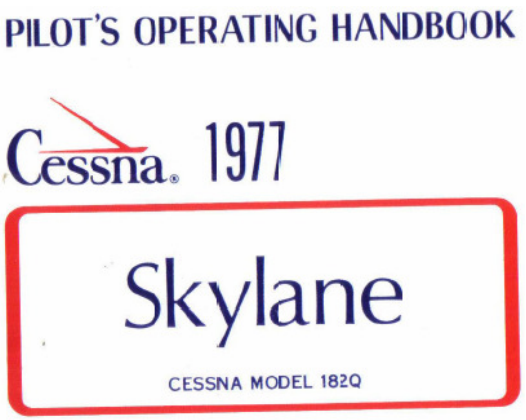
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

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.

TAKEOFF DISTANCE
MAXIMUM WEIGHT 2400 LBS

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

WEIGHT LBS	TAKEOFF SPEED KIAS		PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
	LIFT OFF	AT 50 FT		GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS
2400	51	56	S.L.	795	1460	860	1570	925	1685	995	1810	1065	1945
			1000	875	1605	940	1725	1015	1860	1090	2000	1170	2155
			2000	960	1770	1035	1910	1115	2060	1200	2220	1290	2395
			3000	1055	1960	1140	2120	1230	2295	1325	2480	1425	2685
			4000	1165	2185	1260	2365	1355	2570	1465	2790	1575	3030
			5000	1285	2445	1390	2660	1500	2895	1620	3160	1745	3455
			6000	1425	2755	1540	3015	1665	3300	1800	3620	1940	3990
			7000	1580	3140	1710	3450	1850	3805	2000	4220	–	–
			8000	1755	3615	1905	4015	2060	4480	–	–	–	–

1. 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.

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

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

	Pressure Altitude	Ground Roll
	2,000 feet	1,200 feet
	-1,000 feet	1,090 feet
Difference	1,000 feet	110 feet

4. 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 feet).

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

Kollman ------ **30.42**

↓

29.92

Difference = -00.50 x1000 = -500 ft

PRESSURE ALTITUDE = 2000 FT

Difference = -00.80 x1000 = -+800 ft

29.92

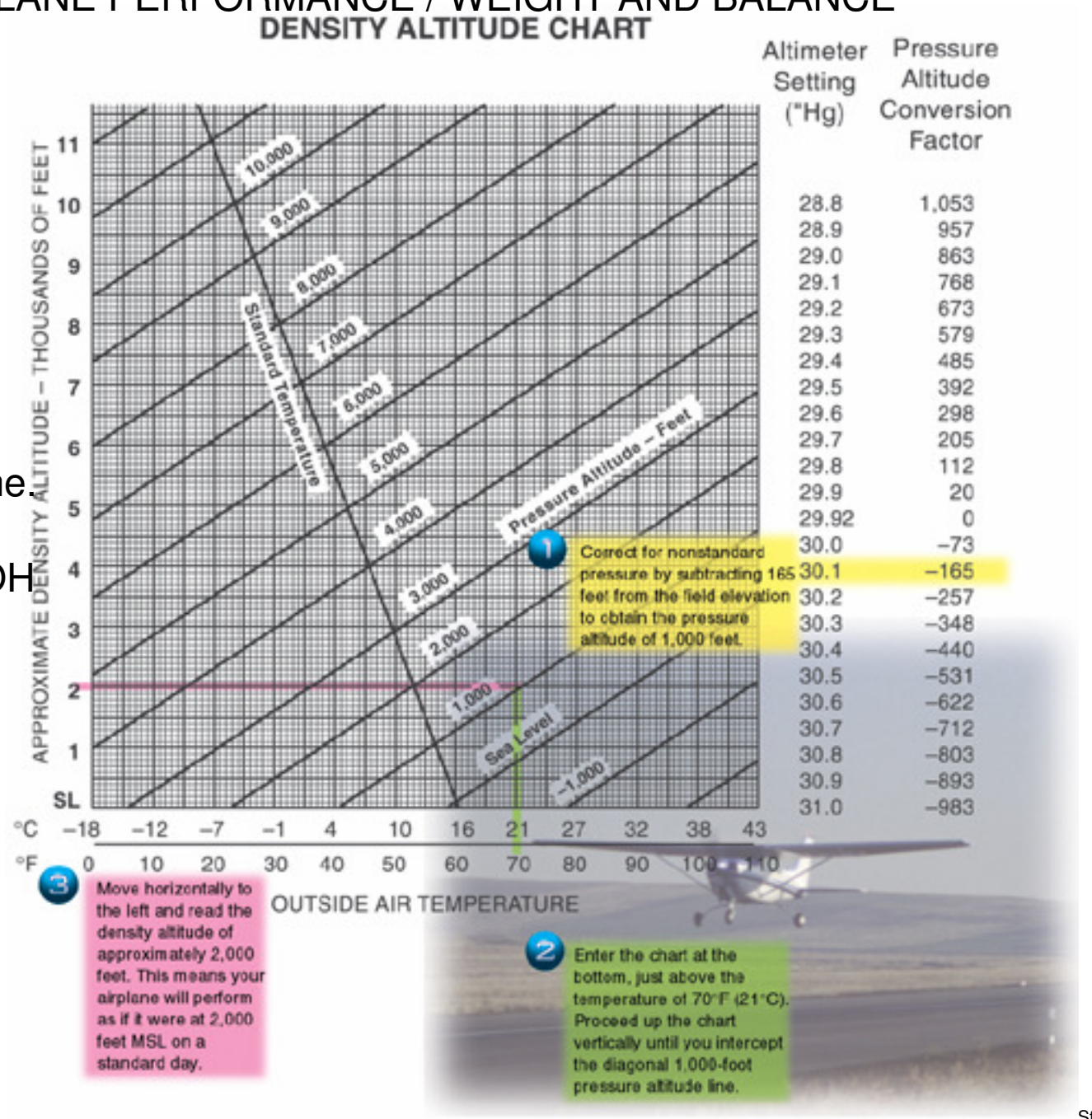
↑

29.12

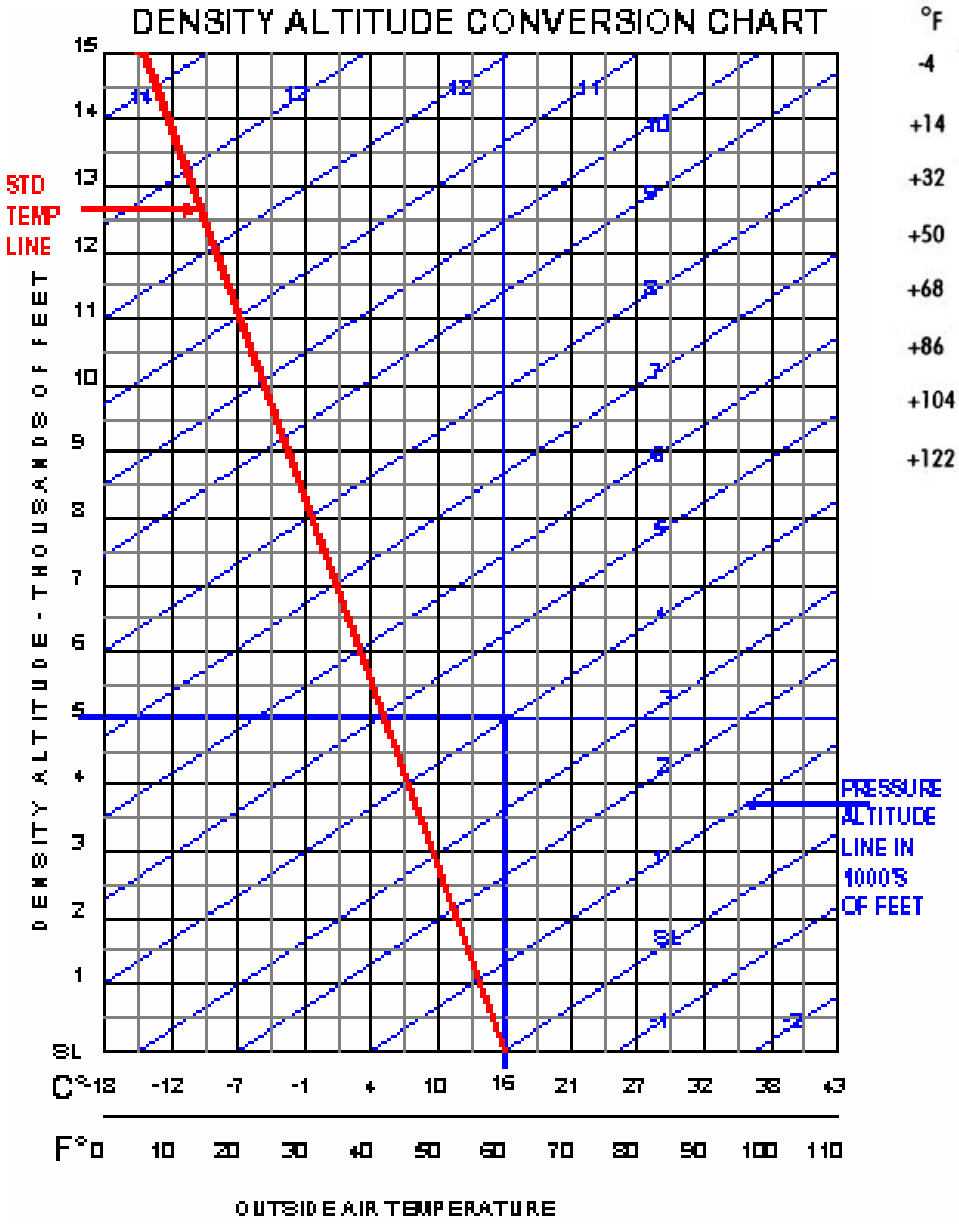
PRESSURE ALTITUDE = 3300 FT

AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

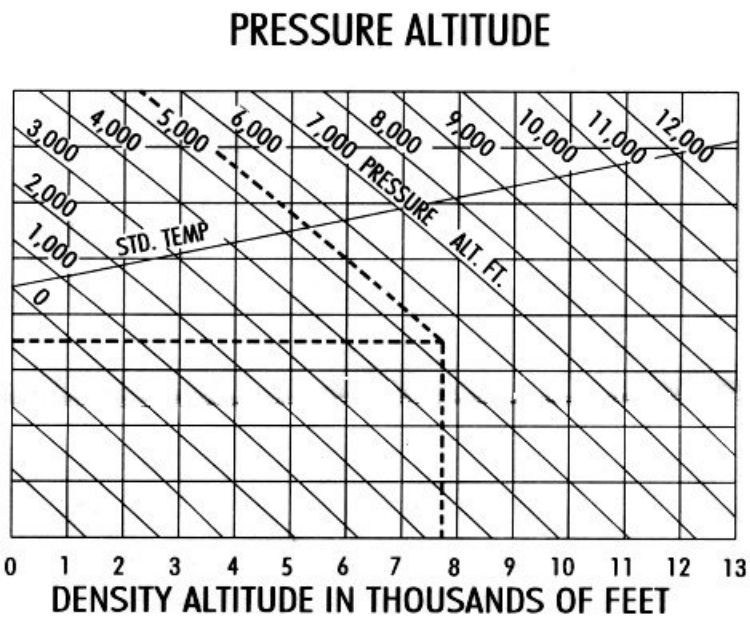
Density Altitude:
Non-standard TEMPERATURE effects on the airplane. We calculated using E6B, but can use POH performance charts.



AIRPLANE PERFORMANCE / WEIGHT AND BALANCE



OUTSIDE AIR °F	°C
-4	-20
+14	-10
+32	0
+50	+10
+68	+20
+86	+30
+104	+40
+122	+50



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

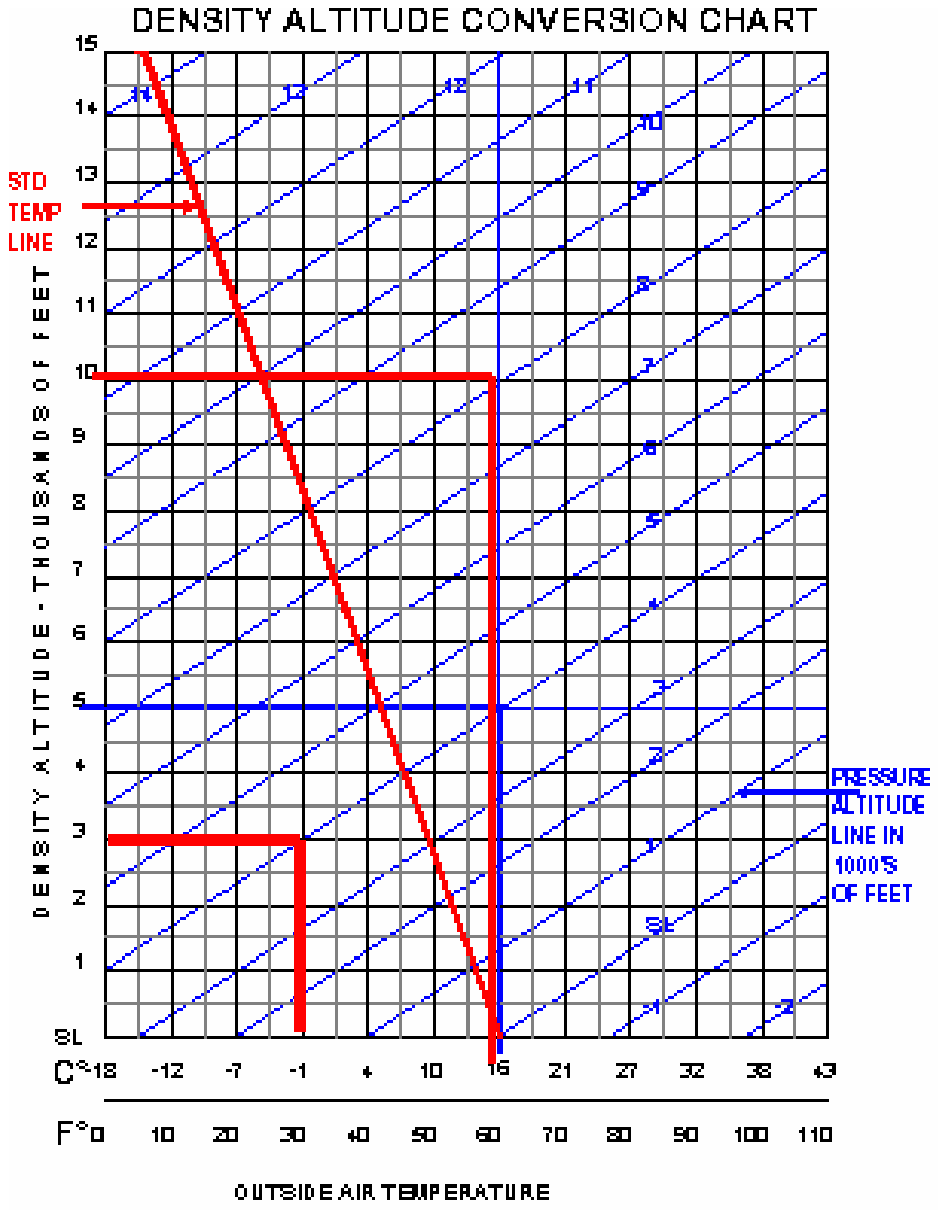
29.92

29.42

+.50x1000

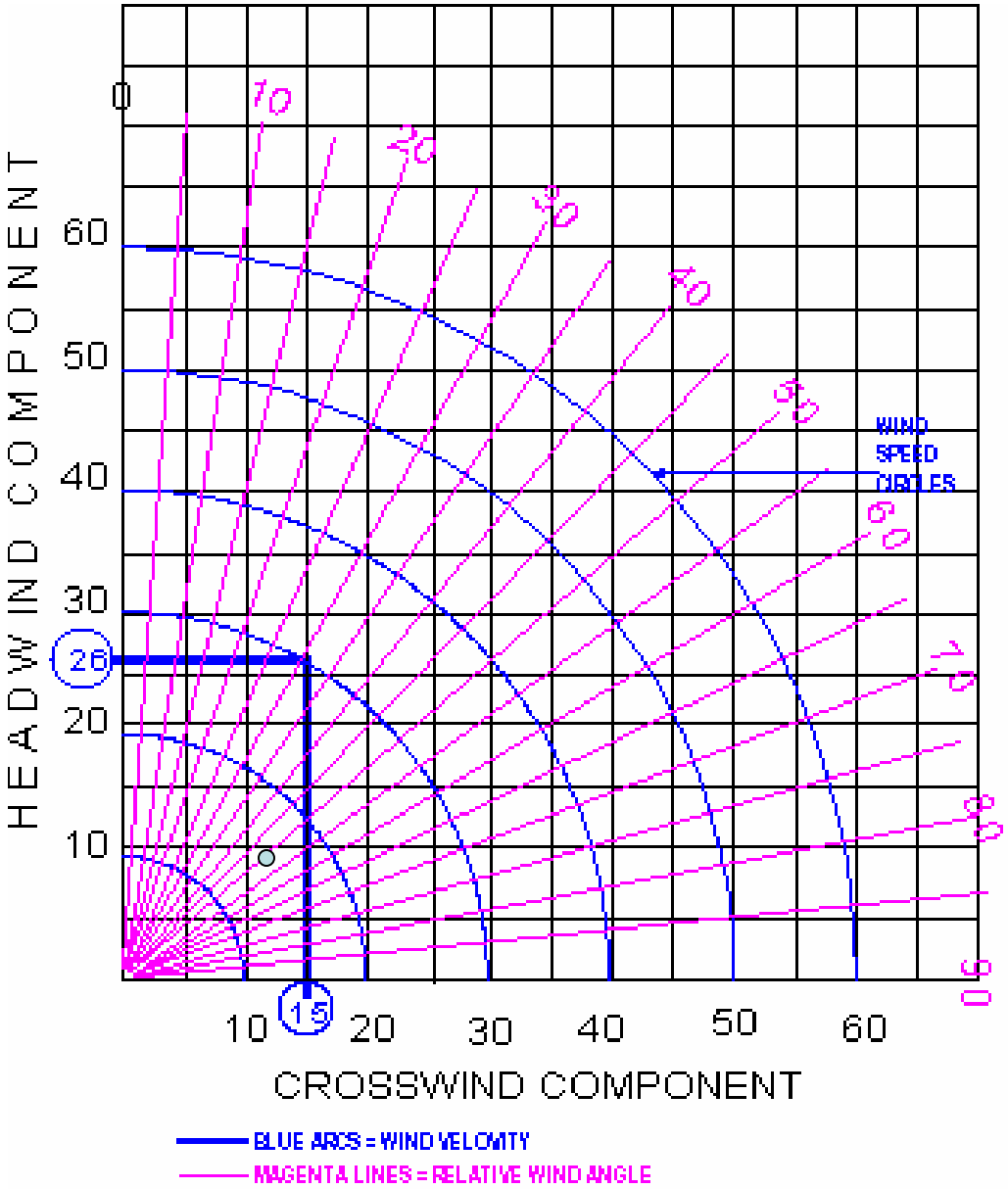
Diff= + 500

Press. Alt=3500+500=4000



AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

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

Created by Steve Reisser

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% (.50 decimal)
3. Multiply that by the wind speed.

Examples (Rwy 09, winds 050@10

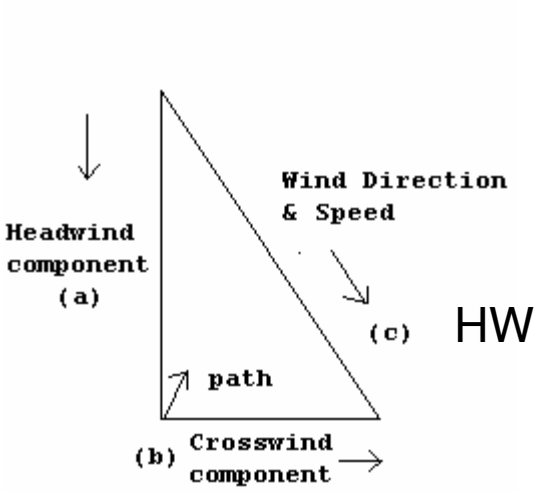
Difference = 40+20=.6*10=6

Rwy 360, winds 310@30

Difference = 50+20=.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 .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 = Square Root (Wind Velocity^2 – XWind Component^2)

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=SQR(100-36)=SQR(64)=8**

Example Flying 90 KTs on a <u>TC of 180</u> with <u>winds of 210 at 12</u>
X-Wind Component is 30+20=-.5*12=6
HW=SQR(144-36)=SQR(108)=approximate 10.4
Ground speed is the TAS +/- HW: GS=90-10=80

Let's take it up a notch ☺

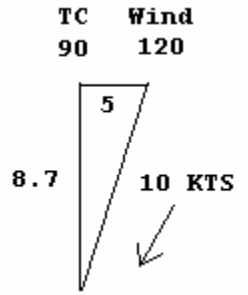
We can mentally determine WCA, to get our TH, and also determine GS in our head! Prerequisite: know your speed in miles / minute - and it's reciprocal (1/x)

TAS	Nm/Min	XW Mult
60	1	1.00
75	1.25	0.80
90	1.50	0.67
120	2	0.50

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 = SQR(100-25)=8.7 round to 9 … GS=120-9=111**



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

WEIGHT LBS	TAKEOFF SPEED KIAS		PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
	LIFT OFF	AT 50 FT		GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS
2400	51	56	S. L.	795	1460	860	1570	925	1685	995	1810	1065	1945
			1000	875	1605	940	1725	1015	1860	1090	2000	1170	2155
			2000	960	1770	1035	1910	1115	2060	1200	2220	1290	2395
			3000	1055	1960	1140	2120	1230	2295	1325	2480	1425	2685
			4000	1165	2185	1260	2365	1355	2570	1465	2790	1575	3030
			5000	1285	2445	1390	2660	1500	2895	1620	3160	1745	3455
			6000	1425	2755	1540	3015	1665	3300	1800	3620	1940	3990
			7000	1580	3140	1710	3450	1850	3805	2000	4220	–	–
			8000	1755	3615	1905	4015	2060	4480	–	–	–	–
2200	49	54	S. L.	650	1195	700	1280	750	1375	805	1470	865	1575
			1000	710	1310	765	1405	825	1510	885	1615	950	1735
			2000	780	1440	840	1545	905	1660	975	1785	1045	1915
			3000	855	1585	925	1705	995	1835	1070	1975	1150	2130
			4000	945	1750	1020	1890	1100	2040	1180	2200	1270	2375
			5000	1040	1945	1125	2105	1210	2275	1305	2465	1405	2665
			6000	1150	2170	1240	2355	1340	2555	1445	2775	1555	3020
			7000	1270	2440	1375	2655	1485	2890	1605	3155	1730	3450
			8000	1410	2760	1525	3015	1650	3305	1785	3630	1925	4005
2000	46	51	S. L.	525	970	565	1035	605	1110	650	1185	695	1265
			1000	570	1060	615	1135	665	1215	710	1295	765	1385
			2000	625	1160	675	1240	725	1330	780	1425	840	1525
			3000	690	1270	740	1365	800	1465	860	1570	920	1685
			4000	755	1400	815	1500	880	1615	945	1735	1015	1865
			5000	830	1545	900	1660	970	1790	1040	1925	1120	2070
			6000	920	1710	990	1845	1070	1990	1150	2145	1235	2315
			7000	1015	1900	1095	2055	1180	2225	1275	2405	1370	2605
			8000	1125	2125	1215	2305	1310	2500	1410	2715	1520	2950

AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

SURFACE TYPE	TAKE-OFF DISTANCE FACTOR	LANDING DISTANCE FACTOR
Paved	x 1.00	x 1.00
Coral	x 1.00	x 1.05
Metal	x 1.05	x 1.08
Rolled earth	x 1.08	x 1.16
Grass	x 1.14	x 1.18

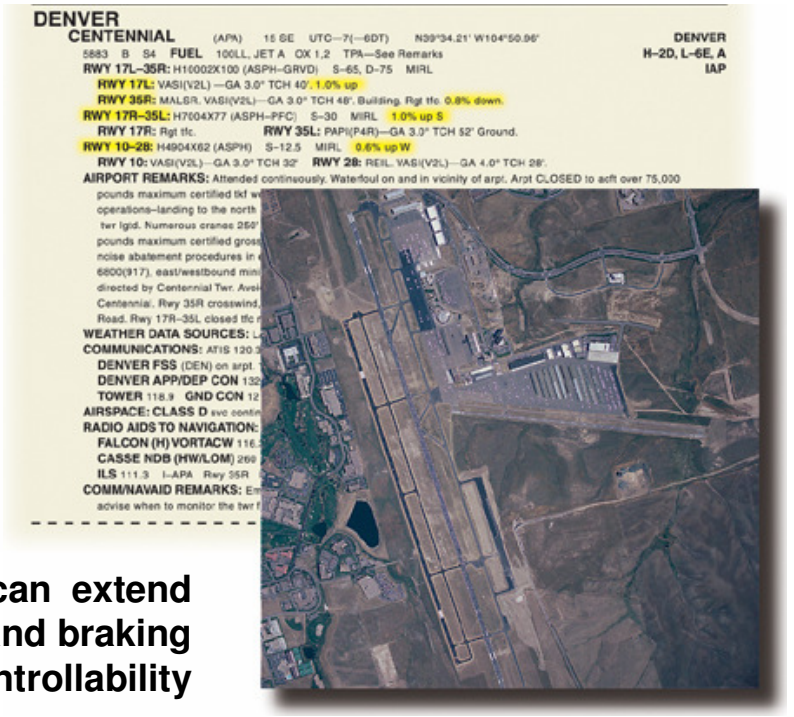
<u>Runway Surface</u>: Many POHs only add distance for sod. Different runway surfaces can add from 5% up to 18% of ground roll to your calculations.

<u>Runway Gradient</u> (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.

Table 2. Runway slope factors

DIRECTION OF SLOPE	% OF SLOPE	TAKE-OFF DISTANCE CORRECTION	LANDING DISTANCE CORRECTION
Uphill	1	+5%	-5%
	2	+10%	-10%
	3	+15%	-15%
Downhill	1	-5%	+5%
	2	-10%	+10%
	3	-15%	+15%

For slopes expressed to a decimal point, the correction is 0.5% distance for each 0.1% slope. For example, for a runway slope of 1.6% the correction factor is 8%.



<u>Runway Conditions</u> (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 !!!

RUNWAY INFO IN A/FD

How does hydroplaning effect an airplane?

LOSS OF CONTROL during Take Off and Landings

Hydroplaning formula for increase of takeoff requirement

Ground roll percentage added = 9 x sqrt(main gear tire pressure)

Example: 25 lbs in tires. 9 * Sqrt 25=5, 9*5=45 add 45% to ground roll

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.

AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

TAKEOFF DISTANCE

MAXIMUM WEIGHT 2300 LBS

SHORT FIELD

CONDITIONS:
Flaps Up
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.

WEIGHT LBS	TAKEOFF SPEED KIAS		PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
	LIFT OFF	AT 50 FT		GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS
2300	52	59	S.L.	720	1300	775	1390	835	1490	895	1590	960	1700
			1000	790	1420	850	1525	915	1630	980	1745	1050	1865
			2000	865	1555	930	1670	1000	1790	1075	1915	1155	2055
			3000	950	1710	1025	1835	1100	1970	1185	2115	1270	2265
			4000	1045	1880	1125	2025	1210	2175	1300	2335	1400	2510
			5000	1150	2075	1240	2240	1335	2410	1435	2595	1540	2795
			6000	1265	2305	1365	2485	1475	2680	1585	2895	1705	3125
			7000	1400	2565	1510	2770	1630	3000	1755	3245	1890	3515
			8000	1550	2870	1675	3110	1805	3375	1945	3670	2095	3990

Figure 5-4. Takeoff Distance (Sheet 1 of 2)

1. Identify the pressure altitude for field elevation: Kollsman window to 29.92.

2. Read column to closest temperature. (2,000@20C) 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**

WEIGHT LBS	TAKEOFF SPEED KIAS		PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
	LIFT OFF	AT 50 FT		GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS
2400	51	59	S.L.	795	1400	860	1570	925	1755	995	1970	1065	2215
			1000	875	1605	940	1725	1015	1860	1090	2000	1170	2155
			2000	960	1770	1035	1910	1115	2060	1200	2220	1290	2395
			3000	1055	1960	1140	2120	1230	2295	1325	2480	1425	2685
			4000	1165	2185	1260	2365	1355	2570	1465	2790	1575	3030
			5000	1285	2445	1390	2660	1500	2895	1620	3160	1745	3455
			6000	1425	2755	1540	3015	1665	3300	1800	3620	1940	3990
			7000	1580	3140	1710	3450	1850	3805	2000	4220	–	–
			8000	1755	3615	1905	4015	2060	4480	–	–	–	–
2200	49	54	S.L.	650	1195	700	1280	750	1375	805	1470	865	1575
			1000	715	1310	765	1405	825	1510	885	1615	950	1735
			2000	780	1440	840	1545	905	1660	975	1785	1045	1915
			3000	856	1585	925	1705	995	1835	1070	1975	1150	2130
			4000	945	1750	1020	1890	1100	2040	1180	2200	1270	2375
			5000	1040	1945	1125	2105	1210	2275	1305	2465	1405	2665
			6000	1150	2170	1240	2355	1340	2555	1445	2775	1555	3020
			7000	1270	2440	1375	2650	1485	2890	1605	3150	1730	3450
			8000	1410	2760	1525	3015	1650	3305	1785	3630	1925	4005
2000	46	51	S.L.	525	970	565	1035	605	1110	650	1185	695	1265
			1000	570	1060	615	1135	665	1215	710	1295	765	1385
			2000	625	1160	675	1240	725	1330	780	1425	840	1525
			3000	690	1270	740	1365	800	1465	860	1570	920	1685
			4000	755	1400	815	1500	880	1615	945	1735	1015	1865
			5000	830	1545	900	1660	970	1790	1040	1925	1120	2070
			6000	920	1710	990	1845	1070	1990	1150	2145	1235	2315
			7000	1015	1900	1095	2055	1180	2225	1275	2405	1370	2605
			8000	1125	2125	1215	2305	1310	2500	1410	2715	1520	2950

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?

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.

WEIGHT LBS	TAKE OFF SPEED KIAS		PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
	LIFT OFF	AT 50 FT		GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS
2400	51	59	S.L.	795	1460	860	1570	925	1685	995	1810	1065	1945
			1000	875	1605	940	1725	1015	1860	1090	2000	1170	2155
			2000	960	1770	1035	1910	1115	2060	1200	2220	1290	2395
			3000	1055	1960	1140	2120	1230	2295	1325	2480	1425	2685
			4000	1165	2185	1260	2365	1365	2570	1465	2790	1575	3030
			5000	1285	2445	1390	2660	1500	2885	1620	3160	1745	3455
			6000	1425	2755	1540	3015	1665	3300	1800	3620	1940	3990
			7000	1580	3140	1710	3450	1850	3805	2000	4220	–	–
			8000	1756	3615	1905	4015	2060	4480	–	–	–	–
2200	49	54	S.L.	650	1195	700	1280	750	1375	805	1470	865	1575
			1000	715	1315	765	1405	825	1510	885	1615	950	1735
			2000	780	1440	840	1545	905	1660	975	1785	1045	1915
			3000	856	1585	925	1705	995	1835	1070	1975	1150	2130
			4000	945	1750	1020	1890	1100	2040	1180	2200	1270	2375
			5000	1040	1945	1125	2105	1210	2275	1305	2465	1405	2665
			6000	1150	2170	1240	2355	1340	2555	1445	2775	1555	3020
			7000	1270	2440	1375	2655	1485	2890	1605	3155	1730	3450
			8000	1410	2760	1525	3015	1650	3305	1785	3630	1925	4005
2000	46	51	S.L.	525	970	565	1035	605	1110	650	1185	695	1265
			1000	570	1060	615	1135	665	1215	710	1295	765	1385
			2000	625	1160	675	1240	725	1330	780	1425	840	1525
			3000	690	1270	740	1365	800	1465	860	1570	920	1685
			4000	756	1400	815	1500	880	1615	945	1735	1015	1865
			5000	830	1545	900	1660	970	1790	1040	1925	1120	2070
			6000	920	1710	990	1845	1070	1990	1150	2145	1235	2315
			7000	1015	1900	1095	2055	1180	2225	1275	2405	1370	2605
			8000	1125	2125	1215	2305	1310	2500	1410	2715	1520	2950

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

WEIGHT LBS	TAKE OFF SPEED KIAS		PRESS ALT FT	0°C		10°C	
	LIFT OFF	AT 50 FT		GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS
2400	51	58	S.L	795	1460	864	1570
			1000	875	1605	940	1725
			2000	960	1770	1035	1910
			3000	1056	1960	1140	2120
			4000	1165	2185	1260	2365
			5000	1285	2445	1390	2660
			6000	1425	2755	1540	3015
			7000	1580	3140	1710	3450
			8000	1756	3615	1905	4015
2200	49	54	S.L	650	1195	700	1280
			1000	715	1315	765	1405
			2000	780	1440	840	1545
			3000	856	1585	925	1705
			4000	945	1750	1020	1890
			5000	1040	1945	1125	2105
			6000	1150	2170	1240	2355
			7000	1270	2440	1370	2650

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.

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)= <u>2325</u>

AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

LANDING CHARTS (WORK SAME AS TO CHARTS)

LANDING DISTANCE

SHORT FIELD

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

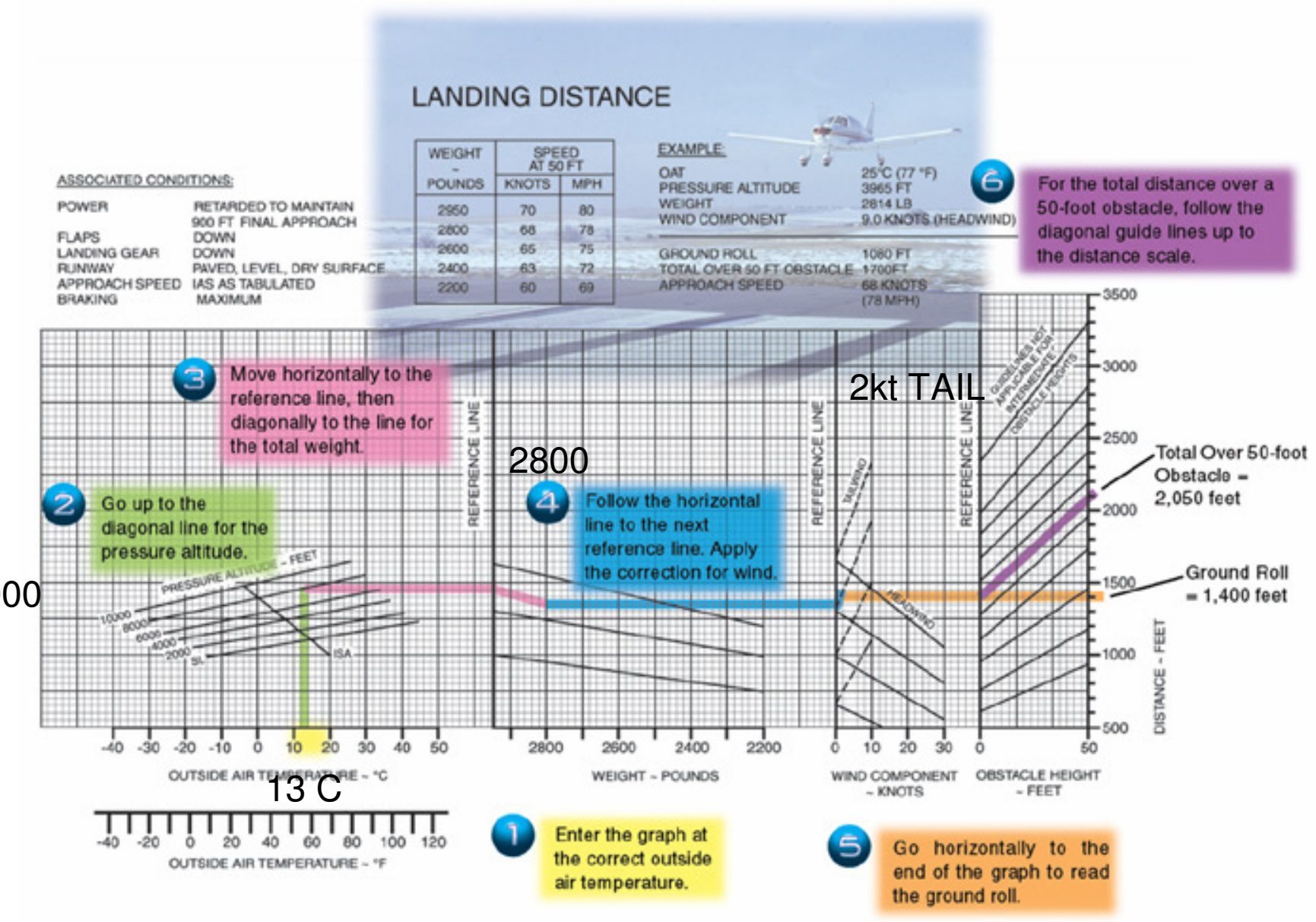
NOTES:
1. Short field technique as specified in Section 4.
2. Decrease distances 10% for each 9 knots headwind. For operation with tailwinds up to 10 knots, increase distances by 10% for each 2 knots
3. For operation on a dry, grass runway, increase distances by 45% of the "ground roll" figure.

WEIGHT LBS	SPEED AT 50 FT KIAS	PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
			GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS
2300	60	S.L.	495	1205	510	1235	530	1265	545	1295	565	1330
		1000	510	1235	530	1265	550	1300	565	1330	585	1365
		2000	530	1265	550	1300	570	1335	590	1370	610	1405
		3000	550	1300	570	1335	590	1370	610	1405	630	1440
		4000	570	1335	590	1370	615	1410	635	1445	655	1480
		5000	590	1370	615	1415	635	1450	655	1485	680	1525
		6000	615	1415	640	1455	660	1490	685	1535	705	1570
		7000	640	1455	660	1495	685	1535	710	1575	730	1615
		8000	665	1500	690	1540	710	1580	735	1620	760	1665

Figure 5-10. Landing Distance

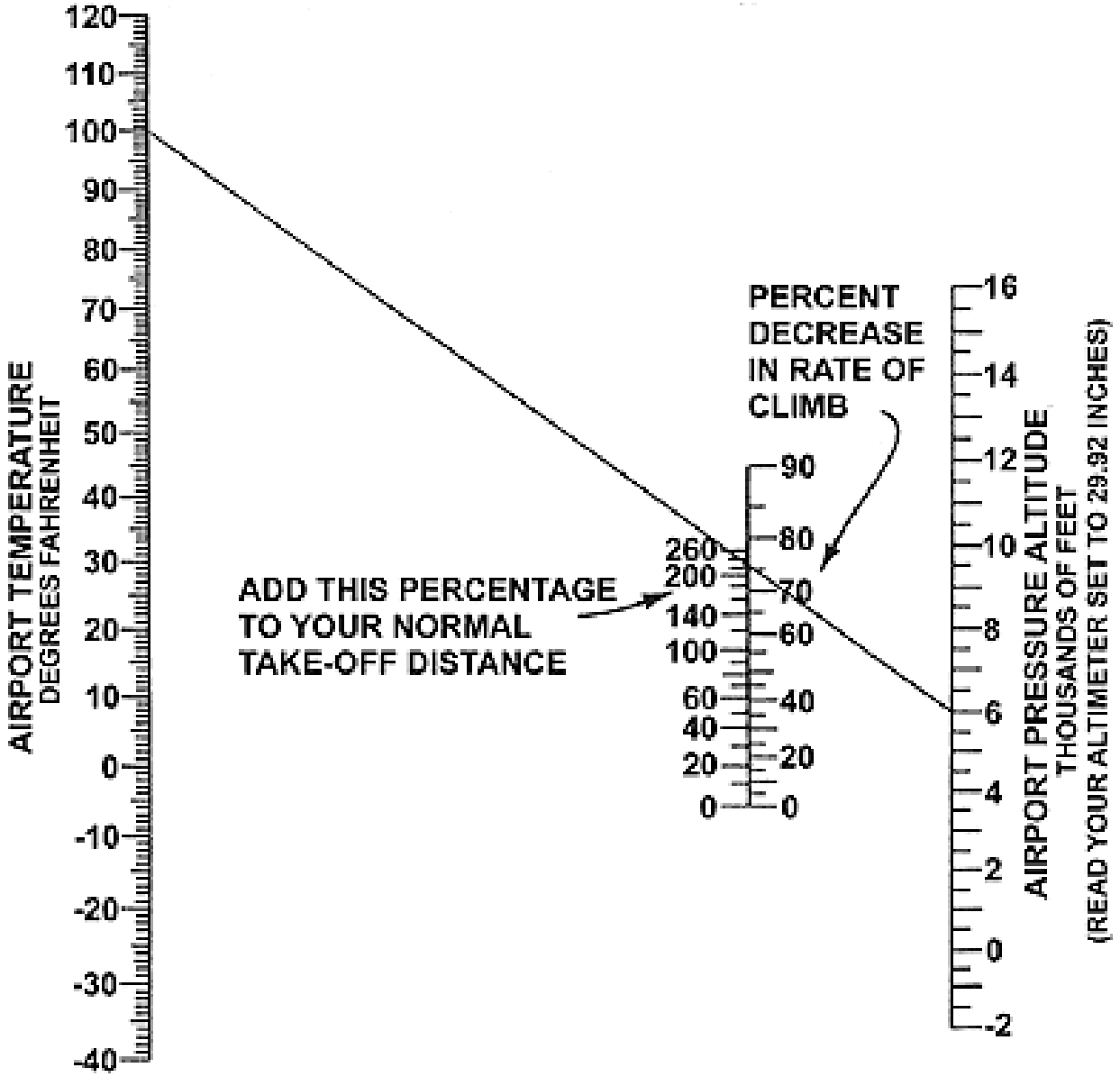
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE ALL IN ONE!

Problem: 13C, PAlt 8000, Weight 2800, 2 Kt tailwind, takeoff over 50 ft obstacle



AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

KOCH CHART – TO/CLIMB ADJUSTMENT CHART



AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

DETERMINING IAS OF STALLS IN DIFFERENT CONFIGURATIONS & ATTITUDES

AIRSPEED CALIBRATION — NORMAL SYSTEM

Flaps 0°		Flaps 15°		Flaps 45°	
KIAS	KCAS	KIAS	KCAS	KIAS	KCAS
80	84	70	79	70	76
100	102	80	86	80	84
120	122	90	94	90	93
140	141	100	103	100	102
160	161	110	112	110	111
180	181	120	121	120	120
200	201	130	131	130	129
220	221	140	141	140	138
240	242	150	151		

KIAS — INDICATED AIRSPEED IN KNOTS KCAS — CALIBRATED AIRSPEED IN KNOTS

STALL SPEEDS — KCAS

4600 LB GROSS WEIGHT

CONFIGURATION	ANGLE OF BANK 0°	20°	40°	60°
Gear and Flaps Up	84	87	97	119
Gear Down and Flaps 15°	80	83	92	113
Gear Down and Flaps 45°	76	79	87	108

6750. 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

1.KCAS=87

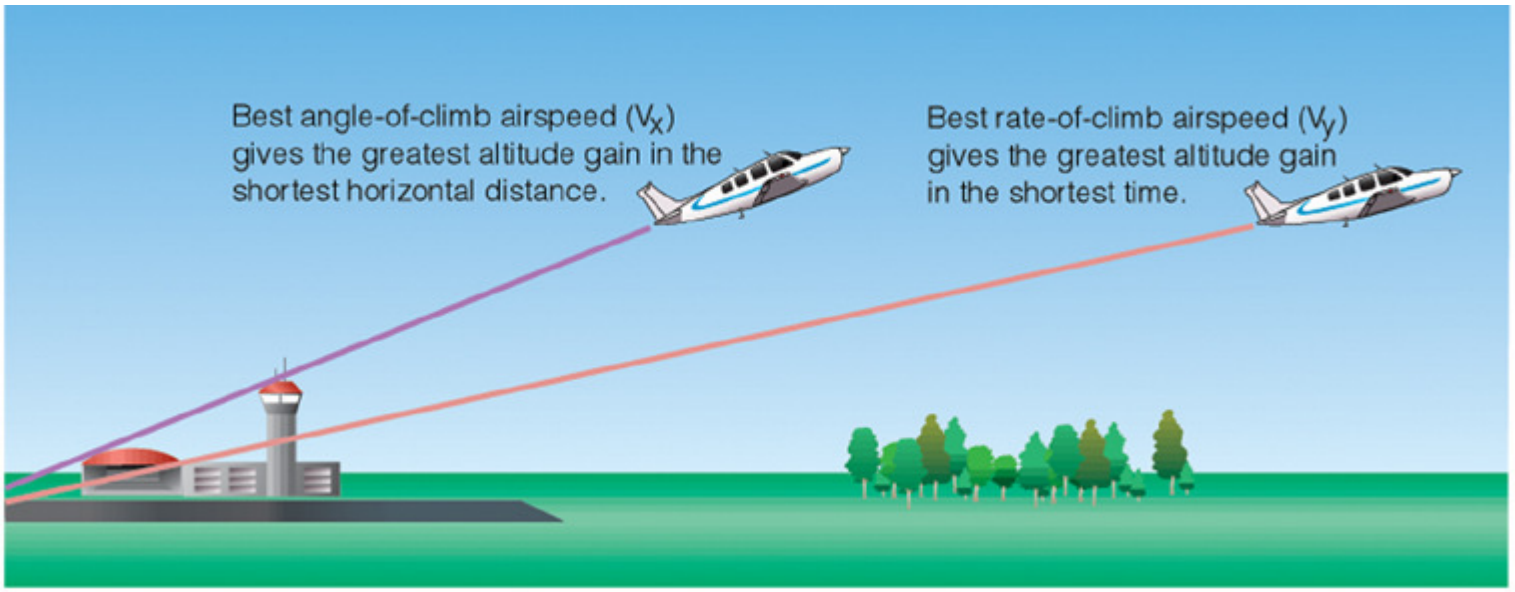
2. Difference=4 Apply 87-4=83

6752. (Refer to figure 25 on page 74.) What would be the indicated stall speed during a 40° banked turn with the gear down and flaps set at 45°?

A— 81 KIAS.
B — 83 KIAS.
C— 89 KIAS.

Answer **B** – 83 KIAS

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.

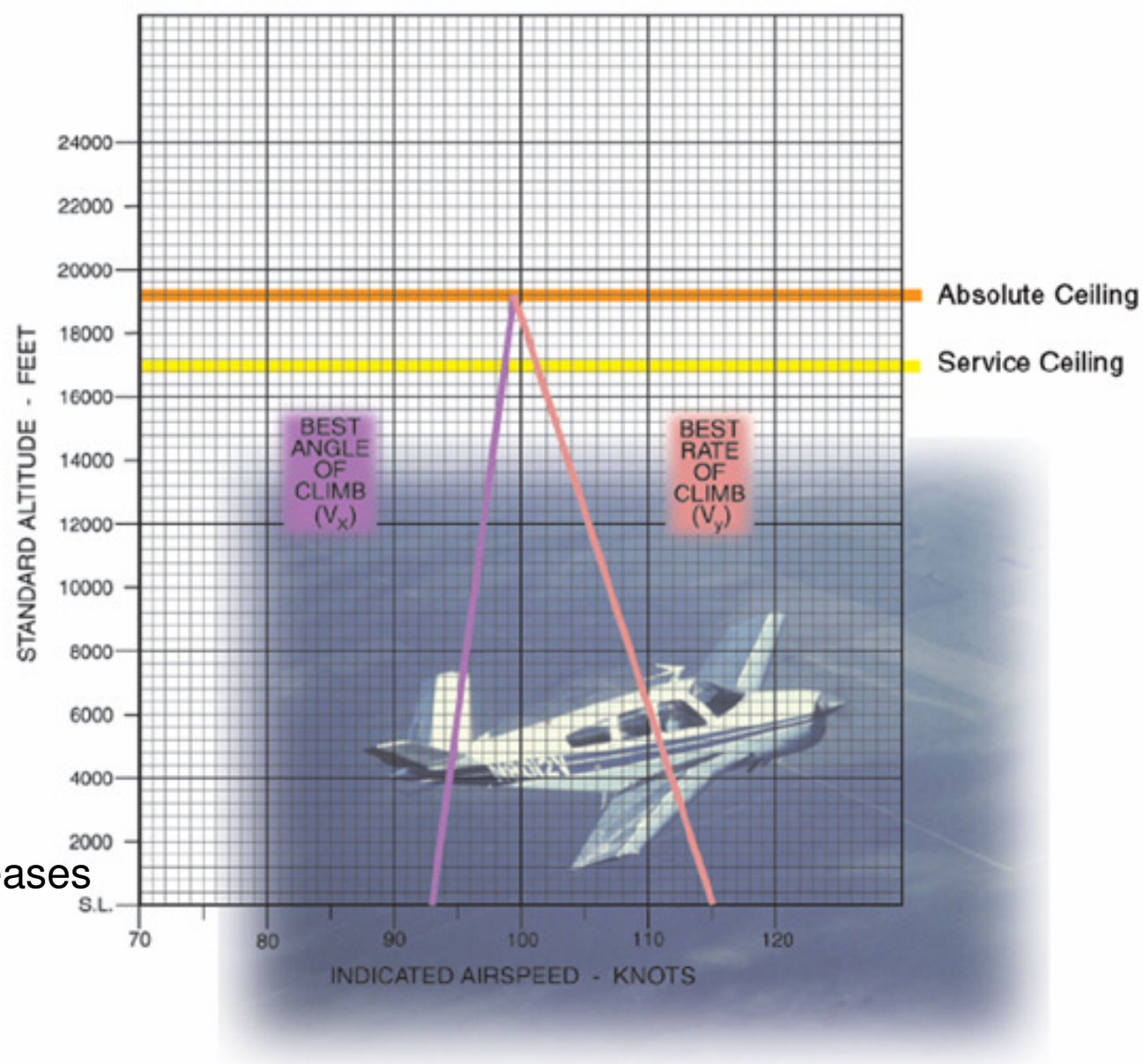
V-SPEEDS SPECIFIC TO YOUR AIRCRAFT AND FOUND IN THE AIRCRAFT PILOT OPERATING HANDBOOK (POH)

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



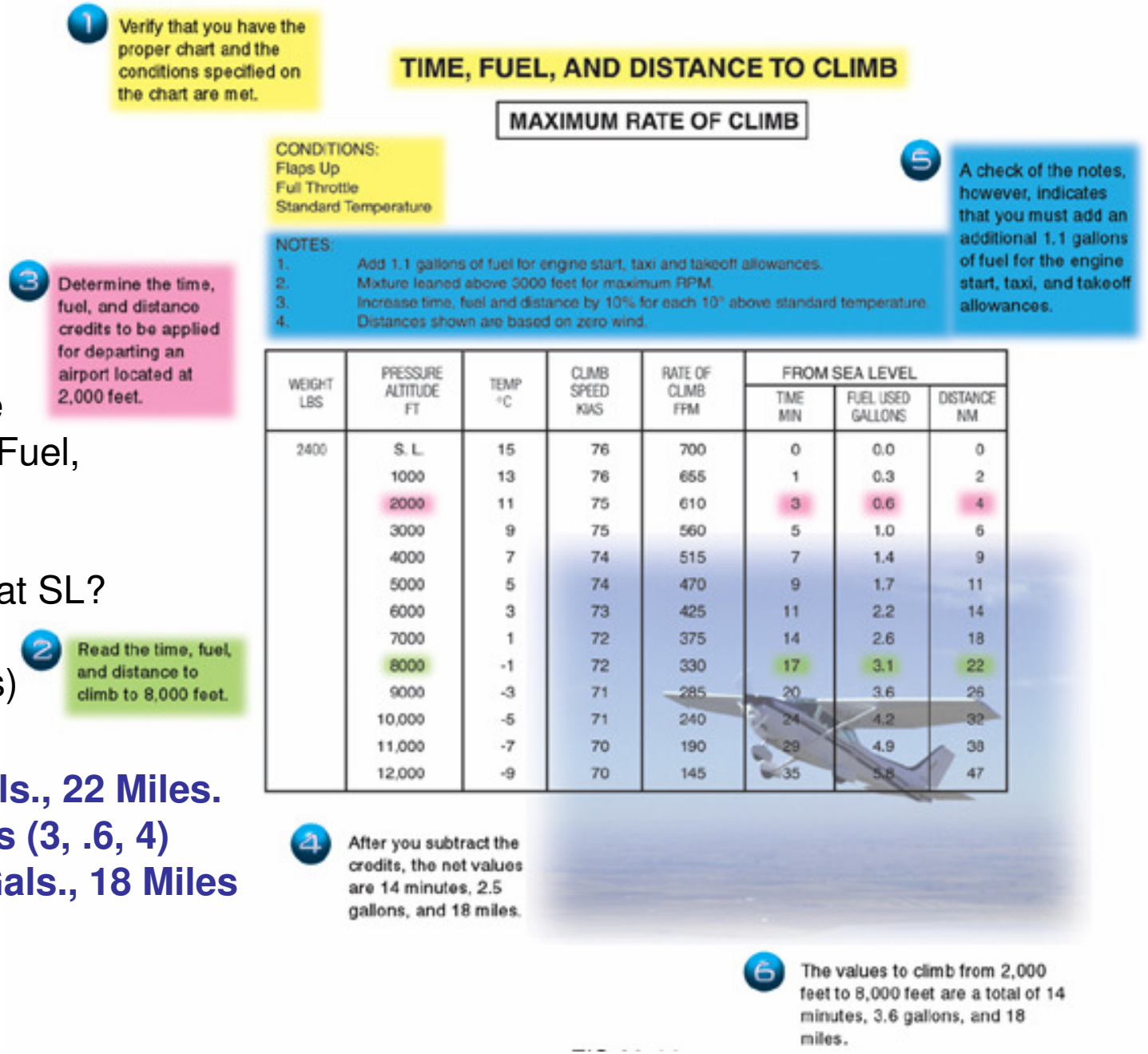
IAS increase with Vx, decreases with Vy at higher altitudes.

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

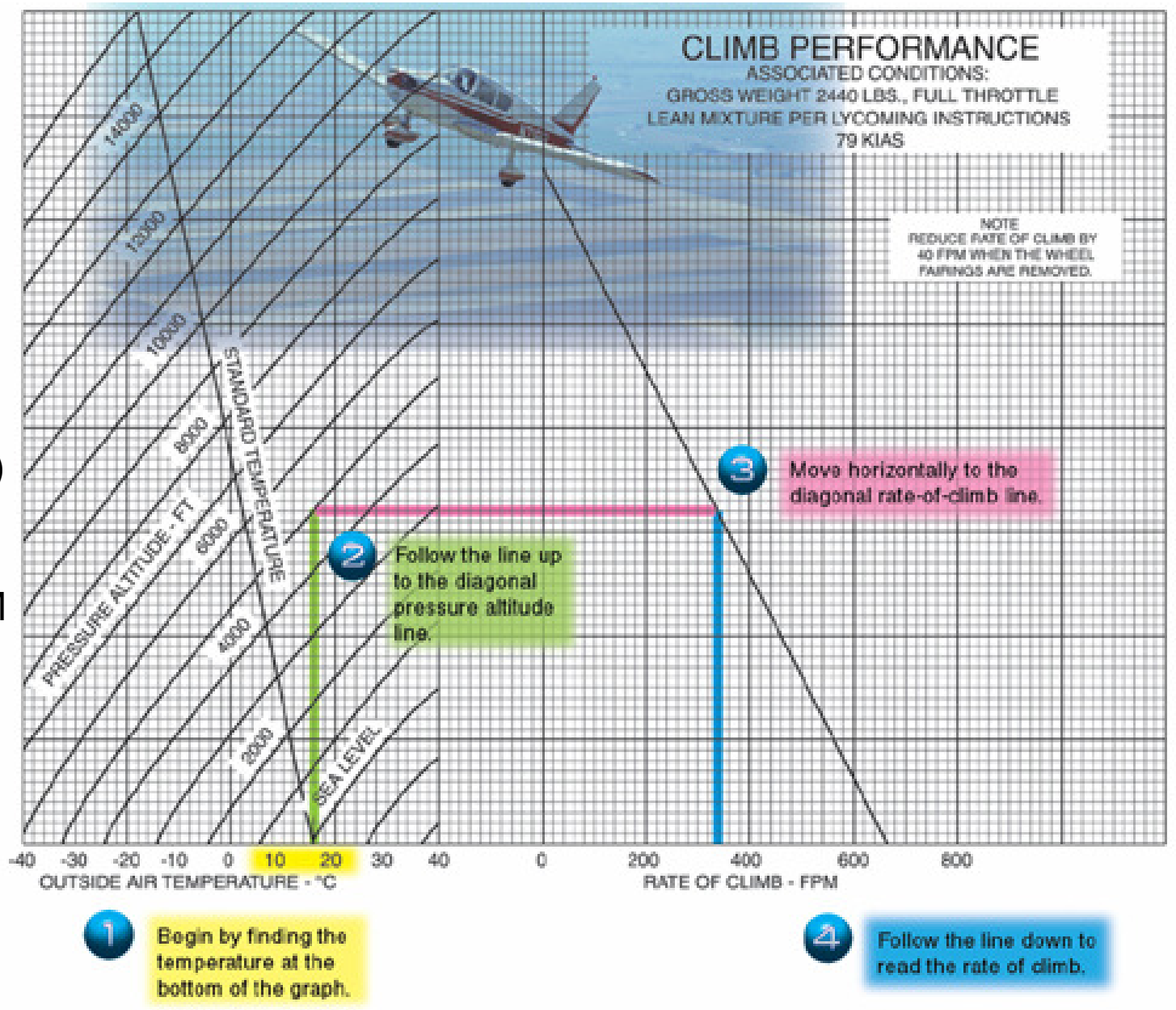
Pr. Alt. = 4000

INTERSECT(3)

DOWN TO

FIND ROC

= 335-340 FPM



Rate of Climb Charts – Interpellation required – watch fine print !

NORMAL CLIMB - 100 KIAS

CONDITIONS:
Flaps Up
Gear Up
2550 RPM
25 Inches MP or Full Throttle
Cowl Flaps Open
Standard Temperature

MIXTURE SETTING	
PRESS ALT	PPH
S.L. to 4000	108
8000	96
12,000	84

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.

WEIGHT LBS	PRESS ALT FT	RATE OF CLIMB FPM	FROM SEA LEVEL		
			TIME MIN	FUEL USED POUNDS	DISTANCE NM
3800	S.L.	580	0	0	0
	2000	580	3	6	6
	4000	570	7	12	12
	6000	470	11	19	19
	8000	365	16	27	28
	10,000	265	22	37	40
	12,000	165	32	51	59
3500	S.L.	685	0	0	0
	2000	685	3	5	5
	4000	675	6	11	10
	6000	565	9	16	16
	8000	455	13	23	23
	10,000	350	18	31	33
	12,000	240	25	41	46
3200	S.L.	800	0	0	0
	2000	800	2	4	4
	4000	795	5	9	8
	6000	675	8	14	13
	8000	560	11	19	19
	10,000	445	15	25	27
	12,000	325	20	33	37

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

CONDITIONS:
Flaps Up
Gear Up
2600 RPM
Cowl Flaps Open

PRESS ALT	MP	PPH
S.L. TO 17,000	35	162
18,000	34	156
20,000	32	144
22,000	30	132
24,000	28	120

WEIGHT LBS	PRESS ALT FT	CLIMB SPEED KIAS	RATE OF CLIMB - FPM			
			-20 °C	0 °C	20 °C	40 °C
4000	S.L.	100	1170	1035	895	755
	4000	100	1080	940	800	655
	8000	100	980	840	695	555
	12,000	100	870	730	590	---
	16,000	100	740	605	470	---
	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 33. – Maximum Rate-of-Climb Chart.

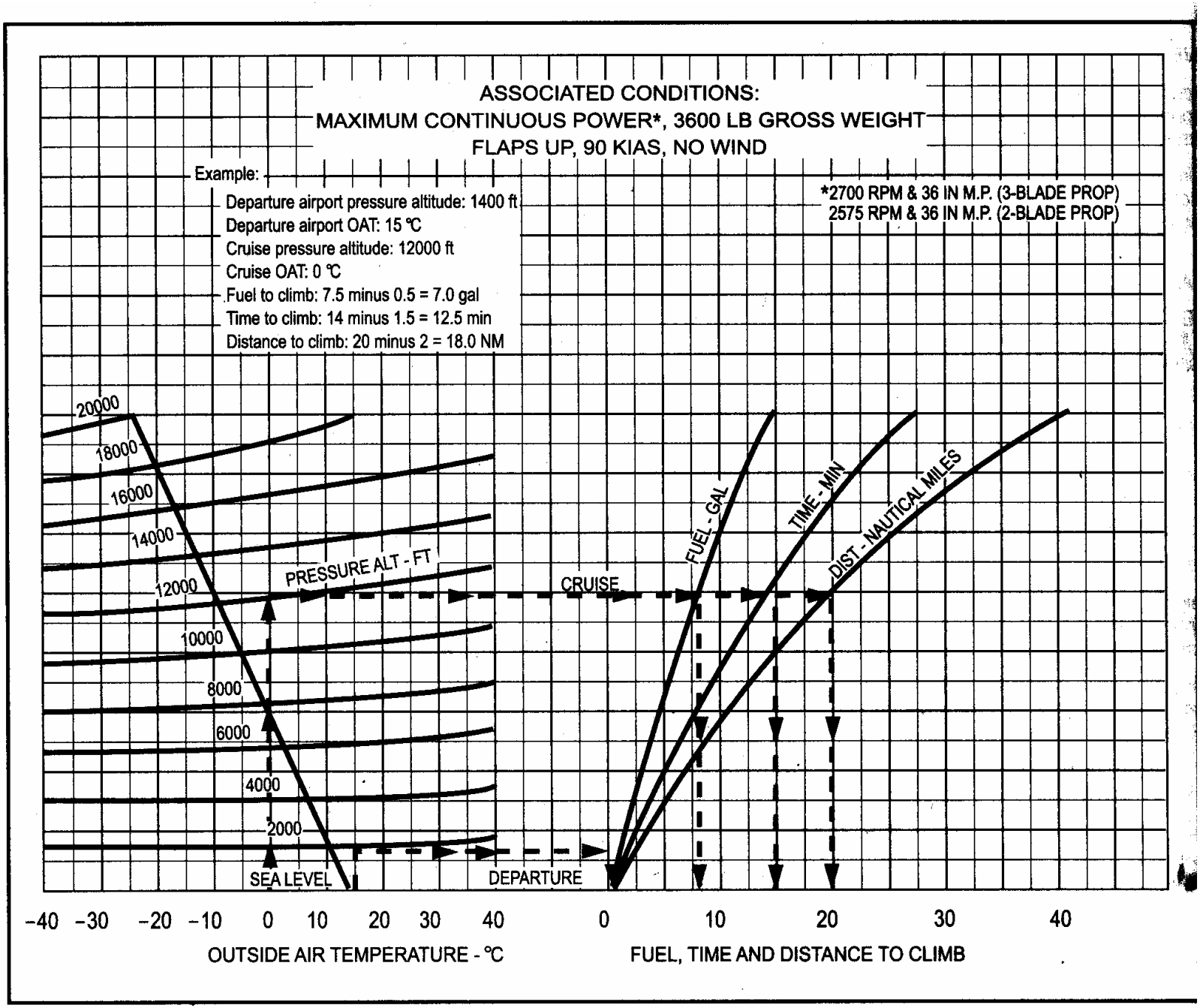
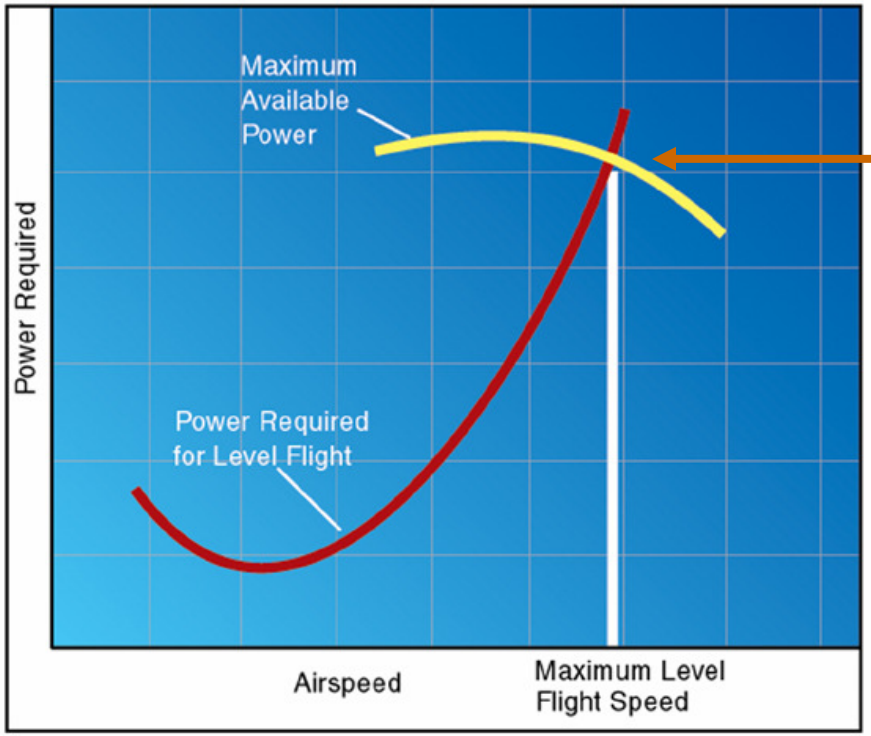


Figure 15. – Fuel, Time, and Distance to Climb.

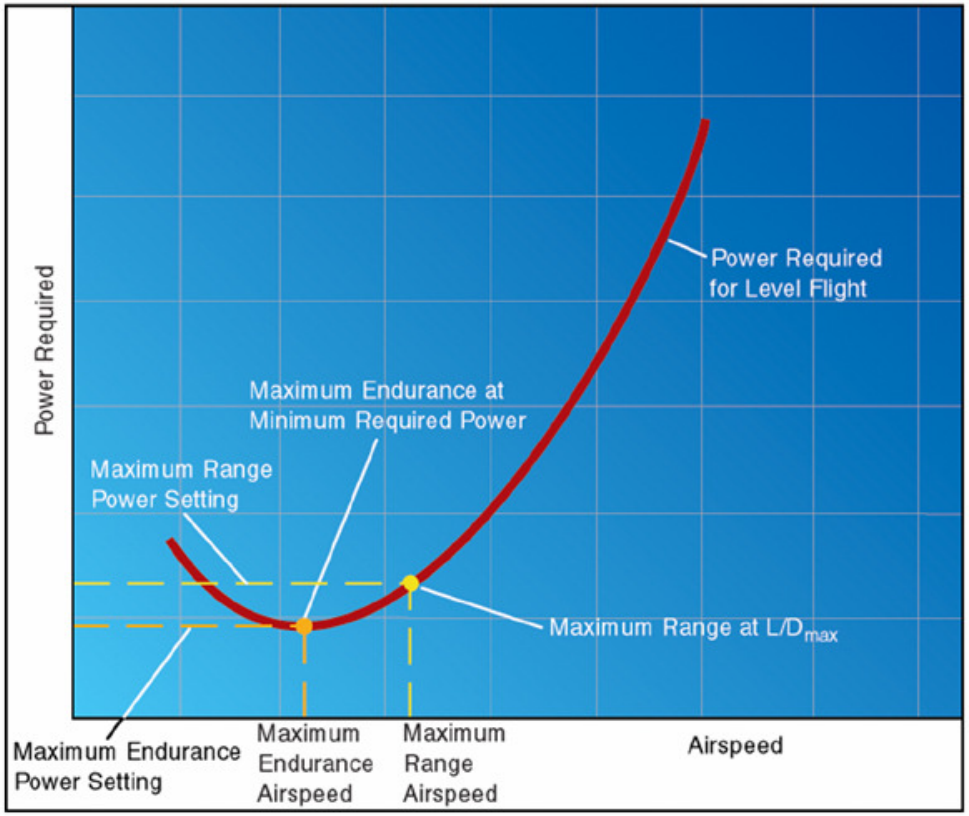
AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

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

PRESS ALT.	ISA –20 °C (–36 °F)								STANDARD DAY (ISA)								ISA + 20 °C (+36 °F)							
	IOAT		ENGINE SPEED	MAN PRESS	FUEL FLOW PER ENGINE		TAS		IOAT		ENGINE SPEED	MAN PRESS	FUEL FLOW PER ENGINE		TAS		IOAT		ENGINE SPEED	MAN PRESS	FUEL FLOW PER ENGINE		TAS	
FEET	°F	°C	RPM	IN HG	PSI	GPH	KTS	MPH	°F	°C	RPM	IN HG	PSI	GPH	KTS	MPH	°F	°C	RPM	IN HG	PSI	GPH	KTS	MPH
SL	27	-3	2450	20.7	6.6	11.5	147	169	63	17	2450	21.2	6.6	11.5	150	173	99	37	2450	21.8	6.6	11.5	153	176
2000	19	-7	2450	20.4	6.6	11.5	149	171	55	13	2450	21.0	6.6	11.5	153	176	91	33	2450	21.5	6.6	11.5	156	180
4000	12	-11	2450	20.1	6.6	11.5	152	175	48	9	2450	20.7	6.6	11.5	156	180	84	29	2450	21.3	6.6	11.5	159	183
6000	5	-15	2450	19.8	6.6	11.5	155	178	41	5	2450	20.4	6.6	11.5	158	182	79	26	2450	21.0	6.6	11.5	161	185
8000	-2	-19	2450	19.5	6.6	11.5	157	181	36	2	2450	20.2	6.6	11.5	161	185	72	22	2450	20.8	6.6	11.5	164	189
10000	-8	-22	2450	19.2	6.6	11.5	160	184	28	-2	2450	19.9	6.6	11.5	163	188	64	18	2450	20.3	6.5	11.4	166	191
12000	-15	-26	2450	18.8	6.4	11.3	162	186	21	-6	2450	18.8	6.1	10.9	163	188	57	14	2450	18.8	5.9	10.6	163	188
14000	-22	-30	2450	17.4	5.8	10.5	159	183	14	-10	2450	17.4	5.6	10.1	160	184	50	10	2450	17.4	5.4	9.8	160	184
16000	-29	-34	2450	16.1	5.3	9.7	156	180	7	-14	2450	16.1	5.1	9.4	156	180	43	6	2450	16.1	4.9	9.1	155	178

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.

AIRPLANE PERFORMANCE / WEIGHT AND BALANCE

Usually determine by desired airspeed or range or endurance.

CRUISE PERFORMANCE

PRESSURE ALTITUDE 2000 FEET

CONDITIONS:
2950 Pounds
Recommended Lean Mixture
Cowl Flaps Closed

NOTE
For best fuel economy at 65% power or less, operate at the leanest mixture that results in smooth engine operation or at peak EGT if an EGT indicator is installed.

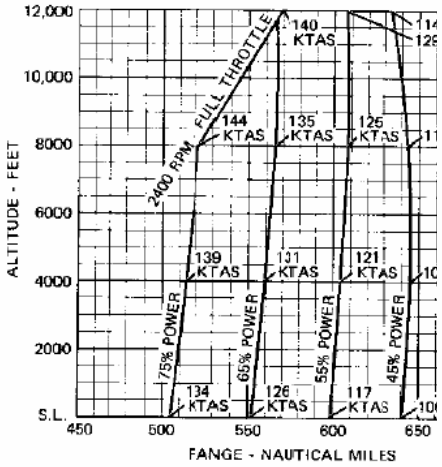
		20°C BELOW STANDARD TEMP -9°C			STANDARD TEMPERATURE 11°C			20°C ABOVE STANDARD TEMP 31°C		
RPM	MP	% BHP	KTAS	GPH	% BHP	KTAS	GPH	% BHP	KTAS	GPH
2400	22	77	134	13.1	74	135	12.6	71	136	12.2
	21	72	131	12.3	69	132	11.8	67	133	11.4
	20	67	128	11.5	65	128	11.1	63	129	10.7
	19	62	124	10.7	60	124	10.3	58	125	10.0
2300	23	78	135	13.3	75	136	12.8	72	137	12.4
	22	73	132	12.5	70	133	12.0	68	133	11.6
	21	68	128	11.7	66	129	11.3	64	130	10.9
	20	64	125	10.9	62	125	10.5	60	126	10.2
2200	23	73	132	12.5	70	133	12.0	68	133	11.6
	22	69	129	11.7	66	129	11.3	64	130	10.9
	21	64	125	11.0	62	126	10.6	60	126	10.2
	20	60	121	10.2	58	122	9.9	56	122	9.6
2100	23	68	128	11.6	66	129	11.2	64	130	10.8
	22	64	125	10.9	62	126	10.5	60	126	10.2
	21	60	121	10.2	58	122	9.9	56	122	9.6
	20	56	118	9.6	54	118	9.3	52	118	9.0
	19	52	113	9.0	50	114	8.7	48	113	8.5
	18	47	109	8.4	46	109	8.1	44	108	7.9

RANGE PROFILE

45 MINUTES RESERVE
56 GALLONS USABLE FUEL

CONDITIONS:
2950 Pounds
Recommended Lean Mixture for Cruise
Standard Temperature
Zero Wind

NOTES:
1. This chart allows for the fuel used for engine start, taxi, takeoff and climb distance during a normal climb as shown in figure 5-6.
2. Reserve fuel is based on 45 minutes at 45% BHP and is 6 gallons.

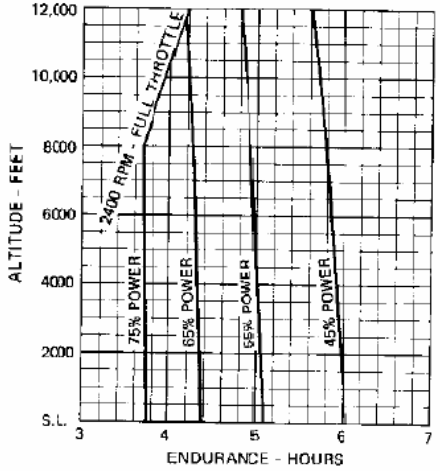


ENDURANCE PROFILE

45 MINUTES RESERVE
56 GALLONS USABLE FUEL

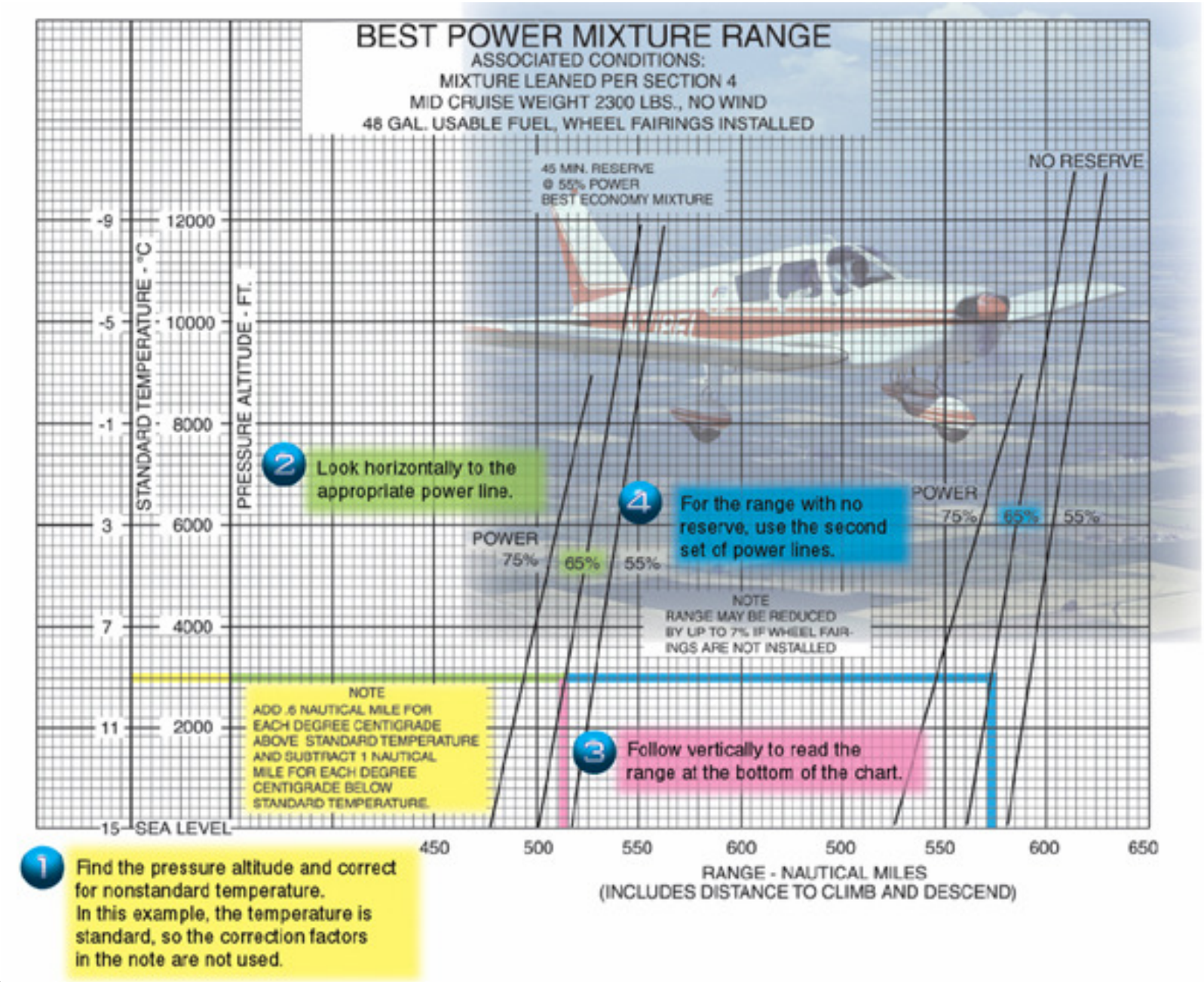
CONDITIONS:
2950 Pounds
Recommended Lean Mixture for Cruise
Standard Temperature

NOTES:
1. This chart allows for the fuel used for engine start, taxi, takeoff and climb, and the time during a normal climb as shown in figure 5-6.
2. Reserve fuel is based on 45 minutes at 45% BHP and is 6 gallons.

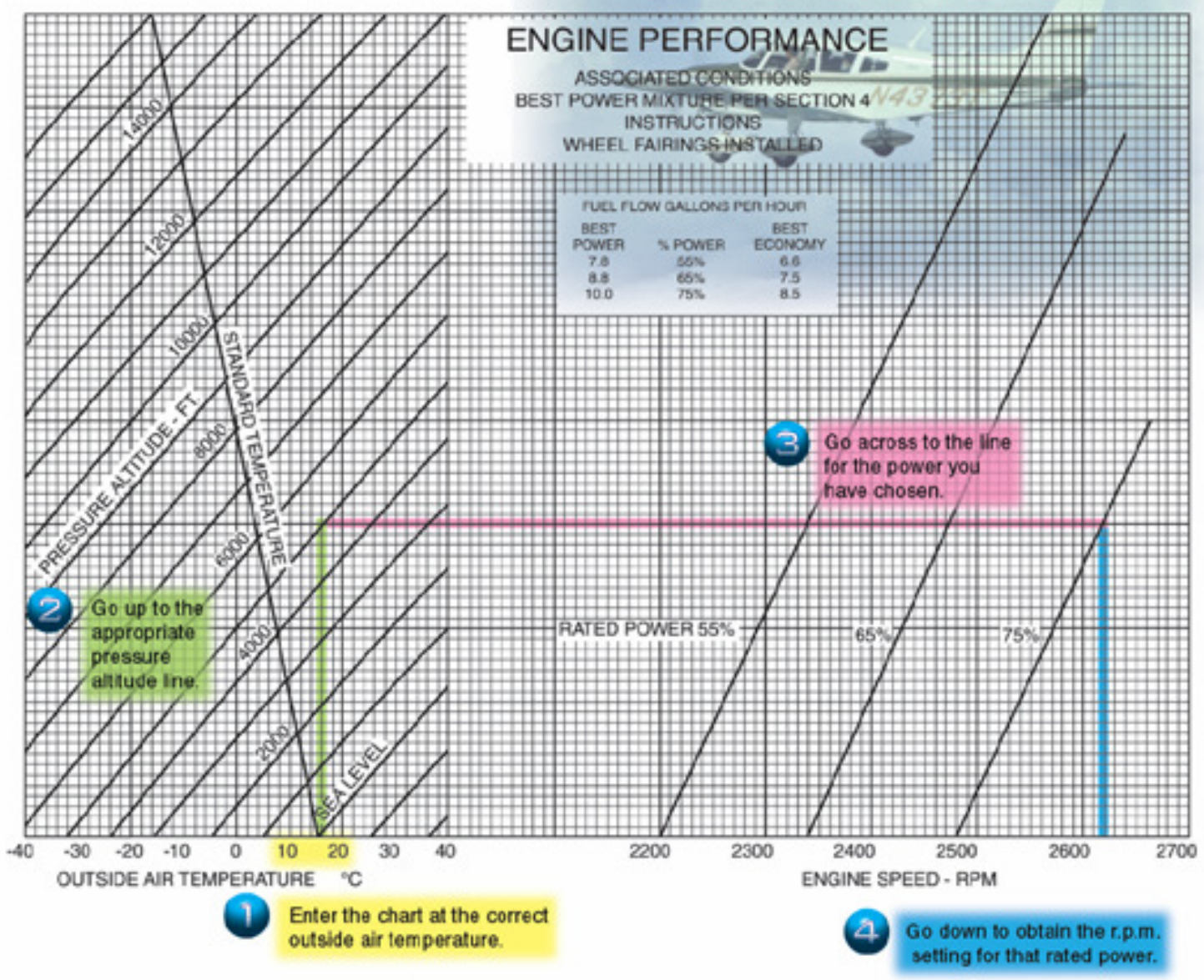


<u>Interpolation required</u>: notice specific altitudes, weights, and temperatures.

AIRPLANE PERFORMANCE / WEIGHT AND BALANCE



AIRPLANE PERFORMANCE / WEIGHT AND BALANCE



Gross Weight - 2300 Lbs.
Standard Conditions
Zero Wind Lean Mixture

NOTE: Maximum cruise is normally limited to 75% power,

					38 GAL (NO RESERVE)		48 GAL (NO RESERVE)	
ALT.	RPM	% BHP	TAS MPH	GAL/ HOUR	ENDR. HOURS	RANGE MILES	ENDR. HOURS	RANGE MILES
2500	2700	86	134	9.7	3.9	525	4.9	660
	2600	79	129	8.6	4.4	570	5.6	720
	2500	72	123	7.8	4.9	600	6.2	760
	2400	65	117	7.2	5.3	620	6.7	780
	2300	58	111	6.7	5.7	630	7.2	795
	2200	52	103	6.3	6.1	625	7.7	790
5000	2700	82	134	9.0	4.2	565	5.3	710
	2600	75	128	8.1	4.7	600	5.9	760
	2500	68	122	7.4	5.1	625	6.4	790
	2400	61	116	6.9	5.5	635	6.9	805
	2300	55	108	6.5	5.9	635	7.4	805
	2200	49	100	6.0	6.3	630	7.9	795
7500	2700	78	133	8.4	4.5	600	5.7	755
	2600	71	127	7.7	4.9	625	6.2	790
	2500	64	121	7.1	5.3	645	6.7	810
	2400	58	113	6.7	5.7	645	7.2	820
	2300	52	105	6.2	6.1	640	7.7	810
10,000	2650	70	129	7.6	5.0	640	6.3	810
	2600	67	125	7.3	5.2	650	6.5	820
	2500	61	118	6.9	5.5	655	7.0	830
	2400	55	110	6.4	5.9	650	7.5	825
	2300	49	100	6.0	6.3	635	8.0	800

Figure 11. – Cruise and Range Performance.

WEIGHT AND BALANCE

WHY SHOULD YOU CARE?

IT'S ABOUT
W E I G H T

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

IT'S ABOUT
B A L A N C E

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**

2950 [Gross] – 1842 [Empty] – (75 * 6) [Fuel] = 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**

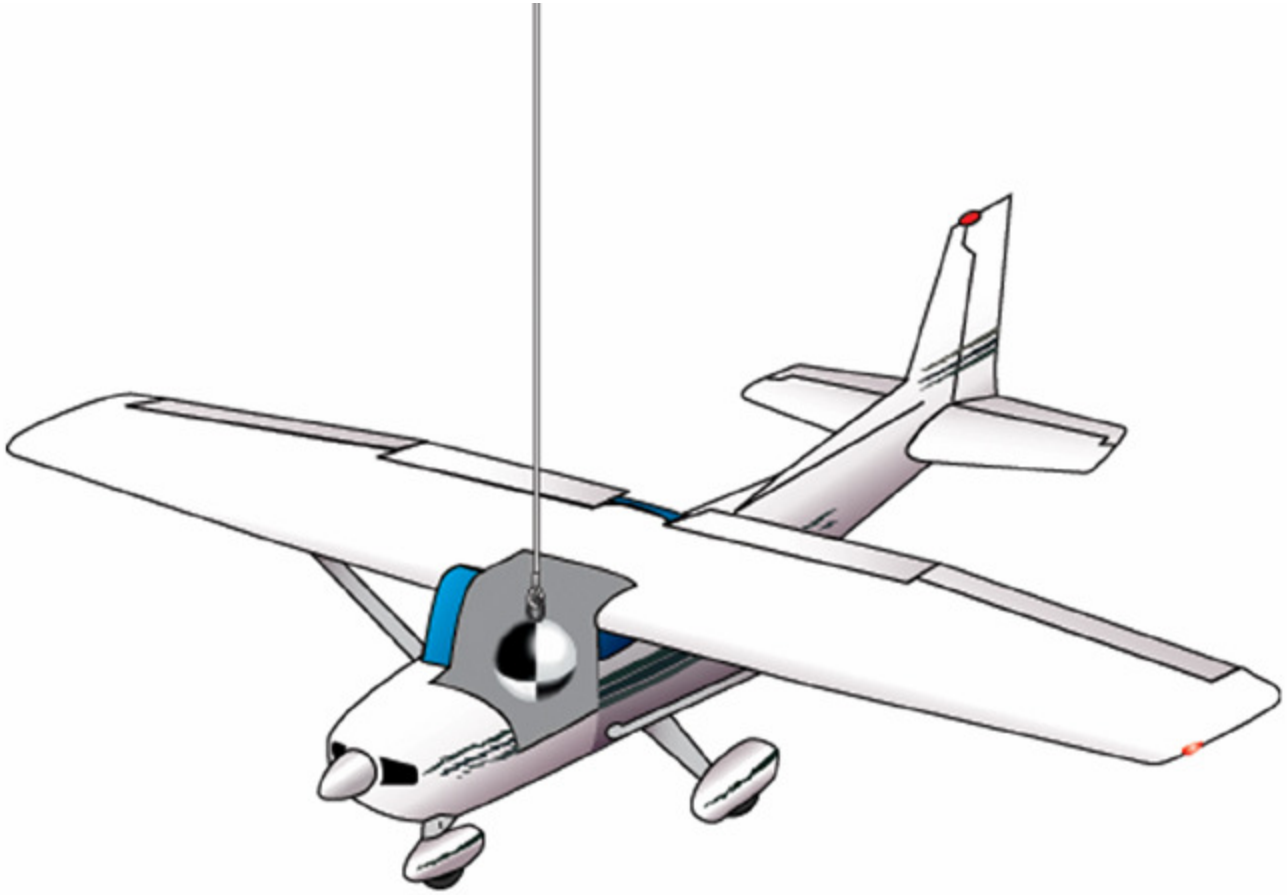
DISCUSSION: What are the RISKS? What are the options in this situation?

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

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.

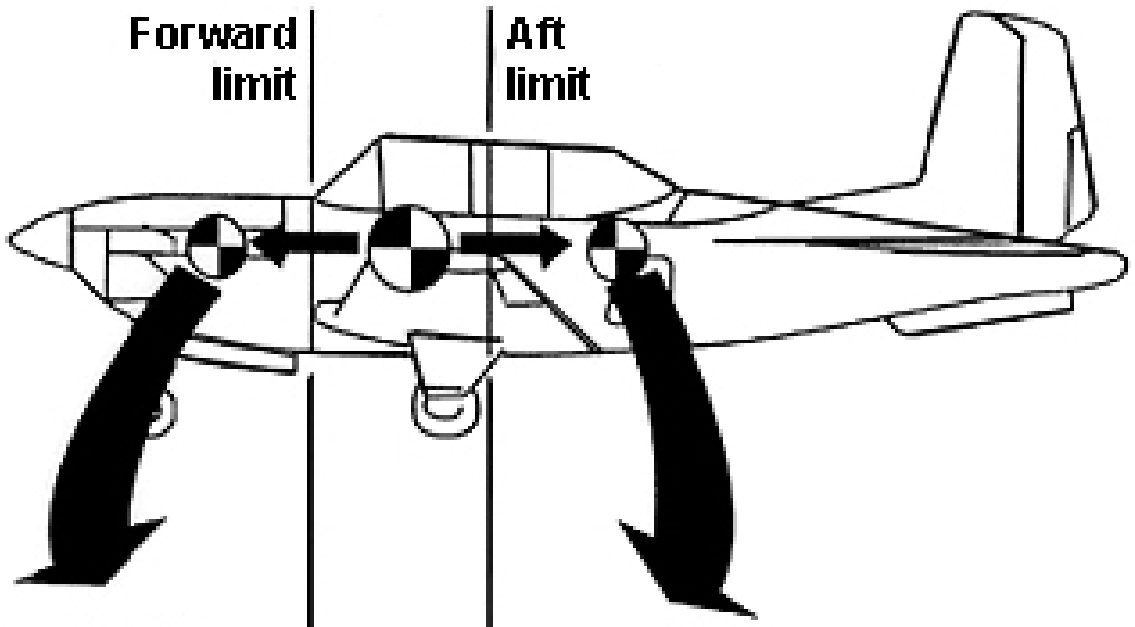
WEIGHT AND BALANCE



“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 take-off and landing

Unstable flight characteristics

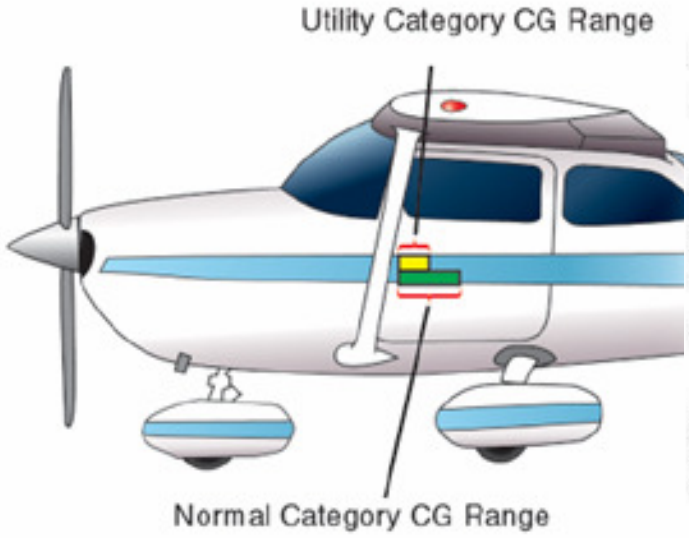
Aircraft structure is easily overstressed

Violent stalls

Aircraft may not recover from a spin

WEIGHT AND BALANCE

Center of gravity has limits of how far forward or rearward CG can be to safely fly the airplane.



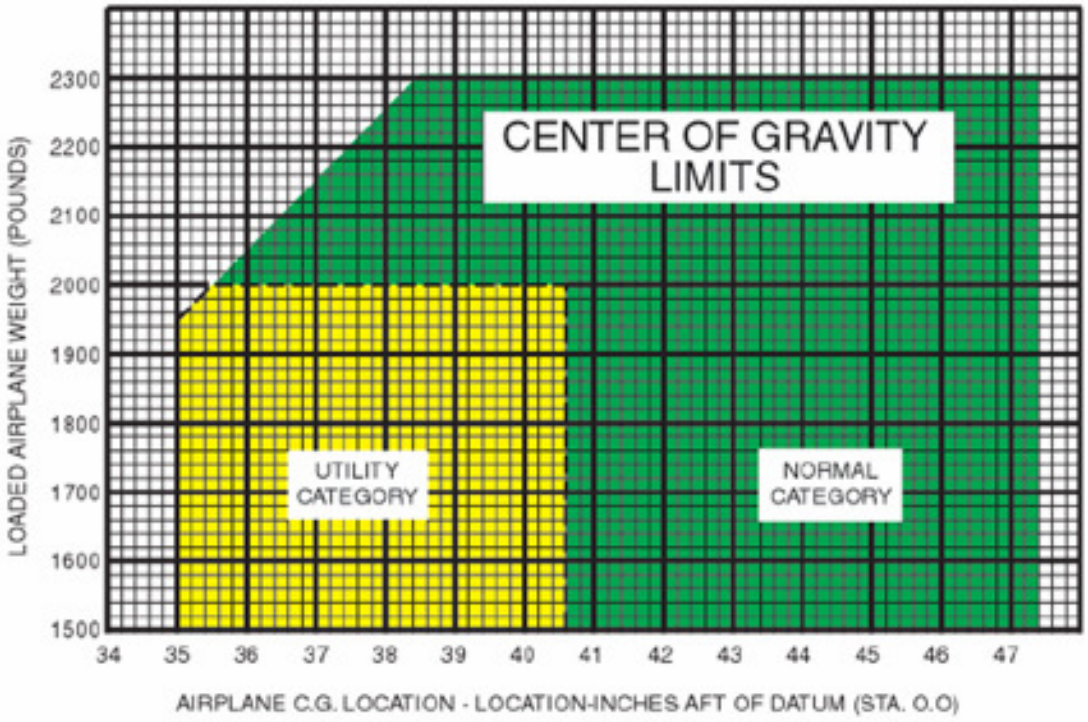
MANEUVER LIMITS

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

Normal +3.8G, -1.52G

Utility +4.4G, -1.76G

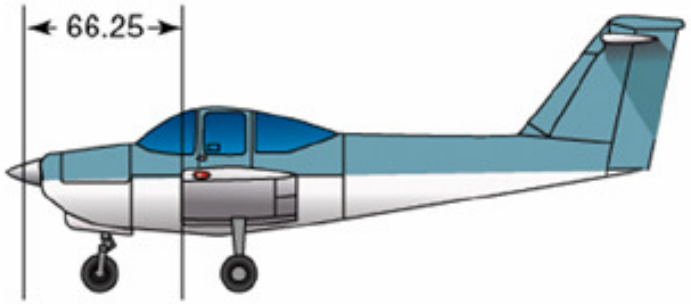
Acrobat +6.0G, -3.00G

Created by Steve Reisser

WEIGHT AND BALANCE

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

The datum is 66.25 inches ahead of the wing's leading edge.

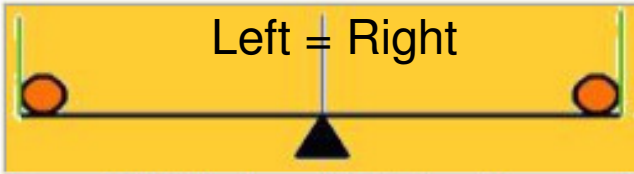


The datum is at the front face of the firewall.

The datum is 109.7 inches ahead of the center of the main gear.

WEIGHT AND BALANCE

BALANCE



5 pounds X 10 inches = 50 inch/pounds

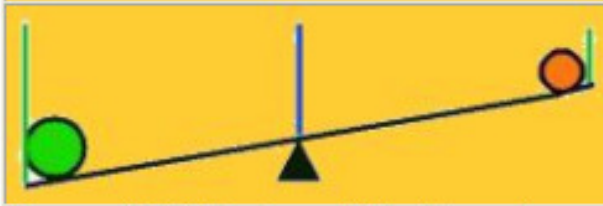
5 pounds X 10 inches = 50 inch/pounds

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

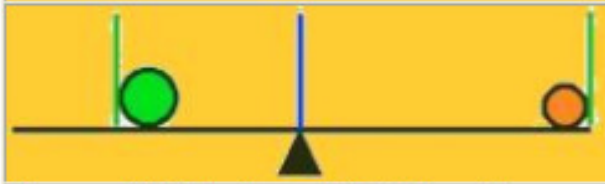
If one of the weights is shifted, an imbalance will also exist.



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.

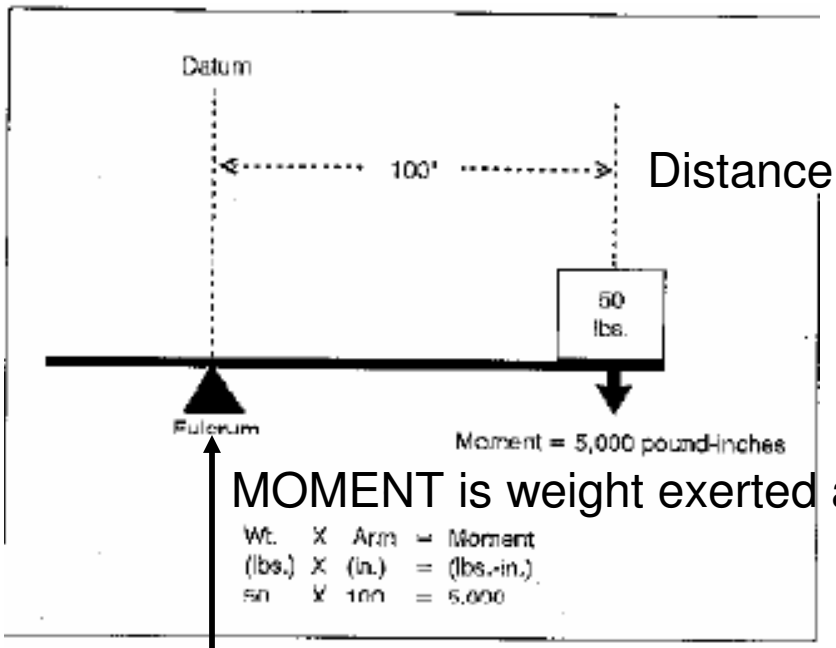


10 pounds X 5 inches = 50 inch/pounds

5 pounds X 10 inches = 50 inch/pounds

Shifting the weight will return the plane to a balanced condition.

WEIGHT AND BALANCE



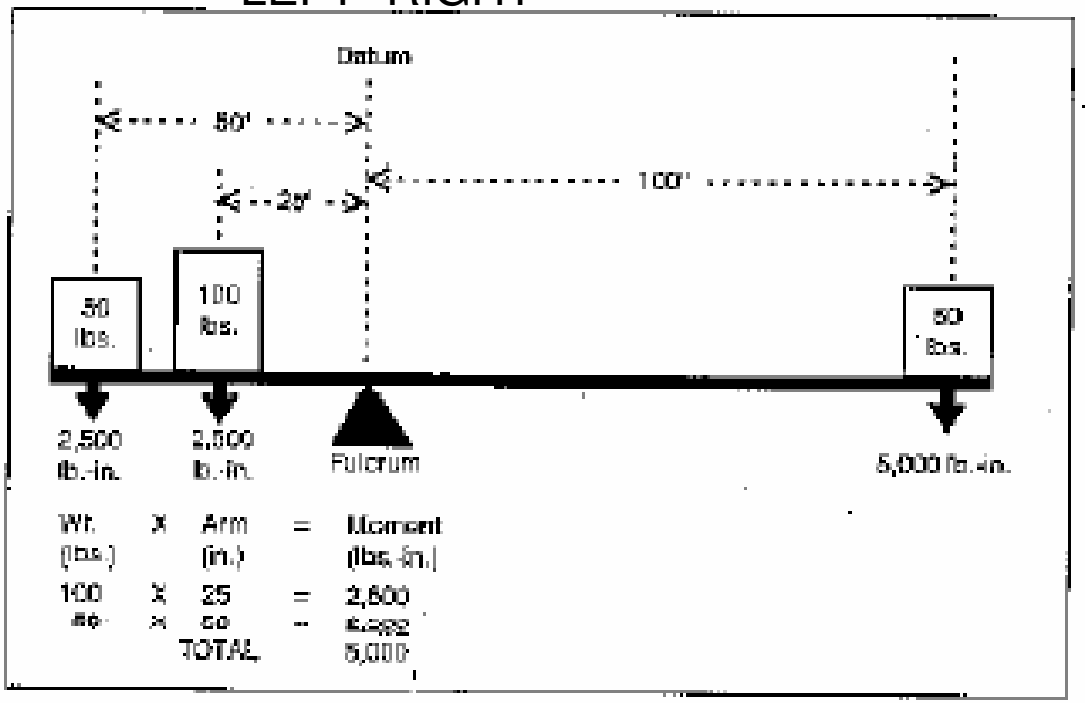
Distance weight is from datum is called ARM

MOMENT is weight exerted at end of the arm

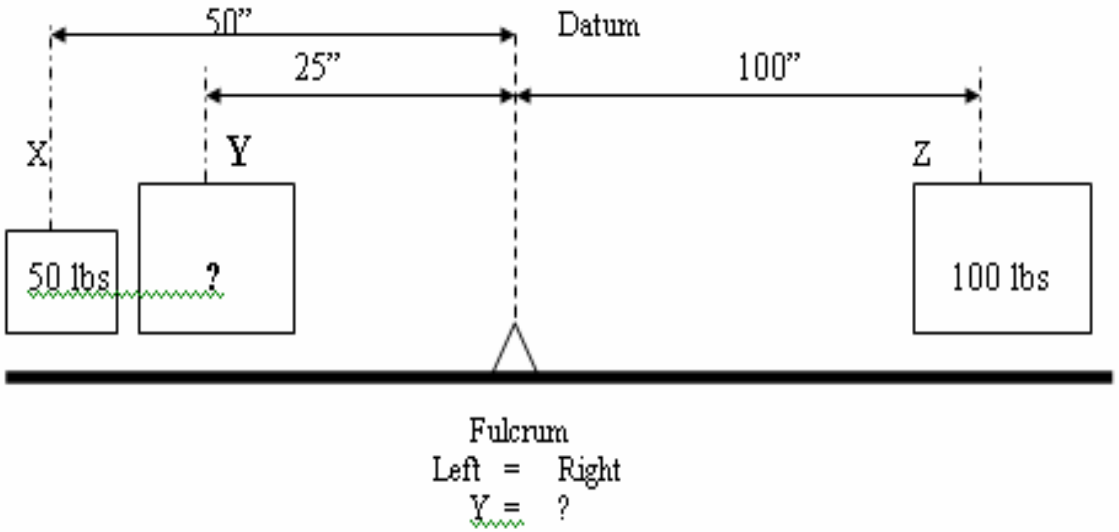
Reference Datum is our fulcrum

BALANCING ACT

LEFT=RIGHT



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*50 + 25Y = 100*100

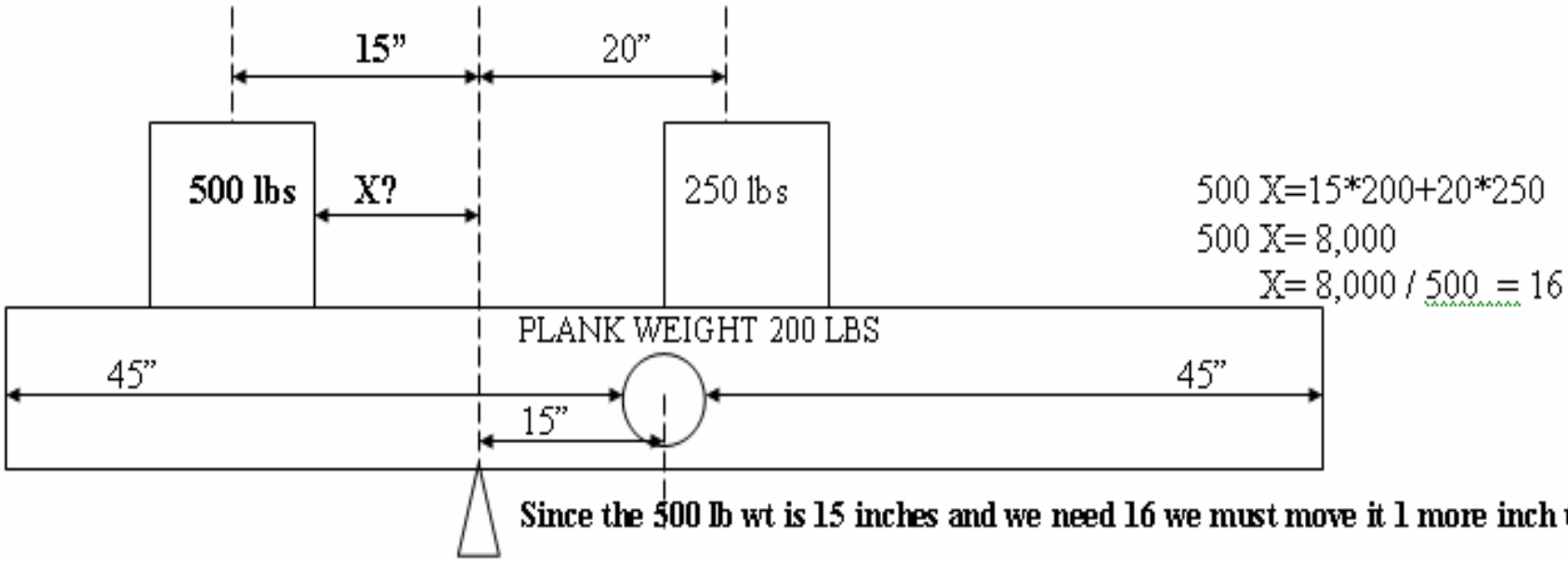
2,500 + 25Y = 10,000

25Y = 10,000-2,500

25Y = 7,500

Y = 300 lbs

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



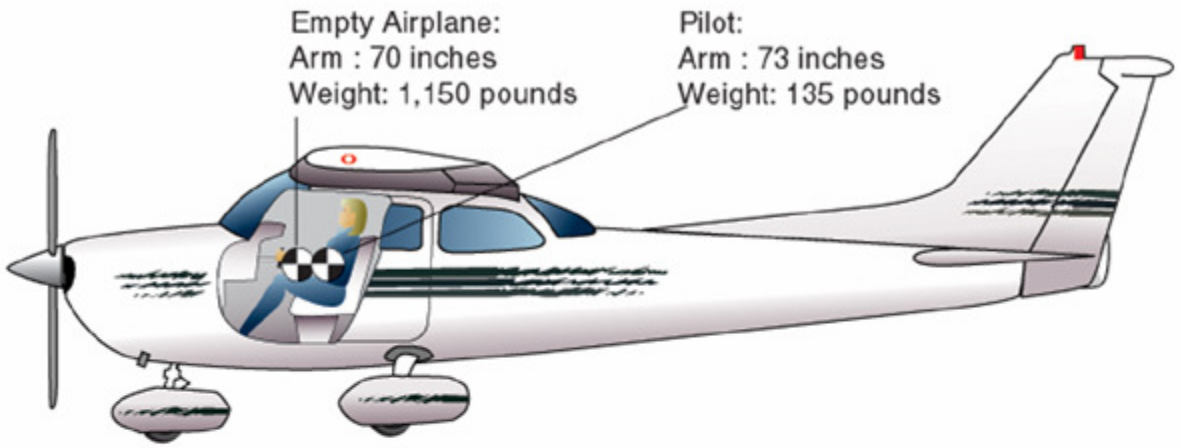
500 X=15*200+20*250

500 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

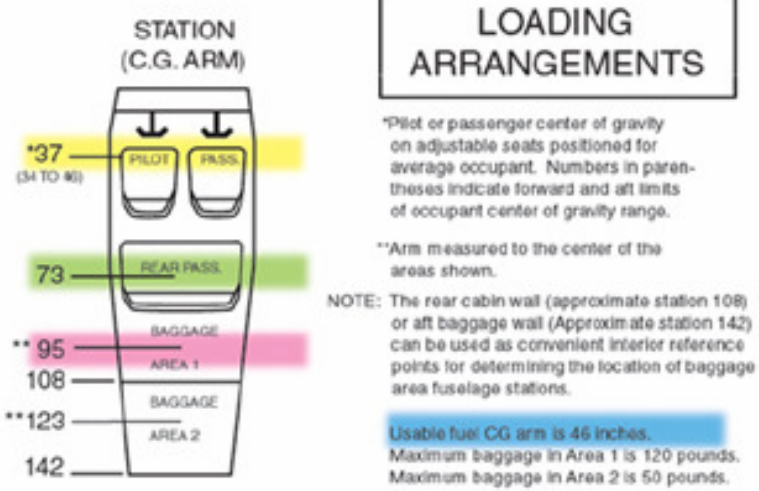
WEIGHT AND BALANCE
CG LOCATION



	Weight		Arm		Moment
Empty Airplane	1,150 pounds	X	70 inches	=	80,500 pound - inches
Pilot	135 pounds	X	73 inches	=	9,855 pound - inches
Total	1,285 pounds				90,355 pound - inches

$$\frac{\text{Total Moment}}{\text{Total Weight}} = \text{CG Arm} \qquad \frac{90{,}355 \text{ pound-inches}}{1{,}285 \text{ pounds}} = 70.3 \text{ inches}$$

WEIGHT AND BALANCE COMPUTATION METHOD



LOADING ARRANGEMENTS

*Pilot or passenger center of gravity on adjustable seats positioned for average occupant. Numbers in parentheses indicate forward and aft limits of occupant center of gravity range.

**Arm measured to the center of the areas shown.

NOTE: The rear cabin wall (approximate station 108) or aft baggage wall (Approximate station 142) can be used as convenient interior reference points for determining the location of baggage area fuselage stations.

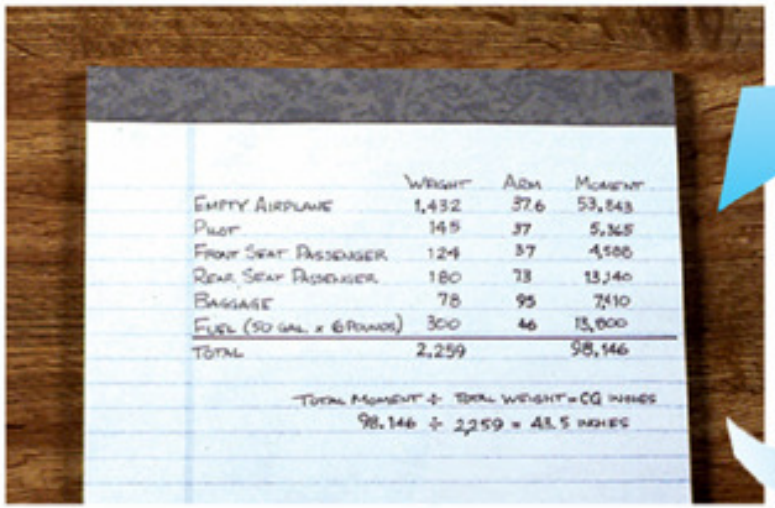
Usable fuel CG arm is 46 inches.
Maximum baggage in Area 1 is 120 pounds.
Maximum baggage in Area 2 is 50 pounds.

Arm for pilot and front seat passenger is 37 inches.

Arm for rear passenger is 73 inches.

Arm for baggage is 95 inches.

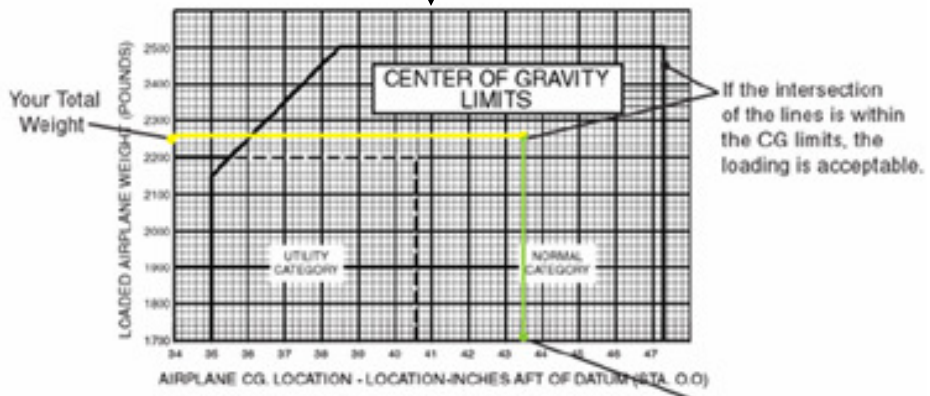
Arm for fuel is 46 inches.



	Weight	Arm	Moment
Empty Airplane	1,432	37.6	53,843
Pilot	145	37	5,365
Front Seat Passenger	124	37	4,588
Rear Seat Passenger	180	73	13,140
Baggage	78	95	7,410
Fuel (50 gal. x 6 Pounds)	300	46	13,800
Total	2,259		98,146

Total Moment ÷ Total Weight = CG inches
98,146 ÷ 2,259 = 43.5 inches

CALCULATE CG AS TOTAL MOMENTS / TOTAL WEIGHT ENTER ON GRAPH



1. Enter the graph at your total weight on the left side.

2. Draw a line from the bottom at your calculated CG.

3. The intersection of the lines is within the CG limits, so the loading is acceptable.

WEIGHT AND BALANCE

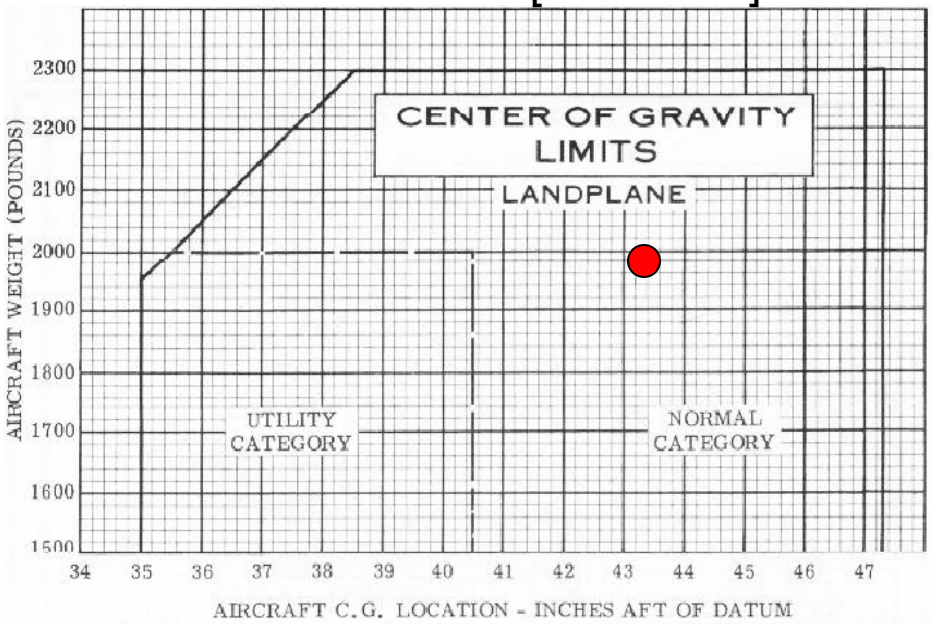
ITEM	WEIGHT		ARM	=	MOMENT
EMPTY WEIGHT	1455.6	x	38.5	=	56040.60
Fuel (40 G. Max)	120	x	45.3	=	
Pilot/Front Seat	210	x	37	=	
Rear Seat	170	x	72.8	=	
Baggage Area 1	60	x	94.9	=	
Baggage Area 2	0	x	123	=	

ITEM	WEIGHT		ARM	=	MOMENT
EMPTY WEIGHT	1455.6	x	38.5	=	56040.60
Fuel (40 G. Max)	120	x	45.3	=	5436.00
Pilot/Front Seat	210	x	37	=	7770.00
Rear Seat	170	x	72.8	=	12376.00
Baggage Area 1	60	x	94.9	=	5694.00
Baggage Area 2	0	x	123	=	0.00
Total	2015.6				87316.60

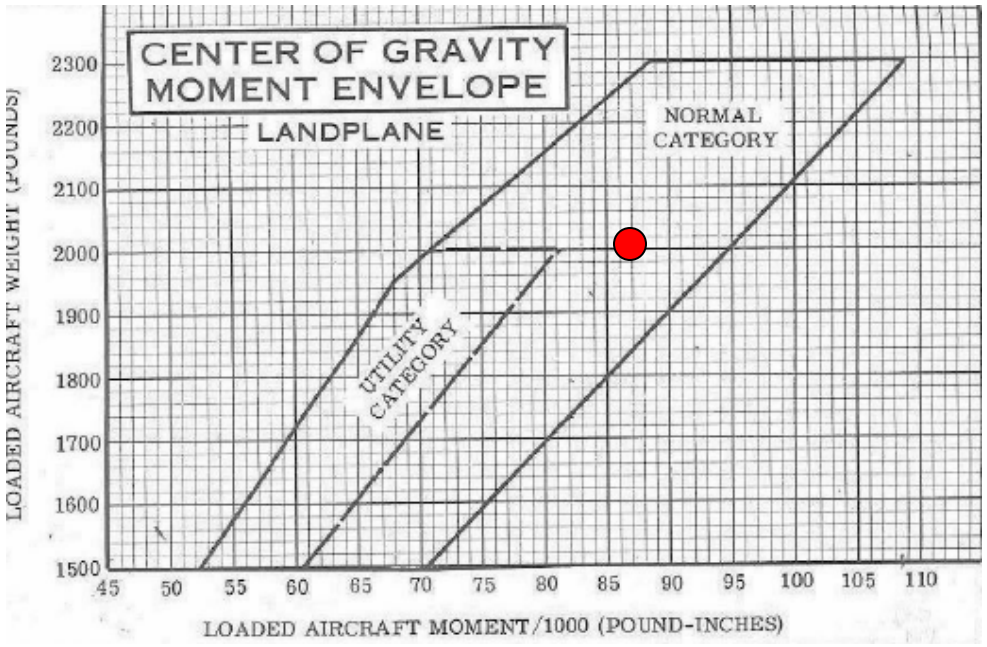
CG MOM/WT= **(A)**
43.32

MOM /1000= **(B)**
87.3

A [MOM/WT]



B [MOM/1000]



WEIGHT AND BALANCE

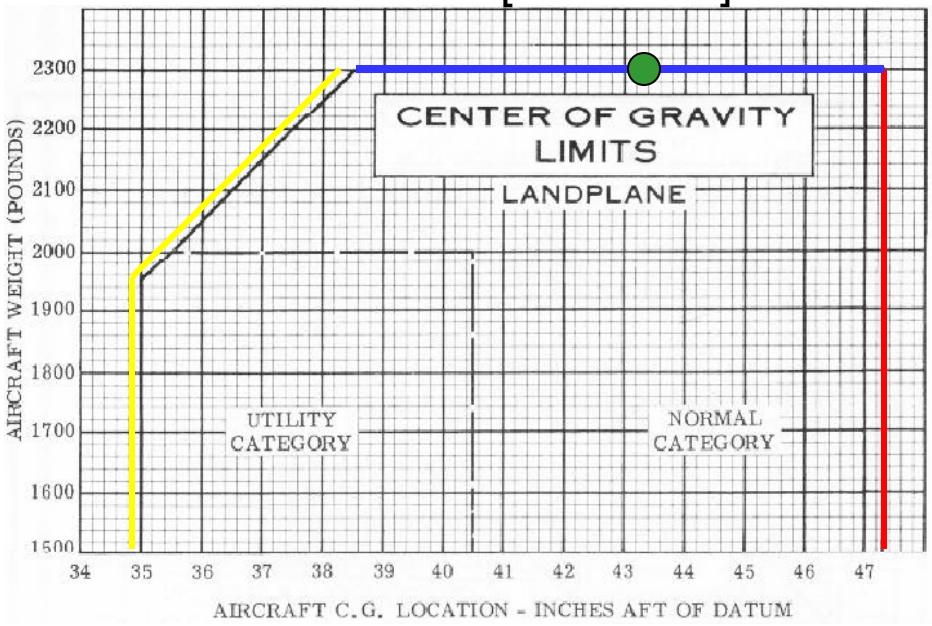
ITEM	WEIGHT		ARM	=	MOMENT
EMPTY WEIGHT	1455.6	x	38.5	=	56040.60
Fuel (40 G. Max)	240	x	45.3	=	
Pilot/Front Seat	340	x	37	=	
Rear Seat	170	x	72.8	=	
Baggage Area 1	94	x	94.9	=	
Baggage Area 2	0	x	123	=	

ITEM	WEIGHT		ARM	=	MOMENT
EMPTY WEIGHT	1455.6	x	38.5	=	56040.60
Fuel (40 G. Max)	240	x	45.3	=	10872.00
Pilot/Front Seat	340	x	37	=	12580.00
Rear Seat	170	x	72.8	=	12376.00
Baggage Area 1	94	x	94.9	=	8902.60
Baggage Area 2	0	x	123	=	0.00
Total	2299.6				100789.2

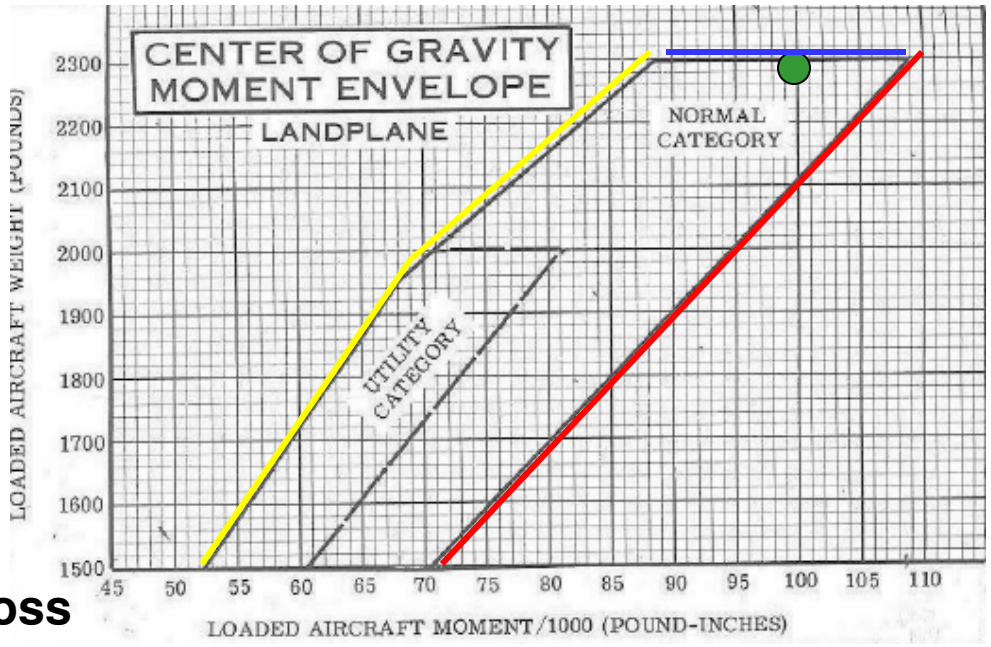
CG WT/MOM=43.83 (A)

MOM /1000= (B) 100.78

A [MOM/WT]



B [MOM/1000]

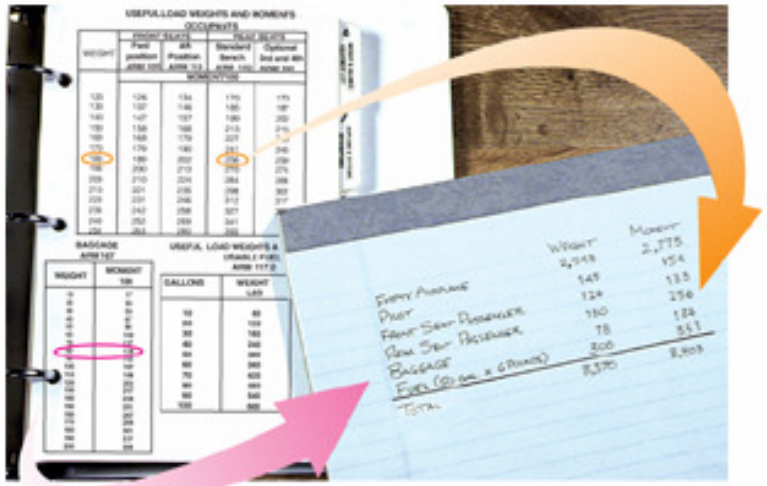


Forward CG Limit

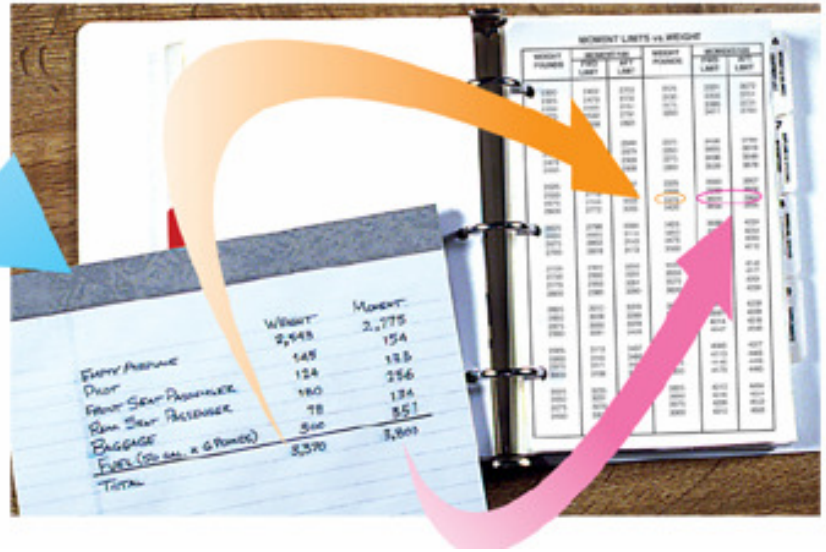
Aft CG Limit **Exceeds Gross**

WEIGHT AND BALANCE

TABLE METHOD



Simplified: Look up weight and total moment, removes need to multiply by arm.



USEFUL LOAD WEIGHTS AND MOMENTS

OCCUPANTS

FRONT SEATS ARM 85		REAR SEATS ARM 121	
Weight	Moment / 100	Weight	Moment / 100
120	102	120	145
130	110	130	157
140	119	140	169
150	128	150	182
160	136	160	194
170	144	170	206
180	153	180	218
190	162	190	230
200	170	200	242

BAGGAGE OR 5TH SEAT OCCUPANT ARM 140

Weight	Moment / 100
10	14
20	28
30	42
40	56
50	70
60	84
70	98
80	112
90	126
100	140
110	154
120	168
130	182
140	196
150	210
160	224
170	238
180	252
190	266
200	280
210	294
220	308
230	322
240	336
250	350
260	364
270	378

USABLE FUEL

MAIN WING TANKS ARM 75		
Gallons	Weight	Moment / 100
5	30	22
10	60	45
15	90	68
20	120	90
25	150	112
30	180	135
35	210	158
40	240	180
44	264	198

AUXILIARY WING TANKS ARM 94

Gallons	Weight	Moment / 100
5	30	28
10	60	56
15	90	85
19	114	107

*OIL

Quarts	Weight	Moment / 100
10	19	5

*Included in basic Empty Weight

Empty Weight – 2015

MOM / 100 – 1554

MOMENT LIMITS vs WEIGHT

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

WEIGHT CONDITION	FORWARD CG LIMIT	AFT CG LIMIT
2950 lb (takeoff or landing)	82.1	84.7
2525 lb	77.5	85.7
2475 lb or less	77.0	85.7

Figure 33. – Airplane Weight and Balance Tables.

MOMENT LIMITS vs WEIGHT (Continued)

Weight	Minimum Moment / 100	Maximum Moment / 100
2100	1617	1800
2110	1625	1808
2120	1632	1817
2130	1640	1825
2140	1648	1834
2150	1656	1843
2160	1663	1851
2170	1671	1860
2180	1679	1868
2190	1686	1877
2200	1694	1885
2210	1702	1894
2220	1709	1903
2230	1717	1911
2240	1725	1920
2250	1733	1928
2260	1740	1937
2270	1748	1945
2280	1756	1954
2290	1763	1963
2300	1771	1971
2310	1779	1980
2320	1786	1988
2330	1794	1997
2340	1802	2005
2350	1810	2014
2360	1817	2023
2370	1825	2031
2380	1833	2040
2390	1840	2048
2400	1848	2057
2410	1856	2065
2420	1863	2074
2430	1871	2083
2440	1879	2091
2450	1887	2100
2460	1894	2108
2470	1902	2117
2480	1911	2125
2490	1921	2134
2500	1932	2143
2510	1942	2151
2520	1953	2160
2530	1963	2168
2540	1974	2176
2550	1984	2184
2560	1995	2192
2570	2005	2200
2580	2016	2208
2590	2026	2216

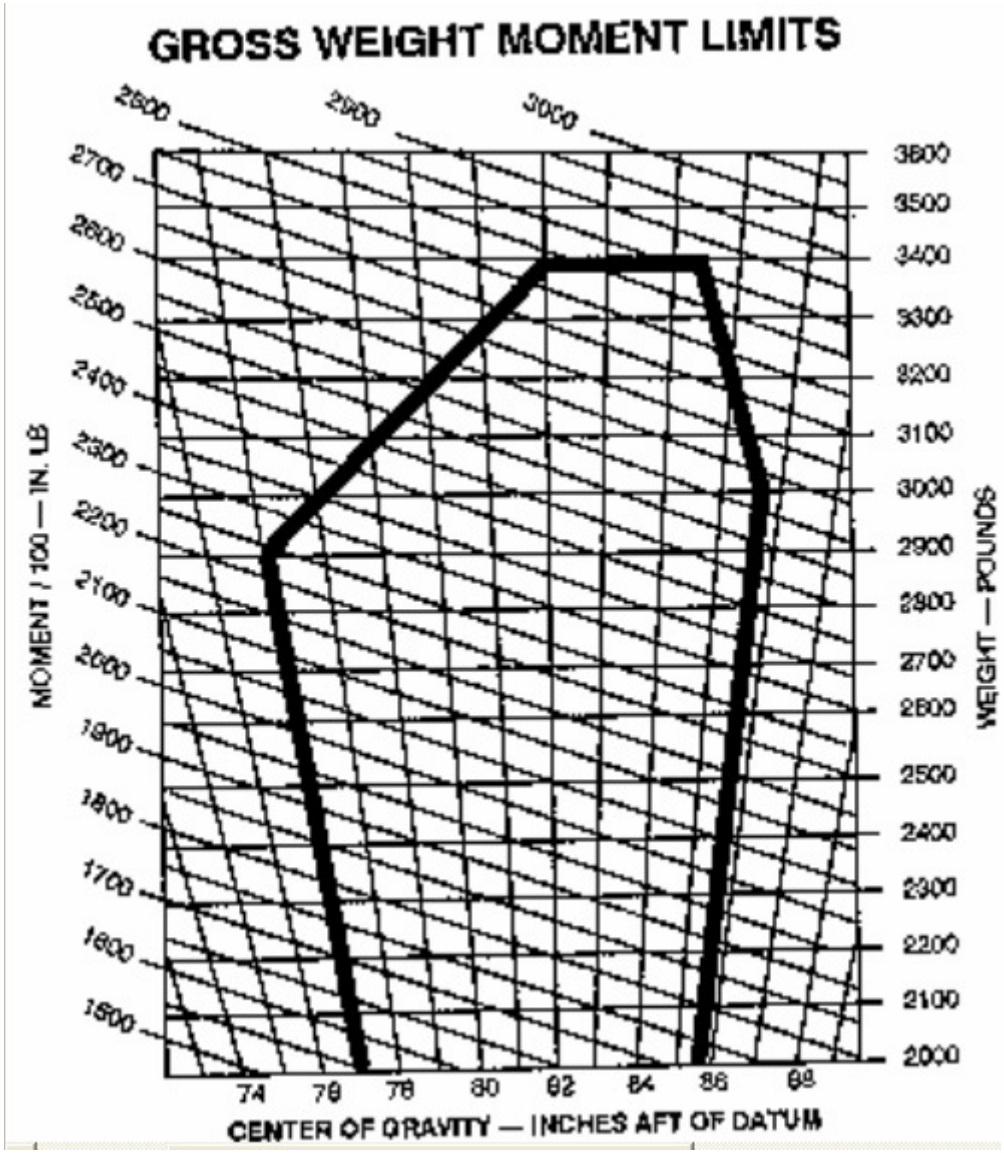
Weight	Minimum Moment / 100	Maximum Moment / 100
2600	2037	2224
2610	2048	2232
2620	2058	2239
2630	2069	2247
2640	2080	2255
2650	2090	2263
2660	2101	2271
2670	2112	2279
2680	2123	2287
2690	2133	2295
2700	2144	2303
2710	2155	2311
2720	2166	2319
2730	2177	2326
2740	2188	2334
2750	2199	2342
2760	2210	2350
2770	2221	2358
2780	2232	2366
2790	2243	2374
2800	2254	2381
2810	2265	2389
2820	2276	2397
2830	2287	2405
2840	2298	2413
2850	2309	2421
2860	2320	2428
2870	2332	2436
2880	2343	2444
2890	2354	2452
2900	2365	2460
2910	2377	2468
2920	2388	2475
2930	2399	2483
2940	2411	2491
2950	2422	2499

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

	Weight	Moment/100 lb.-in
Empty weight w/oil	2,015	1,554
Front seat	387	330
Rear Seat	293	355
Fuel, main (35 gal)	210	158
Total	**2,905**	**2,397**
Baggage	45	63
Max	**2,950**	**2,460**

WEIGHT AND BALANCE



USEFUL LOAD WEIGHTS AND MOMENTS

EMPTY WEIGHT DATA		
*Oil is included in empty weight	Empty Weight (Lb.)	Empty Weight Moment (/100)
Certificated Weight	2110	1952

OCCUPANTS				
Front Seats		Rear Seats		
ARM 85			Fwd Position ARM 111	Aft Position ARM 136
Weight	Moment	Weight	Moment	Moment
120	102	120	145	163
130	111	130	157	177
140	119	140	169	190
150	128	150	182	204
160	136	160	194	218
170	145	170	206	231
180	153	180	218	245
190	162	190	230	258
200	170	200	242	273

FUEL					
ARM 75					
Gallons	Weight	Moment	Gallons	Weight	Moment
5	30	23	45	270	203
10	60	45	48	294	221
15	90	68	55	330	248
20	120	90	60	360	270
25	150	113	65	390	293
30	180	135	70	420	315
35	210	158	75	450	338
40	240	180	80	480	360

BAGGAGE	
ARM 150	
Weight	Moment
10	15
20	30
30	45
40	60
50	75
60	90
70	105
80	120
90	135
100	150
110	165
120	180
130	195
140	210
150	225
160	240
170	255
180	270
190	285
200	300
210	315
220	330
230	345
240	360
250	375
260	390
270	405

NOTE: All moments are equal to $\frac{\text{weight} \times \text{arm}}{100}$

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

BAGGAGE	
ARM 150	
Weight	Moment
10	15
20	30
30	45
40	60
50	75
60	90
70	105
80	120
90	135
100	150
110	165
120	180
130	195
140	210
150	225
160	240
170	255
180	270
190	285
200	300
210	315
220	330
230	345
240	360
250	375
260	390
270	405

EMPTY WEIGHT DATA		
*Oil is included in empty weight	Empty Weight (Lb.)	Empty Weight Moment (/100)
Certificated Weight	2110	1652

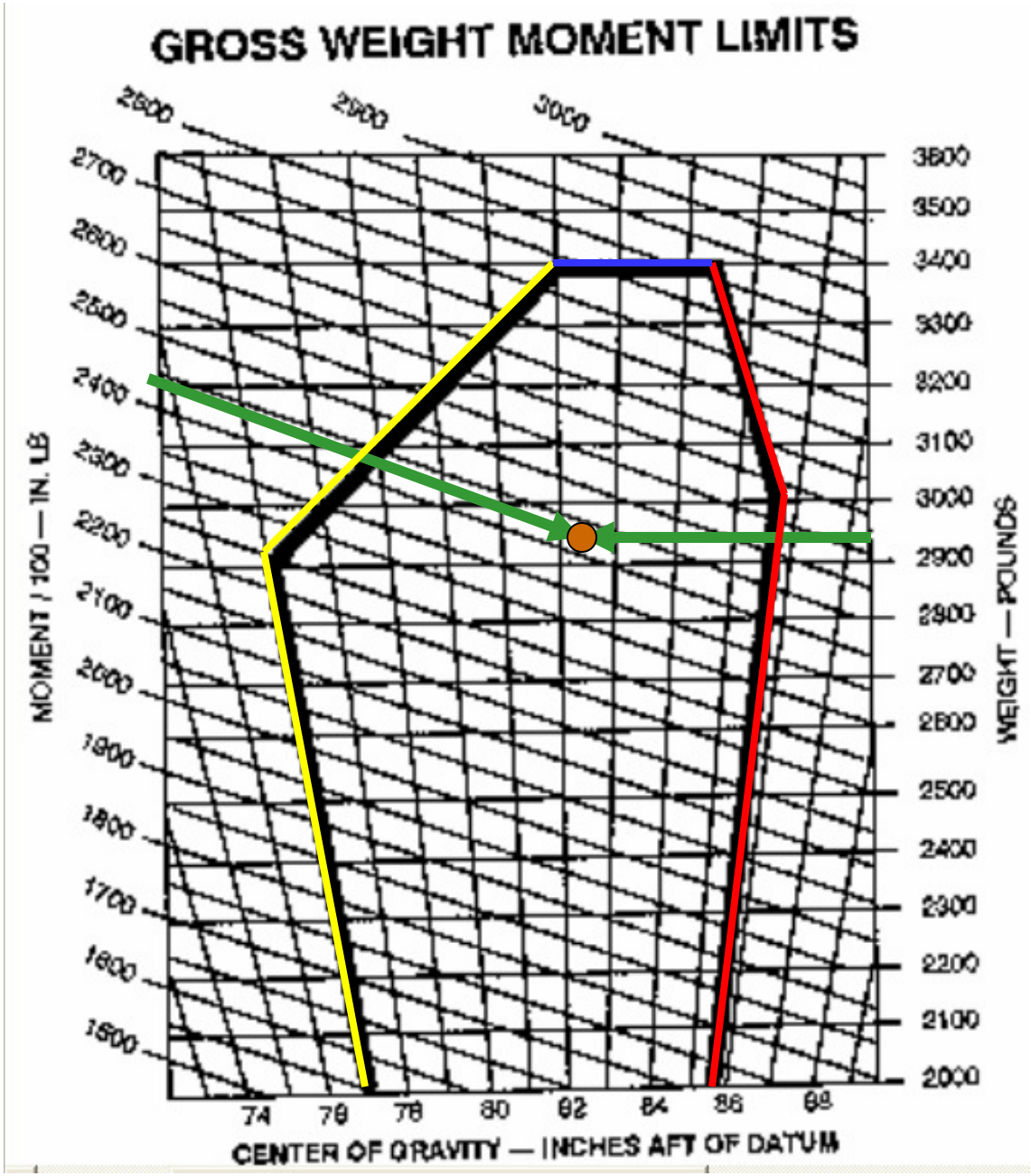
TRY THIS:
Front Seats = 340 lbs
(hint 200+140=340)
Rear Seats = 160 lbs
(@station 111)
Baggage = 55 lbs
(interpolate)
Fuel (45 gals.) =

SUM WEIGHT :
SUM MOMENTS:

OCCUPANTS				
Front Seats ARM 85		Rear Seats		
			Fwd Position ARM 111	Aft Position ARM 136
Weight	Moment	Weight	Moment	Moment
120	102	120	145	163
130	111	130	157	177
140	119	140	169	190
150	128	150	182	204
160	136	160	194	218
170	145	170	206	231
180	153	180	218	245
190	162	190	230	258
200	170	200	242	273

FUEL					
ARM 75					
Gallons	Weight	Moment	Gallons	Weight	Moment
5	30	23	45	270	203
10	60	45	49	294	221
15	90	68	55	330	248
20	120	90	60	360	270
25	150	113	65	390	293
30	180	135	70	420	315
35	210	158	75	450	338
40	240	180	80	480	360

WEIGHT AND BALANCE



Forward CG Limit

Aft CG Limit

Exceeds Gross

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)

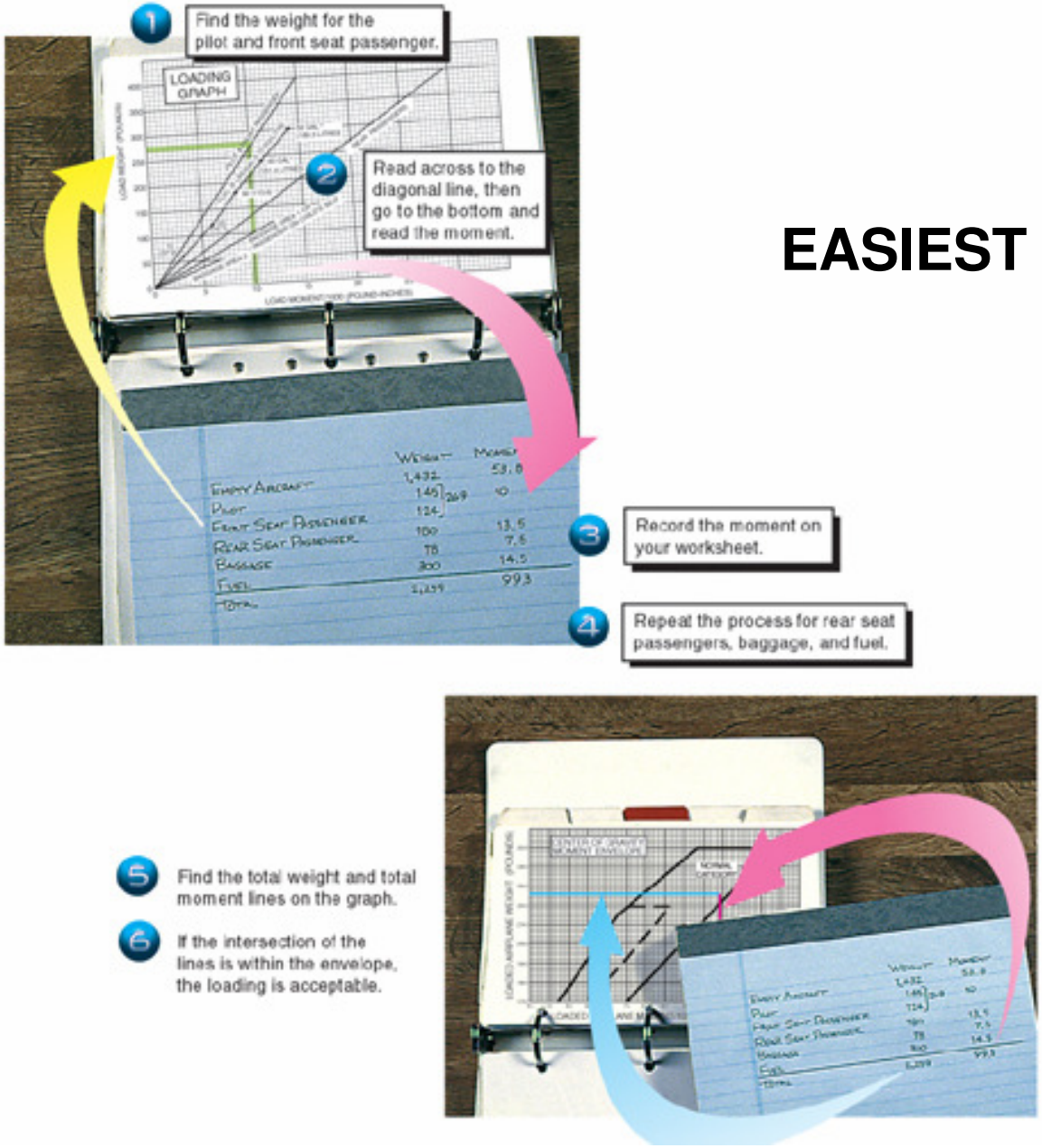
Fuel (45 gals.) = 240 lbs, M=203

TOTAL WEIGHT: 2935
TOTAL MOMENTS: 2421

Created by Steve Reisser

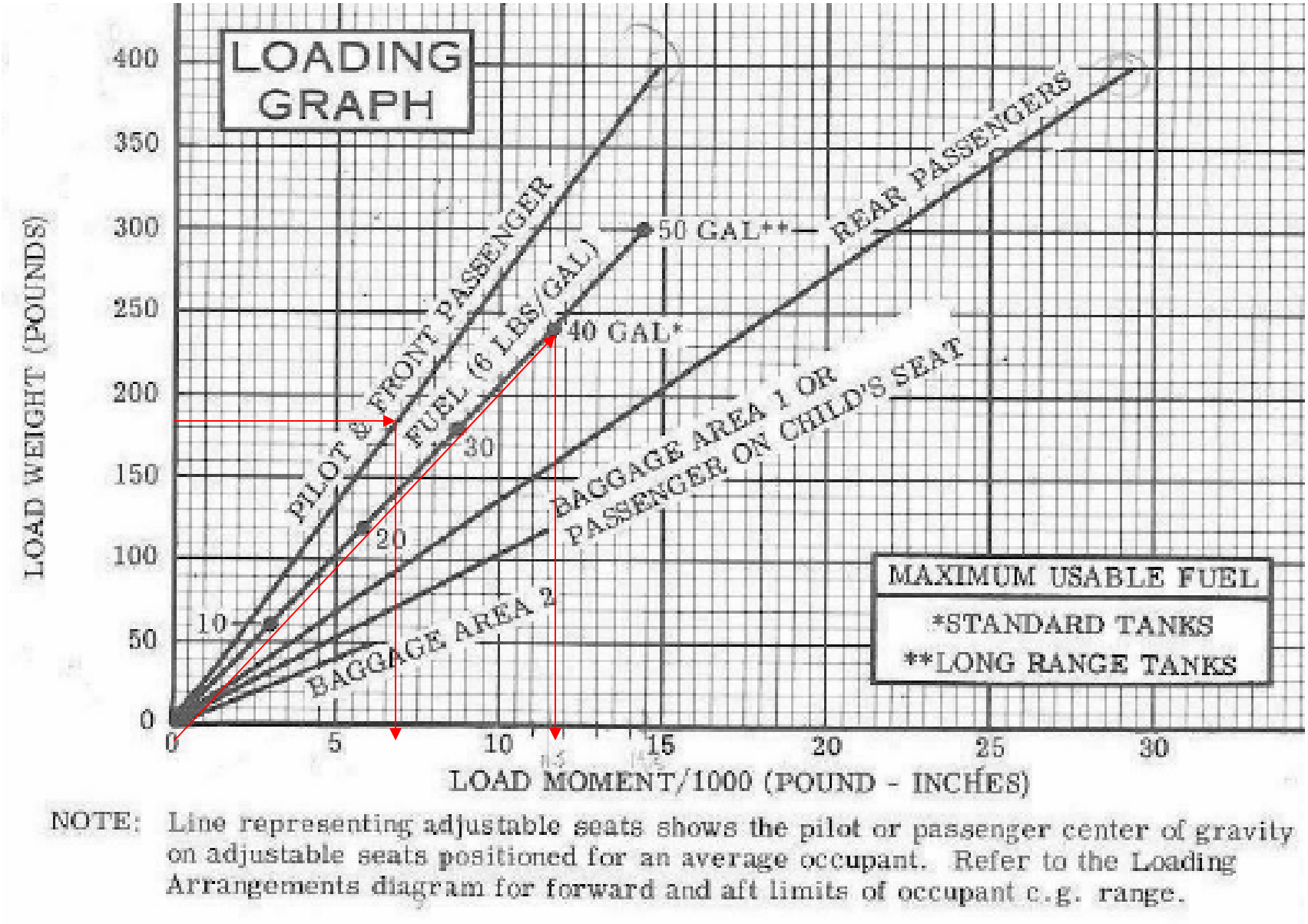
WEIGHT AND BALANCE

GRAPH METHOD



EASIEST OF ALL

WEIGHT AND BALANCE



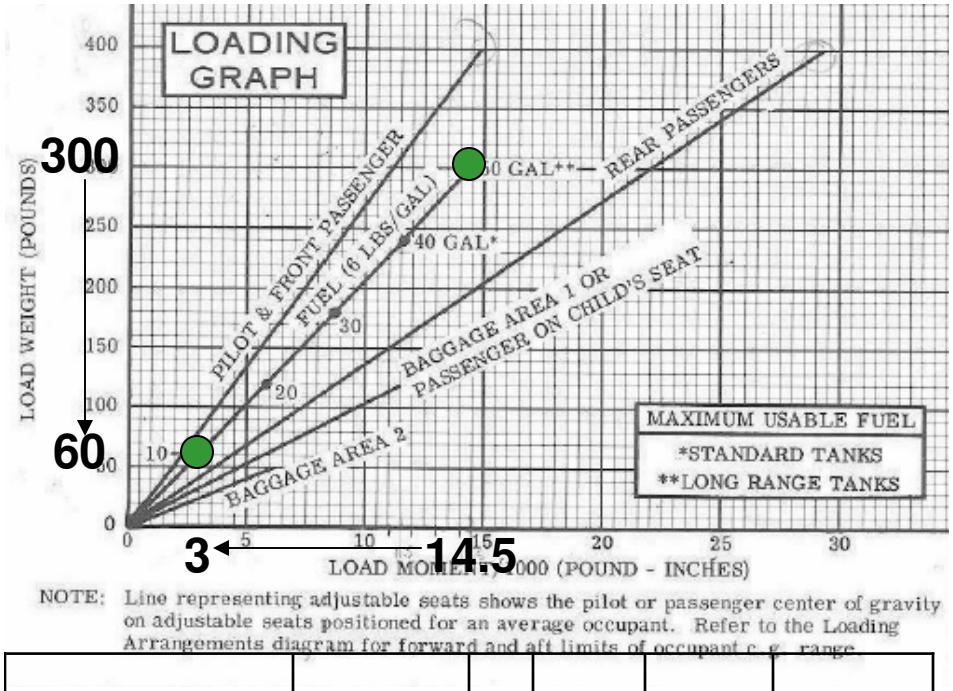
NOTE: Line representing adjustable seats shows the pilot or passenger center of gravity on adjustable seats positioned for an average occupant. Refer to the Loading Arrangements diagram for forward and aft limits of occupant c.g. range.

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

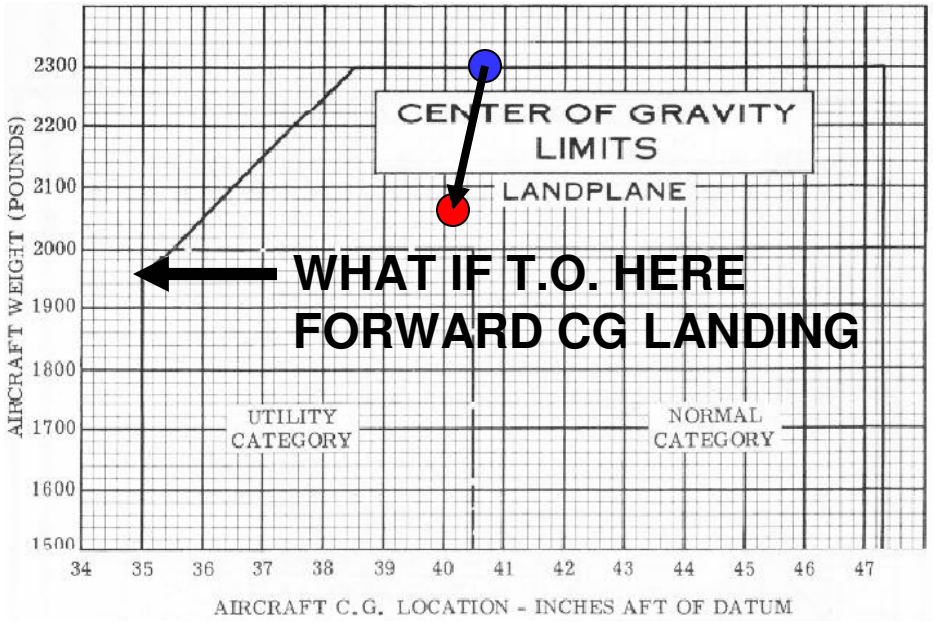
Use "**Center of Gravity Limits**" (Sum of CG)

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?



NOTE: Line representing adjustable seats shows the pilot or passenger center of gravity on adjustable seats positioned for an average occupant. Refer to the Loading Arrangements diagram for forward and aft limits of occupant c. g. range.



ITEM	WEIGHT		ARM	=	MOMENT
EMPTY WEIGHT	1455.6	x	38.5	=	56040.60
Fuel (40 G. Max)	300	x	45.3	=	13590.00
Pilot/Front Seat	340	x	37	=	12580.00
Rear Seat	170	x	72.8	=	12376.00
Baggage Area 1	10.4	x	94.9	=	986.96
Baggage Area 2	0	x	123	=	0.00
Total	2300				95573..56

CG WT/MOM=(A) **41.55**

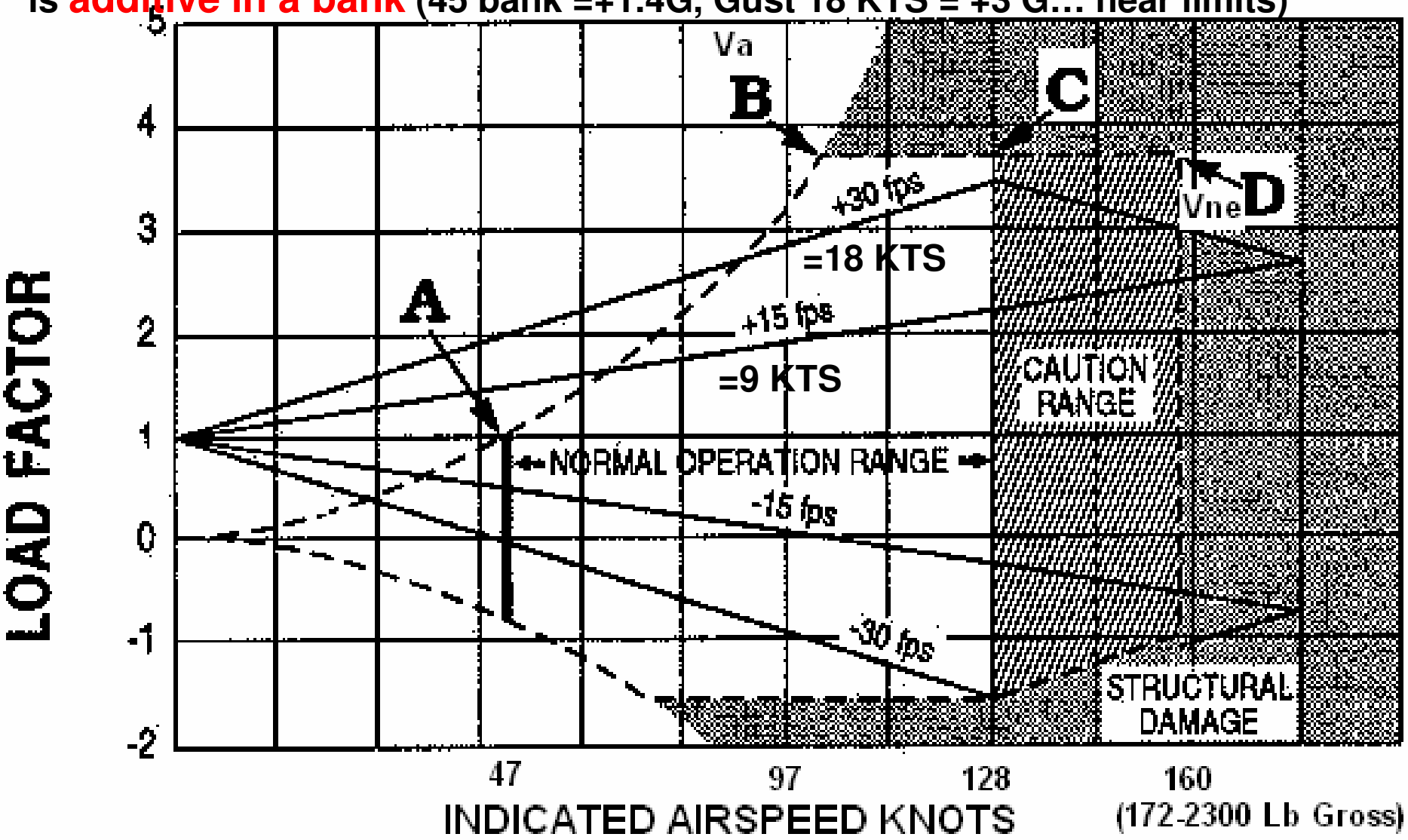
MOM /1000= (B) 95.57

ITEM	WEIGHT		ARM	=	MOMENT
EMPTY WEIGHT	1455.6	x	38.5	=	56040.60
Fuel (40 G. Max)	60	x	45.3	=	2718.00
Pilot/Front Seat	340	x	37	=	12580.00
Rear Seat	170	x	72.8	=	12376.00
Baggage Area 1	10.4	x	94.9	=	986.96
Baggage Area 2	0	x	123	=	0.00
Total	2060				83701.56

CG WT/MOM=(A) **40.63**

MOM /1000= (B) 83.7

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.

Wt. Moved * Dist. between CG Arms = Wt. of Plane * Dist. CG moves

Wt. Moved = (Wt. of Plane * Dist. CG moves) / Dist. Between CB Arms

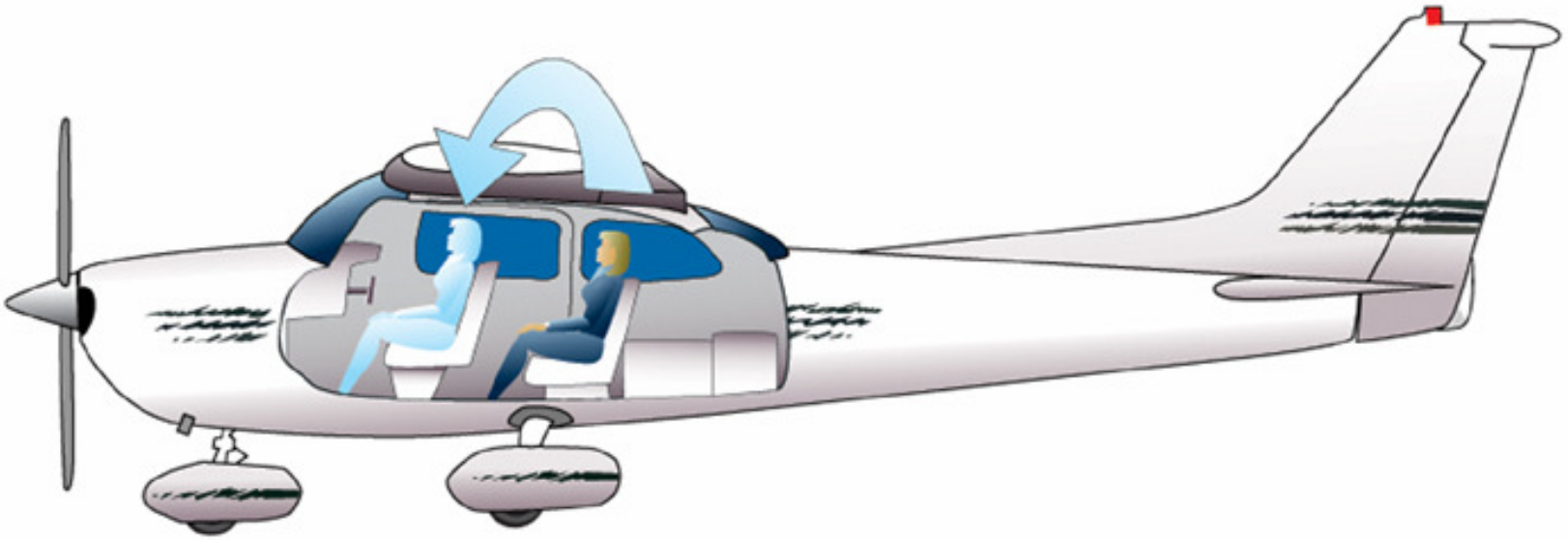
Dist. Between CG Arms = (Wt. of Plane * Dist. CG moves) / Wt Moved

Dist. CG Moves = (Wt. Moved * Dist. Between CG Arms) / Wt of plane

Wt of plane = (Wt. Moved * Dist. Between CG Arms) / Dist CG Moves

WEIGHT AND BALANCE

WEIGHT SHIFT



$$\frac{\text{Weight Moved} = X}{\text{Weight of Airplane} = 2{,}500 \text{ pounds}} = \frac{\text{Distance CG Moves} = 2 \text{ inches}}{\text{Distance Between CG Arms} = 36 \text{ inches}}$$

$$\frac{X}{2{,}500} = \frac{2}{36}$$

$$X = \frac{2{,}500 \times 2}{36}$$

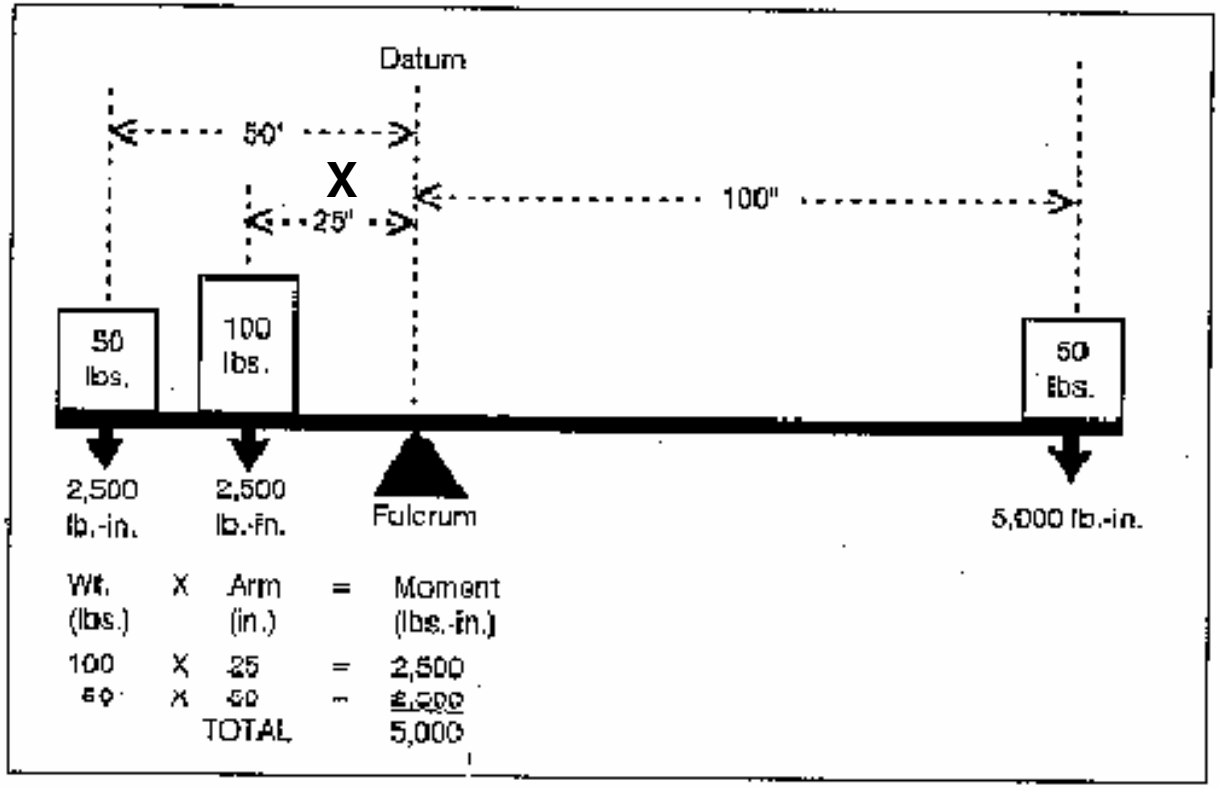
$$X = 138.8 \text{ pounds}$$

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. Lets 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, UNCOMPLICATED FORMULA.

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

$$CG = \frac{\sum M}{\sum W}$$

      2) Since CG was known at some previous (#1) loading condition (with moment = M_1 and weight = W_1), 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,

$$CG = \text{Current Moment/Current Weight becomes } CG = \frac{M_1 \pm \Delta M}{W_1 \pm \Delta W}$$

Commercial Weight Shift

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:

$$New\ CG = \frac{M_1 \pm \Delta M}{W_1 \pm \Delta W}$$

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.

$$New\ CG = \frac{(4,800 \times 98) - 90(145 - 45)}{4,800}$$

$$= \frac{470,400 - 9,000}{4,800}$$

$$= \frac{461,400}{4,800} = 96.13$$

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:

$$New\ CG = \frac{M_1 \pm \Delta M}{W_1 \pm \Delta W}$$

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

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

$$335,800 = 343,100 - 140x$$

$$140x = 343,100 - 335,800$$

$$140x = 7,300$$

$$x = 52.14\ lb.$$

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.

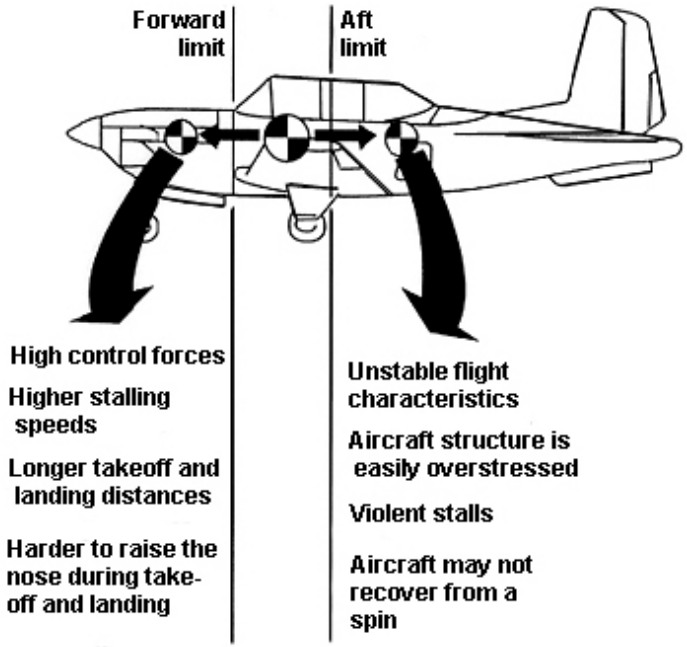
WEIGHT AND BALANCE

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 AVIAITION 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)