<table>
<thead>
<tr>
<th>Weight Condition</th>
<th>Forward CG Limit</th>
<th>Aft CG Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2960 lb (tokeoff or landing)</td>
<td>82.1</td>
<td>84.7</td>
</tr>
<tr>
<td>2252 lb</td>
<td>77.5</td>
<td>85.7</td>
</tr>
<tr>
<td>2475 lb or less</td>
<td>77.0</td>
<td>85.7</td>
</tr>
</tbody>
</table>

---

### Moment Limits vs Weight (Continued)

<table>
<thead>
<tr>
<th>Weight</th>
<th>Minimum Moment</th>
<th>Maximum Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2100</td>
<td>1817</td>
<td>1800</td>
</tr>
<tr>
<td>2110</td>
<td>1825</td>
<td>1808</td>
</tr>
<tr>
<td>2120</td>
<td>1817</td>
<td>1808</td>
</tr>
<tr>
<td>2130</td>
<td>1825</td>
<td>1808</td>
</tr>
<tr>
<td>2140</td>
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<td>1817</td>
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<td>2150</td>
<td>1843</td>
<td>1825</td>
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<tr>
<td>2160</td>
<td>1851</td>
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<tr>
<td>2170</td>
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<td>2180</td>
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<td>2190</td>
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<td>2200</td>
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<td>1885</td>
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<tr>
<td>2220</td>
<td>1903</td>
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<td>1920</td>
<td>1911</td>
</tr>
<tr>
<td>2250</td>
<td>1928</td>
<td>1920</td>
</tr>
<tr>
<td>2260</td>
<td>1937</td>
<td>1928</td>
</tr>
<tr>
<td>2270</td>
<td>1945</td>
<td>1937</td>
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<td>1963</td>
<td>1954</td>
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<td>1971</td>
<td>1963</td>
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<tr>
<td>2310</td>
<td>1980</td>
<td>1971</td>
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<tr>
<td>2320</td>
<td>1988</td>
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<td>2100</td>
<td>2091</td>
</tr>
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<td>2460</td>
<td>2108</td>
<td>2100</td>
</tr>
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</tr>
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<td>2117</td>
</tr>
<tr>
<td>2490</td>
<td>2134</td>
<td>2125</td>
</tr>
</tbody>
</table>

---

**Figure 33.** Airplane Weight and Balance Tables.

---

**Figure 34.** Airplane Weight and Balance Tables.
What is the maximum amount of baggage that can be carried when the airplane is loaded as follows?

Front Seat occupants 387 lbs
Rear Seat occupants 293 lbs
Fuel 35 gallons

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>Moment/100 lb.-in</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Empty weight w/oil</strong></td>
<td>2,015</td>
<td>1,554</td>
</tr>
<tr>
<td>Front seat</td>
<td>387</td>
<td>330</td>
</tr>
<tr>
<td>Rear Seat</td>
<td>293</td>
<td>355</td>
</tr>
<tr>
<td>Fuel, main (35 gal)</td>
<td>210</td>
<td>158</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2,905</td>
<td>2,397</td>
</tr>
<tr>
<td>Baggage</td>
<td>45</td>
<td>63</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>2,950</td>
<td>2,460</td>
</tr>
</tbody>
</table>
WEIGHT AND BALANCE

SUM THE WEIGHTS
SUM THE MOMENTS

← PLOT

DON’T FORGET EMPTY WEIGHT
[Common error]

THIS IS A COMMON FORMAT FOR W/B ON THE FAA EXAMINATION
WEIGHT AND BALANCE

**TRY THIS:**
Front Seats = 340 lbs (hint 200+140=340)
Rear Seats = 160 lbs (@station 111)
Baggage = 55 lbs (interpolate)
Fuel (45 gals.) =

**SUM WEIGHT :**
**SUM MOMENTS:**
WEIGHT AND BALANCE

EMPTY WEIGHT = 2110, M=1652

Front Seats = 340 lbs, M=289 (hint 200+140=340)[M170+119]

Rear Seats = 160 lbs, M=194 (@station 111)

Baggage = 55 lbs, M=83 (interpolate 50-60)

Fuel (45 gals.) = 240 lbs, M=203

TOTAL WEIGHT: 2935
TOTAL MOMENTS: 2421
### USEFUL LOAD WEIGHTS AND MOMENTS

#### OCCUPANTS

<table>
<thead>
<tr>
<th>Weight</th>
<th>Moment 100</th>
<th>Weight</th>
<th>Moment 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>102</td>
<td>145</td>
<td>120</td>
</tr>
<tr>
<td>130</td>
<td>110</td>
<td>157</td>
<td>130</td>
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<tr>
<td>140</td>
<td>119</td>
<td>169</td>
<td>140</td>
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<tr>
<td>150</td>
<td>128</td>
<td>182</td>
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<td>160</td>
<td>136</td>
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<td>160</td>
</tr>
<tr>
<td>170</td>
<td>144</td>
<td>206</td>
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</tr>
<tr>
<td>180</td>
<td>153</td>
<td>218</td>
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<tr>
<td>190</td>
<td>162</td>
<td>230</td>
<td>190</td>
</tr>
<tr>
<td>200</td>
<td>170</td>
<td>242</td>
<td>200</td>
</tr>
</tbody>
</table>

#### REAR SEATS

<table>
<thead>
<tr>
<th>Weight</th>
<th>Moment 100</th>
<th>Weight</th>
<th>Moment 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>102</td>
<td>145</td>
<td>120</td>
</tr>
<tr>
<td>130</td>
<td>110</td>
<td>157</td>
<td>130</td>
</tr>
<tr>
<td>140</td>
<td>119</td>
<td>169</td>
<td>140</td>
</tr>
<tr>
<td>150</td>
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<td>150</td>
</tr>
<tr>
<td>160</td>
<td>136</td>
<td>194</td>
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<td>170</td>
<td>144</td>
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<td>180</td>
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<td>190</td>
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<td>230</td>
<td>190</td>
</tr>
<tr>
<td>200</td>
<td>170</td>
<td>242</td>
<td>200</td>
</tr>
</tbody>
</table>

#### MAIN WING TANKS

<table>
<thead>
<tr>
<th>Gallons</th>
<th>Weight</th>
<th>Moment 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>15</td>
<td>90</td>
<td>68</td>
</tr>
<tr>
<td>20</td>
<td>120</td>
<td>90</td>
</tr>
<tr>
<td>25</td>
<td>150</td>
<td>112</td>
</tr>
<tr>
<td>30</td>
<td>180</td>
<td>135</td>
</tr>
<tr>
<td>35</td>
<td>210</td>
<td>158</td>
</tr>
<tr>
<td>40</td>
<td>240</td>
<td>180</td>
</tr>
<tr>
<td>44</td>
<td>264</td>
<td>198</td>
</tr>
</tbody>
</table>

#### Auxiliary Wing Tanks

<table>
<thead>
<tr>
<th>Gallons</th>
<th>Weight</th>
<th>Moment 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>56</td>
</tr>
<tr>
<td>15</td>
<td>90</td>
<td>82</td>
</tr>
<tr>
<td>19</td>
<td>114</td>
<td>107</td>
</tr>
</tbody>
</table>

#### OIL

<table>
<thead>
<tr>
<th>Quarts</th>
<th>Weight</th>
<th>Moment 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>19</td>
<td>5</td>
</tr>
</tbody>
</table>

*Included in basic Empty Weight

**Empty Weight - 2015 MOM / 100 - 1654**

**MOM LIMITS vs WEIGHT**

Moment limits are based on the following weight and center of gravity limit data (landing gear down).

### AUXILIARY WING TANKS

<table>
<thead>
<tr>
<th>Gallons</th>
<th>Weight</th>
<th>Moment 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
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</tr>
<tr>
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<td>90</td>
<td>82</td>
</tr>
<tr>
<td>19</td>
<td>114</td>
<td>107</td>
</tr>
</tbody>
</table>

**Weight Condition**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Forward CG Limit</th>
<th>Aft CG Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2950 lb</td>
<td>82.1</td>
<td>84.7</td>
</tr>
<tr>
<td>or landing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2257 lb</td>
<td>77.5</td>
<td>85.7</td>
</tr>
</tbody>
</table>

---

Figure 133. – Airplane Weight and Balance Tables.

---

Figure 134. – Airplane Weight and Balance Tables.
WEIGHT AND BALANCE
GRAPH METHOD

EASIEST OF ALL
* When using this method, Empty Weight and Moments given. You look up the rest.

Use **Center of Gravity Limits** (Sum of CG)
WEIGHT AND BALANCE

Will your CG change during a cross country burning 40 gallons of fuel?
If so, how much and in what direction will the CG change?

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WEIGHT</th>
<th>ARM</th>
<th>=</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMPTY WEIGHT</td>
<td>1455.6</td>
<td>x</td>
<td>38.5</td>
<td>56040.60</td>
</tr>
<tr>
<td>Fuel (40 G. Max)</td>
<td>300</td>
<td>x</td>
<td>45.3</td>
<td>13590.00</td>
</tr>
<tr>
<td>Pilot/Front Seat</td>
<td>340</td>
<td>x</td>
<td>37</td>
<td>12580.00</td>
</tr>
<tr>
<td>Rear Seat</td>
<td>170</td>
<td>x</td>
<td>72.8</td>
<td>12376.00</td>
</tr>
<tr>
<td>Baggage Area 1</td>
<td>10.4</td>
<td>x</td>
<td>94.9</td>
<td>986.96</td>
</tr>
<tr>
<td>Baggage Area 2</td>
<td>0</td>
<td>x</td>
<td>123</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2300</td>
<td></td>
<td></td>
<td>95573.56</td>
</tr>
</tbody>
</table>

CG WT/MOM=(A) 41.55

WHAT IF T.O. HERE
FORWARD CG LANDING

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WEIGHT</th>
<th>ARM</th>
<th>=</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
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<td>x</td>
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<td>Fuel (40 G. Max)</td>
<td>60</td>
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<td>45.3</td>
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<td>340</td>
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</tr>
<tr>
<td>Baggage Area 2</td>
<td>0</td>
<td>x</td>
<td>123</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2060</td>
<td></td>
<td></td>
<td>83701.56</td>
</tr>
</tbody>
</table>

CG WT/MOM=(A) 40.63

MOM /1000= 95.57

CREATED BY STEVE REISSER
A final consideration: Loads add/subtract total weight of aircraft. At GROSS this is serious business. (i.e., vertical gust 18 KTS at 113 LOADS +3, effect is additive in a bank (45 bank =+1.4G, Gust 18 KTS = +3 G... near limits)
WEIGHT AND BALANCE

WEIGHT SHIFT

MOST weight shift issues are covered by the formula

\[
\frac{\text{Weight Moved}}{\text{Weight of Plane}} = \frac{\text{Distance CG moves}}{\text{Distance between CG Arms}}
\]

Given 3 of the four above, the 4th unknown value can be determined by simple algebraic formulation.

\[
\text{Wt. Moved} \times \text{Dist. between CG Arms} = \text{Wt. of Plane} \times \text{Dist. CG moves}
\]

\[
\text{Wt. Moved} = \frac{(\text{Wt. of Plane} \times \text{Dist. CG moves})}{\text{Dist. Between CB Arms}}
\]

\[
\text{Dist. Between CG Arms} = \frac{(\text{Wt. of Plane} \times \text{Dist. CG moves})}{\text{Wt Moved}}
\]

\[
\text{Dist. CG Moves} = \frac{(\text{Wt. Moved} \times \text{Dist. Between CG Arms})}{\text{Wt of plane}}
\]

\[
\text{Wt of plane} = \frac{(\text{Wt. Moved} \times \text{Dist. Between CG Arms})}{\text{Dist CG Moves}}
\]
Ops, we are aft-CG by 2 inches. How much weight must we move from back? Difference in back/front seats is 36 inches. Plug formula and solve. You must move 138.6 lbs. from back seat to front seat.
ADVANCED WEIGHT AND BALANCE

LEFT = RIGHT  If you shift one, then you need to shift the other.

Example. Let's move the RIGHT 50 lbs to the LEFT (10 inches) [Arm to right changes from 100” to 90 inches]. How far and in What direction must you move the 100 lbs on the LEFT to keep CG in balance?

LEFT  =  RIGHT
100(x) + 50(50")  =  50(90")
100(x) + 2500  =  4500
100(x)  =  4500 - 2500
NEW POSITION (x) = (2000)/100 = 20”
100 lbs must be moved from position 25 to position 20.
You must move the 100 lbs to the RIGHT 5 inches.
Commercial Weight Shift

WEIGHT CHANGE AND WEIGHT SHIFT COMPUTATIONS

1. Authors' note: The following is an effective, intuitively appealing handout used by Dr. Melville R. Byington at Embry-Riddle Aeronautical University (used with permission).

   a. **Background** -- Center of gravity shift problems can be intimidating when an organized approach is not followed. If one goes to the usual texts for assistance, the result is often either

      1) “Just plug this/these formulas” (without adequate rationale), or
      2) Follow a set of (up to six) formulas to solve the problems, or
      3) Follow a tabular approach, which is often lengthy and tedious.

   b. **Basic theory** -- The foregoing “methods” obscure what can and should be a logical, straightforward approach. The standard question is, “If the CG started out there, and certain changes occurred, where is it now?” It can be answered directly using a SINGLE, UNIVERSAL, UNCOMPILCATED FORMULA.

      1) At any time, the CG is simply the sum of all moments (ΣM) divided by the sum of all weights (ΣW).

         \[ \text{CG} = \frac{\Sigma M}{\Sigma W} \]

      2) Since CG was known at some previous (#1) loading condition (with moment = M₁ and weight = W₁), it is logical that this become the point of departure. Due to weight addition, removal, or shift, the moment has changed by some amount, ΔM. The total weight has also changed if, and only if, weight has been added or removed. Therefore, the current CG is merely the current total moment divided by the current total weight. In equation format,

         \[ \text{CG} = \text{Current Moment/Current Weight becomes} \quad \text{CG} = \frac{M₁ ± \Delta M}{W₁ ± \Delta W} \]
62. An airplane is loaded to a gross weight of 4,800 pounds, with three pieces of luggage in the rear baggage compartment. The CG is located 98 inches aft of datum, which is 1 inch aft of limits. If luggage which weighs 90 pounds is moved from the rear baggage compartment (145 inches aft of datum) to the front compartment (45 inches aft of datum), what is the new CG?

A. 96.13 inches aft of datum.
B. 95.50 inches aft of datum.
C. 99.87 inches aft of datum.

Answer (A) is correct. (AWBH Chap 2)

DISCUSSION: To determine the new CG, use the following formula:

\[ \text{New CG} = \frac{M_1 + \Delta W}{W_1 + \Delta W} \]

where \(M_1\) = original moment and \(W_1\) = original weight.

Since there is no change in weight, \(\Delta W = 0\) and weight shifted forward causes a "-" moment change.

\[
\text{New CG} = \frac{(4,800 \times 98) - 90(145 - 45)}{4,800} = \frac{470,400 - 9,000}{4,800} = \frac{461,400}{4,800} = 96.13
\]

Answer (B) is incorrect because the new CG is 96.13, not 95.50. Answer (C) is incorrect because the new CG is 96.13, not 99.87.
Commercial Weight Shift

63. An aircraft is loaded with a ramp weight of 3,650 pounds and having a CG of 94.0, approximately how much baggage would have to be moved from the rear baggage area at station 180 to the forward baggage area at station 40 in order to move the CG to 92.0?

A. 52.14 pounds.
B. 62.24 pounds.
C. 78.14 pounds.

Answer (A) is correct. (AWBH Chap 2)

DISCUSSION: To determine how much weight needs to be shifted forward (causing a "-" moment change), use the following formula:

\[
\text{New CG} = \frac{M_1 + \Delta M}{W_1 + \Delta W}
\]

where \(M_1\) = original moment and \(W_1\) = original weight, and since there is no change in weight, \(\Delta W = 0\).

\[92.0 = \frac{(3,650 \times 94.0) - x(180 - 40)}{3,650}\]

\[92.0 = \frac{335,800 - 140x}{3,650}\]

\[335,800 = 343,100 - 140x\]

\[140x = 343,100 - 335,800\]

\[140x = 7,300\]

\[x = 52.14 \text{ lb.}\]

Answer (B) is incorrect because only 52.14 lb., not 62.24 lb., of baggage needs to be shifted. Answer (C) is incorrect because only 52.14 lb., not 78.14 lb., of baggage needs to be shifted.
WEIGHT AND BALANCE

FORWARD CG
- Higher pull force on the yoke.
- Additional pull on the yoke needed to maintain straight and level flight.
- Full back yoke fails to hold the nose up. (may not detect this problem until you attempt to rotate the airplane for takeoff (WHEELBARROW).
- Stall speed increases when the CG is farther forward.
- Stability generally improves with a forward CG.

AFT CG
- The airplane may feel more controllable and more sensitive.
- The airplane may be more difficult to trim, because a small trim change will have a larger effect.
- Aft CG decreases an airplane's stability.
- VERY DANGEROUS
WEIGHT AND BALANCE

NEXT WEEK: Quiz on Performance/W-B. Bring calculator or your E6B to do the computations.

FEDERAL AVIATION REGULATIONS

SOURCES OF AVIATION INFORMATION
AIM, FARs, A/FD, and INTERNET SOURCES

THESE ARE THE LAST UNITS BEFORE WE BEGIN DIRECT PREPARATION FOR THE FAA WRITTEN.

(Please bring your AIM/FAR and Airport/Facilities Directory)