

# Weight and Balance

# Weight Watchers: Performance

- ▶ Longer takeoff run
- ▶ Reduced rate & angle of climb
- ▶ Lower maximum altitude
- ▶ Reduced maneuverability
- ▶ Longer landing roll
- ▶ Excess weight on nose/tailwheel

# Weight Watchers: Speed

- ▶ Higher takeoff speed
- ▶ Reduced cruising speed
- ▶ Higher stalling speed
- ▶ Higher approach and landing speed

# Ways to change weight

- ▶ Short term:
  - ▶ Fuel
  - ▶ Baggage
- ▶ Long term
  - ▶ Installed equipment

# Determining Empty Weight

- ▶ Initially done by manufacturer
- ▶ Must be recalculated if weight changes by
  - ▶ > 1 lb (if empty weight < 5,000 lb)
  - ▶ > 2 lb (empty weight 5,000-50,000 lb)
  - ▶ > 5 lb (empty weight > 50,000 lb)

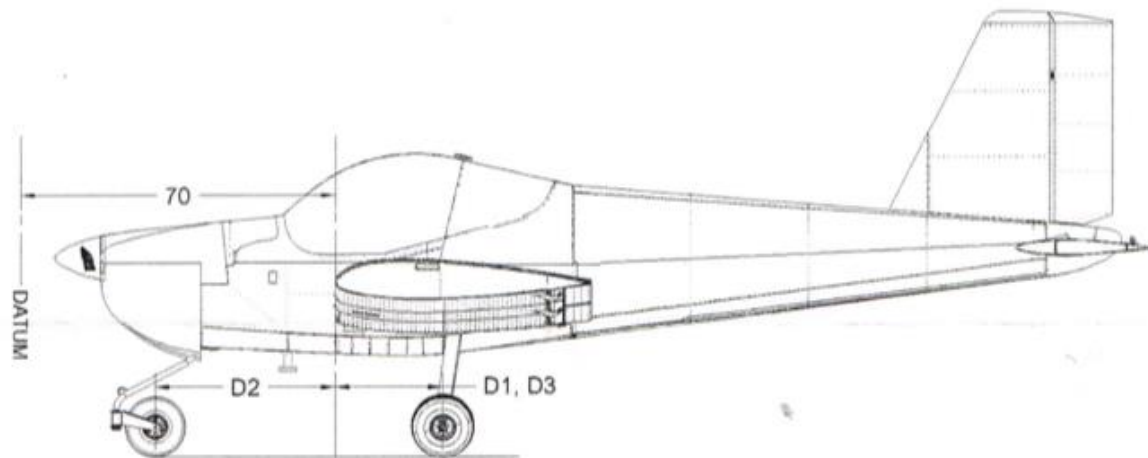


TABLE 1

	LEFT WHEEL	NOSE WHEEL	RIGHT WHEEL
WEIGHT	$\frac{304.5}{(W1)}$ lb	$\frac{159.0}{(W2)}$ lb	$\frac{322.0}{(W3)}$ lb
DISTANCE FROM AXLE CENTER TO LEADING EDGE	$\frac{23.50}{(D1)}$ inches	$\frac{46.50}{(D2)}$ inches	$\frac{23.50}{(D3)}$ inches

TABLE 2

	WEIGHT	ARM	MOMENT
LEFT WHEEL	$\frac{304.5}{(W1)}$ lb	$(70 + \frac{23.5}{(D1)}) = \frac{93.5}{(A1)}$ inches	$(\frac{304.5}{(W1)}) (\frac{93.5}{(A1)}) = \frac{28,470.75}{(M1)}$ in-lb
NOSE WHEEL	$\frac{159.0}{(W2)}$ lb	$(70 - \frac{46.5}{(D2)}) = \frac{23.5}{(A2)}$ inches	$(\frac{159.0}{(W2)}) (\frac{23.5}{(A2)}) = \frac{4,690.50}{(M2)}$ in-lb
RIGHT WHEEL	$\frac{322.0}{(W3)}$ lb	$(70 + \frac{23.5}{(D3)}) = \frac{93.5}{(A3)}$ inches	$(\frac{322.0}{(W3)}) (\frac{93.5}{(A3)}) = \frac{30,107.00}{(M3)}$ in-lb

EMPTY WEIGHT =  $\frac{785.5}{(W1 + W2 + W3)}$  lb      EMPTY ARM =  $\frac{80.5452}{(\text{Empty Moment} / \text{Empty Weight})}$  inches

EMPTY MOMENT =  $\frac{63,268.25}{(M1 + M2 + M3)}$  in-lb

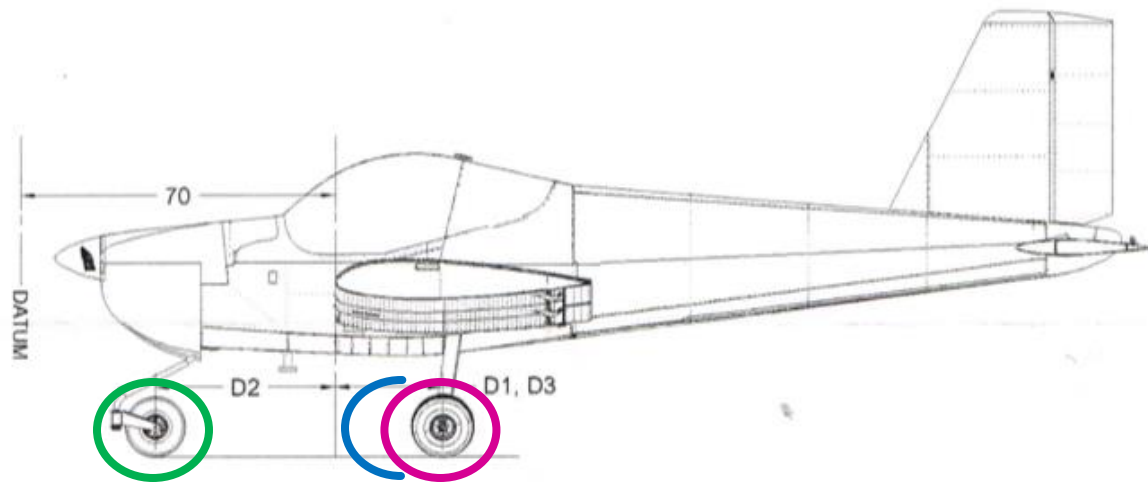


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NOSE WHEEL	$\frac{159.0}{(W2)}$ lb	$(70 - \frac{46.5}{(D2)}) = \frac{23.5}{(A2)}$ inches	$(\frac{159.0}{(W2)}) * (\frac{23.5}{(A2)}) = \frac{3,736.50}{(M2)}$ in-lb
RIGHT WHEEL	$\frac{322.0}{(W3)}$ lb	$(70 + \frac{23.5}{(D3)}) = \frac{93.5}{(A3)}$ inches	$(\frac{322.0}{(W3)}) * (\frac{93.5}{(A3)}) = \frac{30,107.00}{(M3)}$ in-lb

EMPTY WEIGHT =  $\frac{785.5}{(W1 + W2 + W3)}$  lb

EMPTY ARM =  $\frac{80.5452}{(\text{Empty Moment} / \text{Empty Weight})}$  inches

EMPTY MOMENT =  $\frac{63,268.25}{(M1 + M2 + M3)}$  in-lb

# What is included in empty weight?

- ▶ Airframe
- ▶ Engine
- ▶ Equipment as specified in list
- ▶ Unusable fuel
- ▶ Undrainable oil
- ▶ Other items as noted on loading chart

## Load:

- ▶ Pilot plus
- ▶ other occupants –plus–
- ▶ baggage –plus–
- ▶ usable fuel –plus–
- ▶ drainable oil

## Useful Load:

- ▶ Maximum takeoff weight –minus–
- ▶ Empty weight

**MTOW = 1320**  
**Empty weight = 785.5**  
**Useful load = 534.5**

Date: 04/06/18 Revision: 7

**OPERATING WEIGHTS & LOADING**

Category	Max Weight	Center of Gravity Range
Light Sport	1320 lb	80.49" to 85.39" (18.4 to 27% Chord)

**NOTE**

All measurements are aft of the datum line which is 70 inches forward of the wing leading edge.

Baggage 50 lb maximum

Maximum pilot / passenger weight 300lbs per seat, weight and balance permitting.

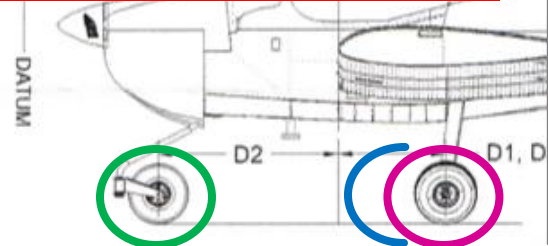


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RIGHT WHEEL	$\frac{322.0}{(W3)}$ lb	$(70 + \frac{23.5}{(D3)}) = \frac{93.5}{(A3)}$ inches	$(\frac{322.0}{(W3)}) * (\frac{93.5}{(A3)}) = \frac{30,107.00}{(M3)}$ in-lb

EMPTY WEIGHT =  $\frac{785.5}{(W1 + W2 + W3)}$  lb

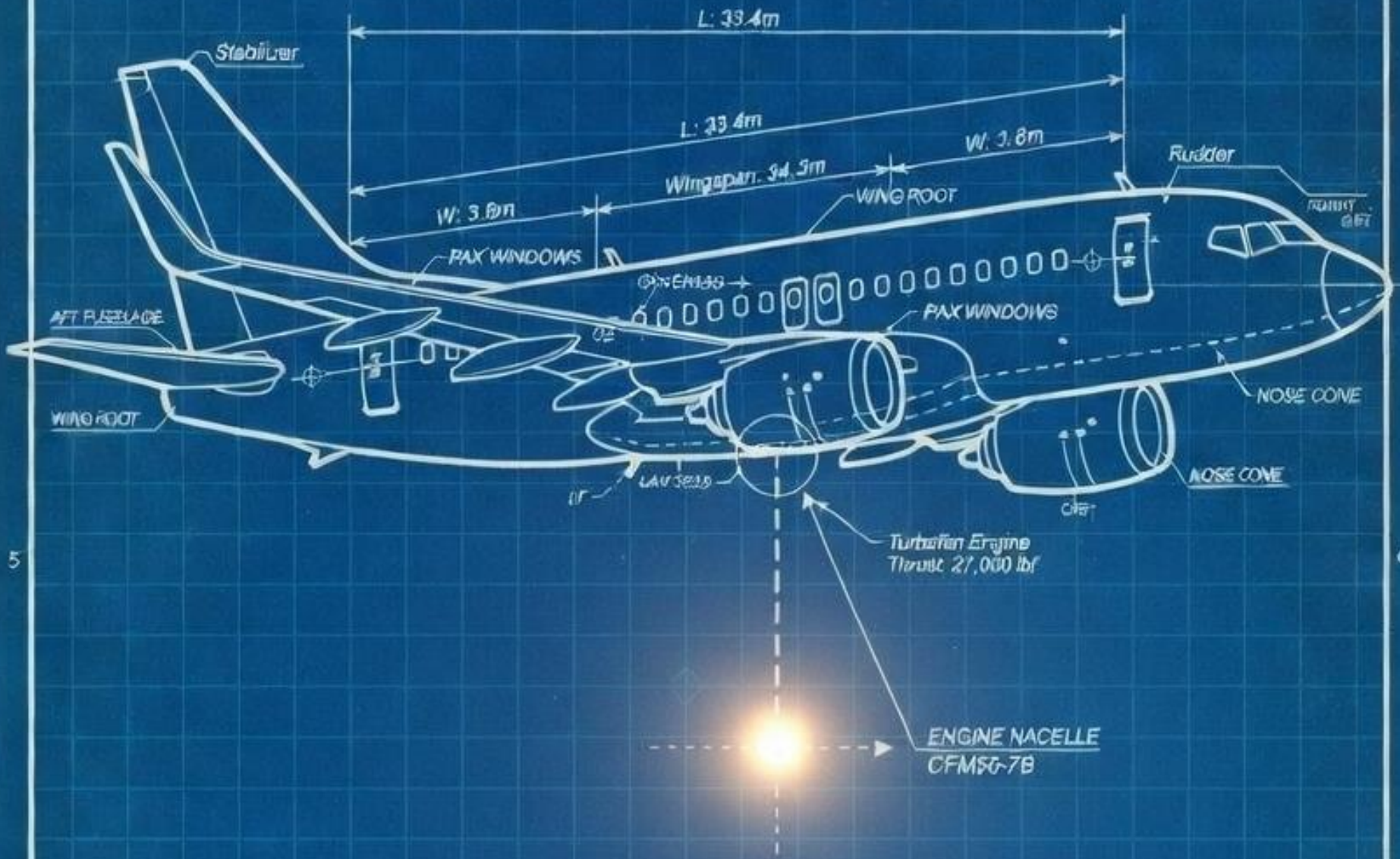
EMPTY ARM =  $\frac{80.5452}{(Empty\ Moment / Empty\ Weight)}$  inches

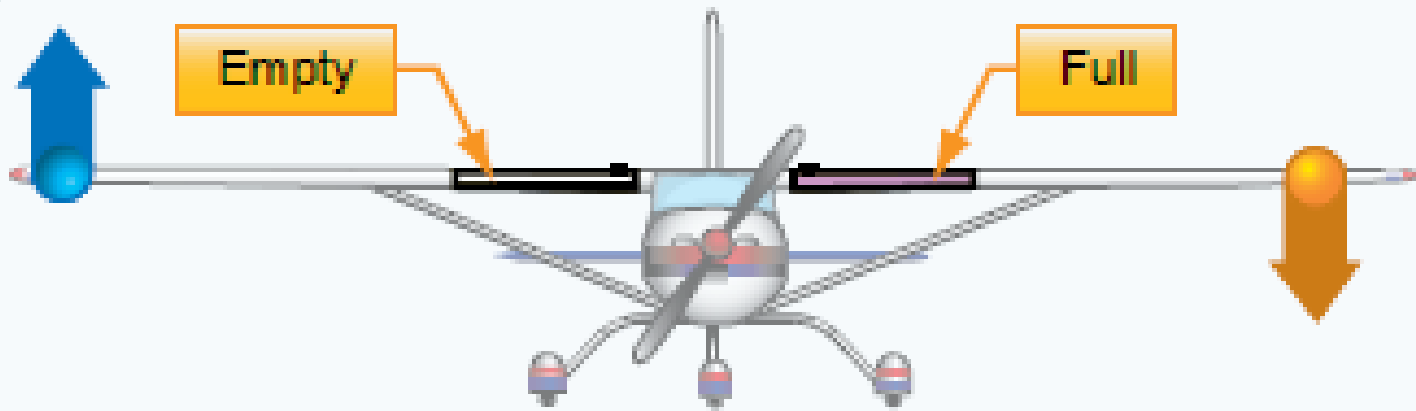
EMPTY MOMENT =  $\frac{63,268.25}{(M1 + M2 + M3)}$  in-lb

Item No	Equipment List Description	Ref Drawing	Wt (lbs.)	Arm (ins.)
24-04-S	Basic Avionics Kit Installation <ul style="list-style-type: none"> <li>- Support Straps Installation</li> <li>- Avionics Cooling Fan Installation</li> <li>- Avionics Ground Installations</li> <li>- Circuit Breaker Panel Installation</li> <li>- Microphone Installation</li> <li>- Omni Antenna Installation</li> <li>- Omni Antenna Cable Assembly Installation</li> </ul>		4,3* 0.1 1.6 0.1 1.5 0.2 0.5 0.3	55,5* 10.0 3.0 41.0 16.5 18,5 252.1 248,0
<b>Chapter 25 – Equipment/Furnishings</b>				
25-01-R	Seat, Pilot, Adjustable		33.8	41.5
25-02-S	Seat, Copilot, Adjustable		33.8	41.5
25-03-S	Seat, Rear, Two Piece Back Cushion		50.0	82.0
25-04-R	Seat Belt and Shoulder Harness, Inertia Reel, Pilot and Copilot		5.2	50,3
25-05-S	Seat Belt and Shoulder Harness, Inertia Reel, Rear Seat		5.2	87.8
25-06-S	Sun Visors (Set of 2)		1.2	33,0
25-07-S	Baggage Retaining Net		0.5	108.0
25-08-S	Cargo Tie Down Rings (10 Tie Downs)		0.4	108.0
25-09-S	Pilot's Operating Checklist (Stowed in Instrument Panel Map Case)		0.3	15.0
25-10-R	Pilot's Operating Handbook and FAA Approved Airplane Flight Manual (Stowed in Pilot's Seat Back)		1.2	61,5
25-11-S	Fuel Sampling Cup		0.1	14,3
25-12-S	Tow Bar, Nose Gear (Stowed)		1.7	108.0
25-13-S	Emergency Locator Transmitter Installation <ul style="list-style-type: none"> <li>- ELT Transmitter</li> <li>- Antenna and Cable Assembly</li> <li>- Hardware</li> </ul>		2,2* 1.7 0.4 0.1	134,8* 135.0 133.0 138,0
<b>Chapter 26 – Fire Protection</b>				
26-01-S	Fire Extinguisher Installation <ul style="list-style-type: none"> <li>- Fire Extinguisher</li> <li>- Mounting Clamp &amp; Hardware</li> </ul>		5,3* 4.8 0.5	29,0* 29.0 29.0
<b>Chapter 27 – Flight Controls</b>				
27-01-S	Dual Controls Installation, Right Seat <ul style="list-style-type: none"> <li>- Control Wheel, Copilot</li> <li>- Rudder and Brake Pedal Installation Copilot</li> </ul>		6,3* 2.0 4.3	12,9* 26,0 6.8

# Balance and CG

- ▶ Balance of an aircraft refers to the location of its center of gravity (CG)
- ▶ Definition: CG is that point about which an aircraft would balance if it were possible to suspend it there
- ▶ The theoretical point at which the entire weight of the aircraft is assumed to be concentrated

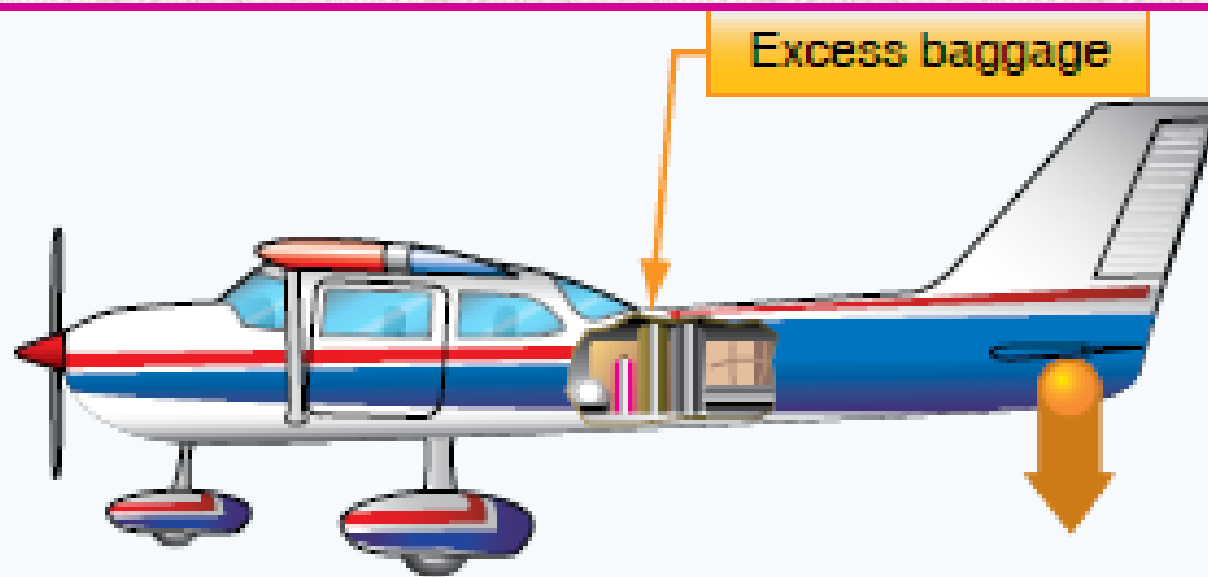




Lateral unbalance will cause wing heaviness.

# Lateral balance

- ▶ Not always computed
- ▶ Methods of control
  - ▶ Aileron trim (if so equipped)
  - ▶ Constant control pressure on yoke/stick
- ▶ Reduces operating efficiency
  - ▶ Aircraft is “out-of-streamline”
  - ▶ Increased drag



Excess baggage

Longitudinal unbalance will cause either nose or tail heaviness.

# Longitudinal balance

- ▶ More consequential
- ▶ Computed for each flight
- ▶ Controlled by loading decisions
- ▶ Limits are established for both forward and aft CG

# Forward (“nose heavy”) CG

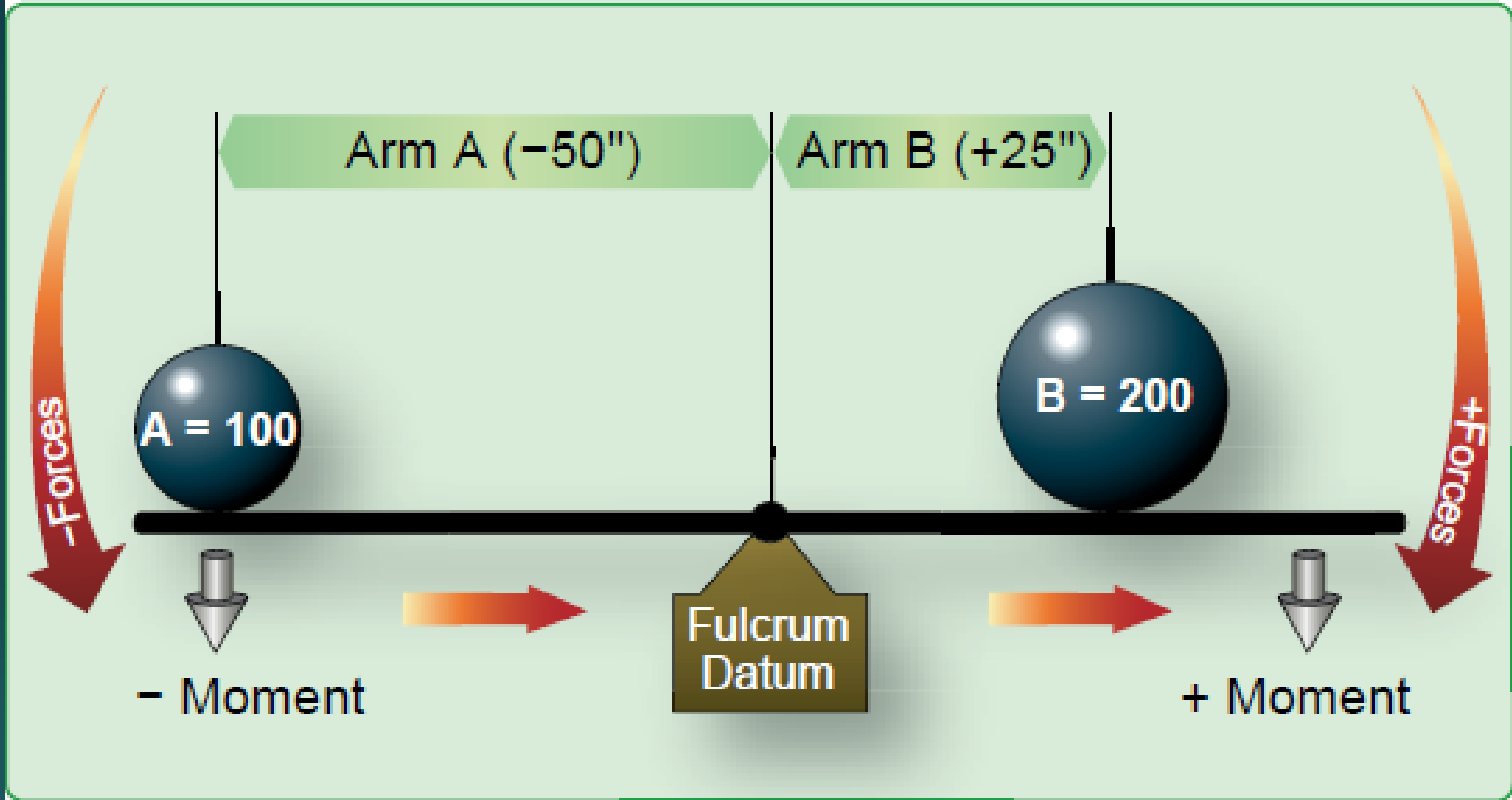
- ▶ Difficult to raise nose sufficiently for takeoff/landing
- ▶ Excessive load on nosewheel
- ▶ Higher stalling speed
- ▶ Higher control forces

# Aft (“tail heavy”) CG

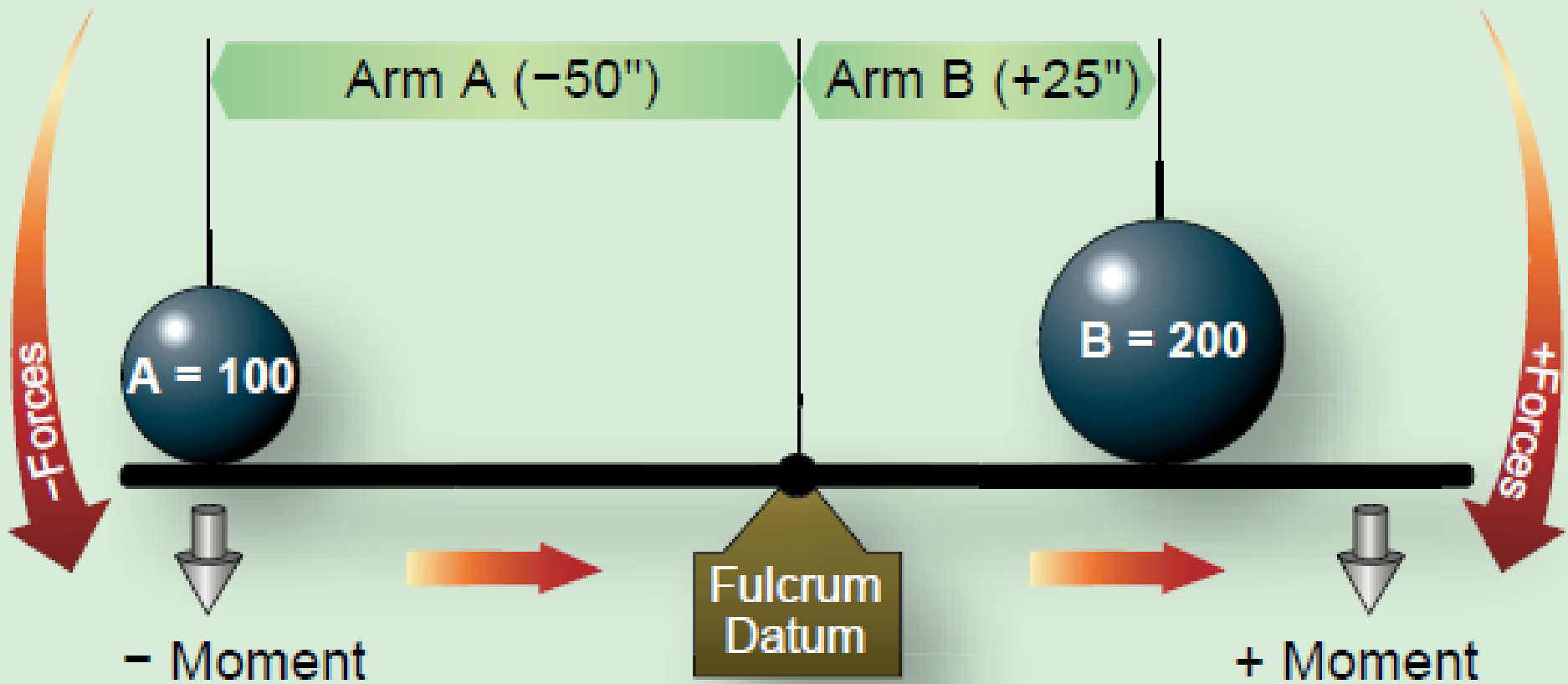
- ▶ Difficult to recover from stalls/spins
- ▶ Produces very light control forces, making it easy to overstress
- ▶ Decreases stability (tendency of plane to right itself after a disturbance)

# Law of the lever

A lever is balanced when the weight on one side of the fulcrum times its arm is equal to the weight on the opposite side times its arm.

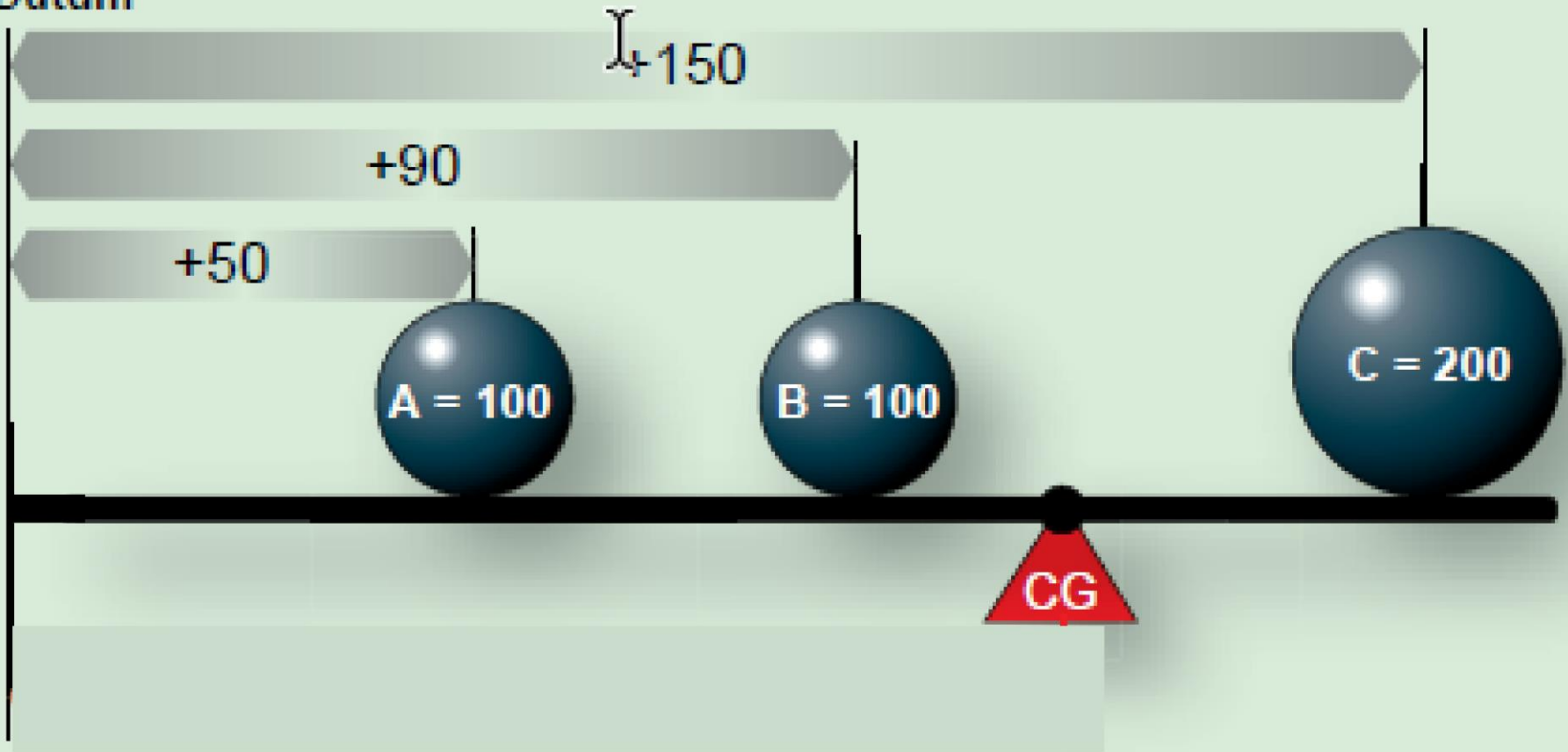


- ▶ Fulcrum: the point on which the lever pivots
- ▶ Datum: the reference point from which the arm is measured
- ▶ Weight = lbs
- ▶ Arm: distance from datum to the weight (usually measured in inches)
- ▶ Moment: the downward force resulting from the weight at its position. This is calculated as arm x weight and denominated in inch-pounds



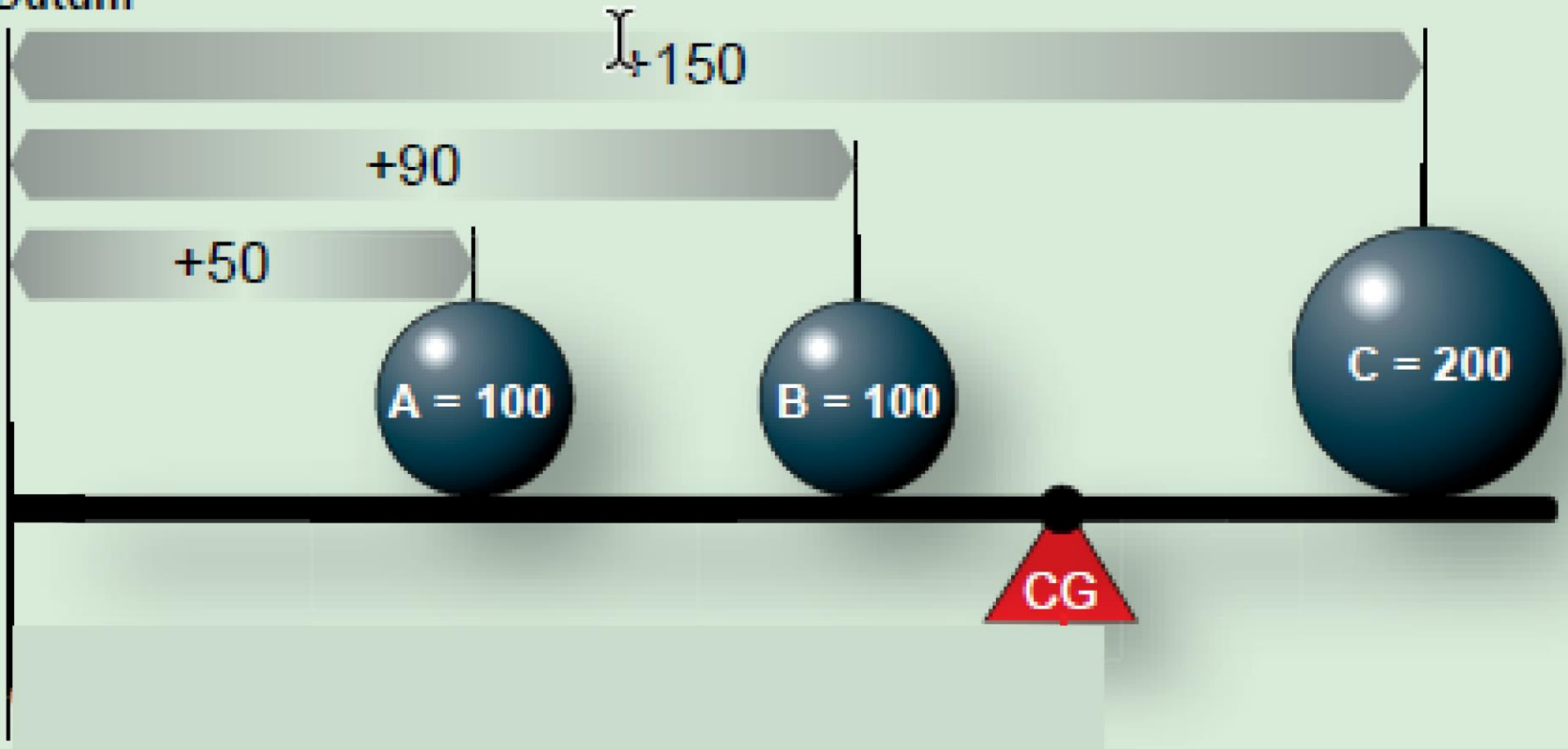
Side A:	Side B:
Weight = 100 lb	Weight = 200 lb
Arm = -50 inches	Arm = 25 inches
Moment = $100 \times -50 = -5000$ in lbs	Moment = $200 \times 25 = 5000$ in lbs
This lever is balanced about its fulcrum	

Datum



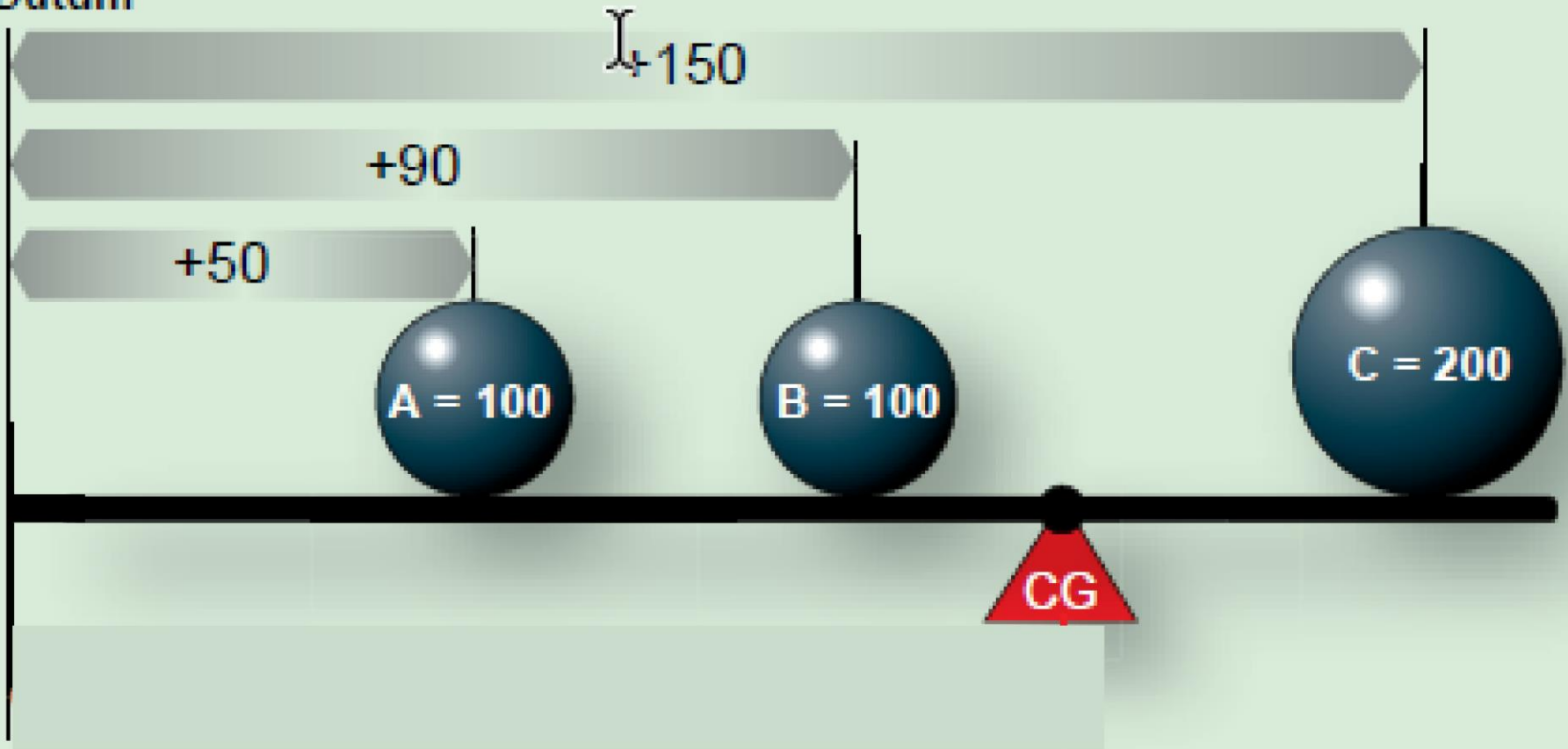
There is no requirement that the fulcrum and the datum be in the same place. We can solve this for where to place the fulcrum so that it becomes the center of gravity.

Datum



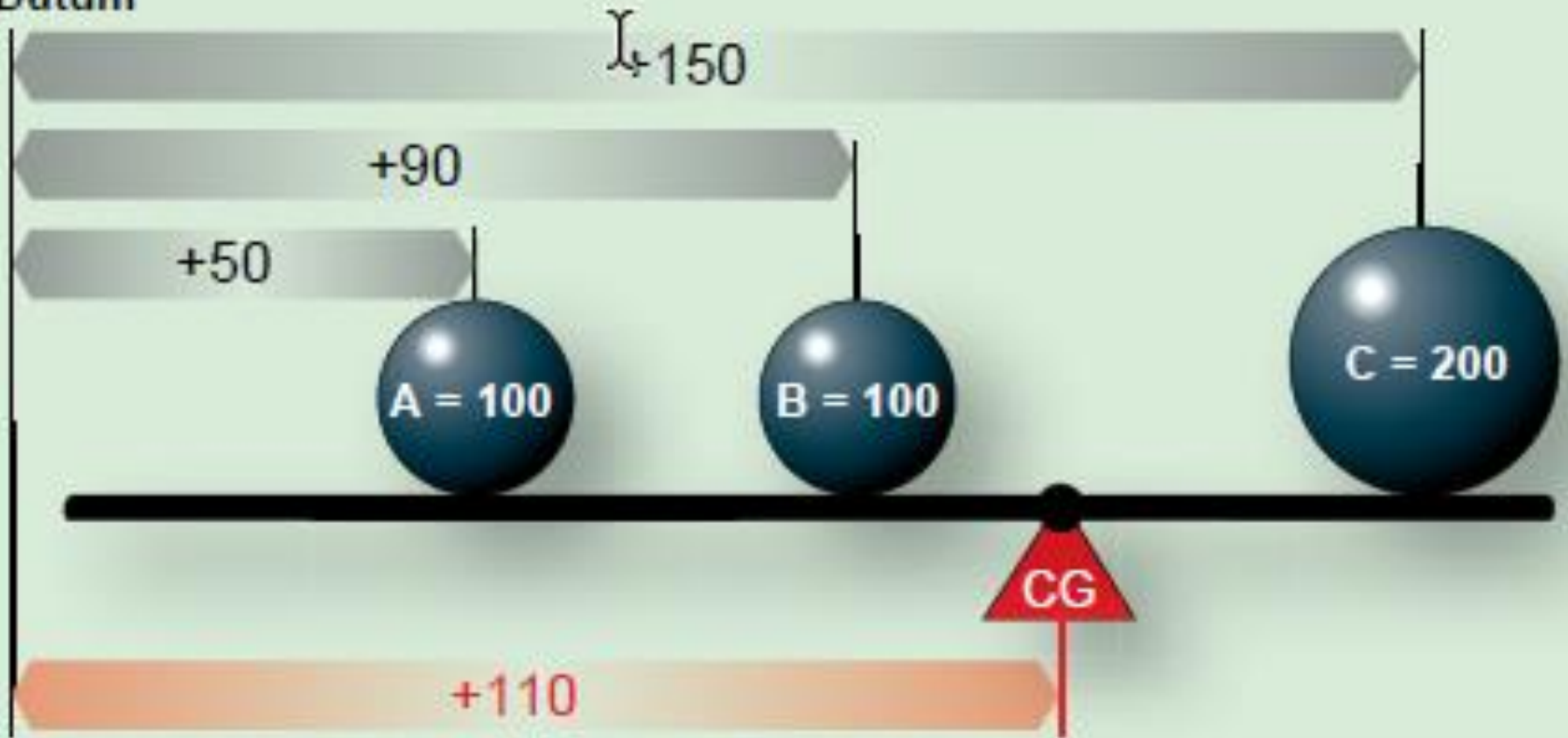
Item	Weight	*	Arm	=	Moment	CG
A	100		+50			
B	100		+90			
C	200		+150			
$\Sigma$ items						

Datum



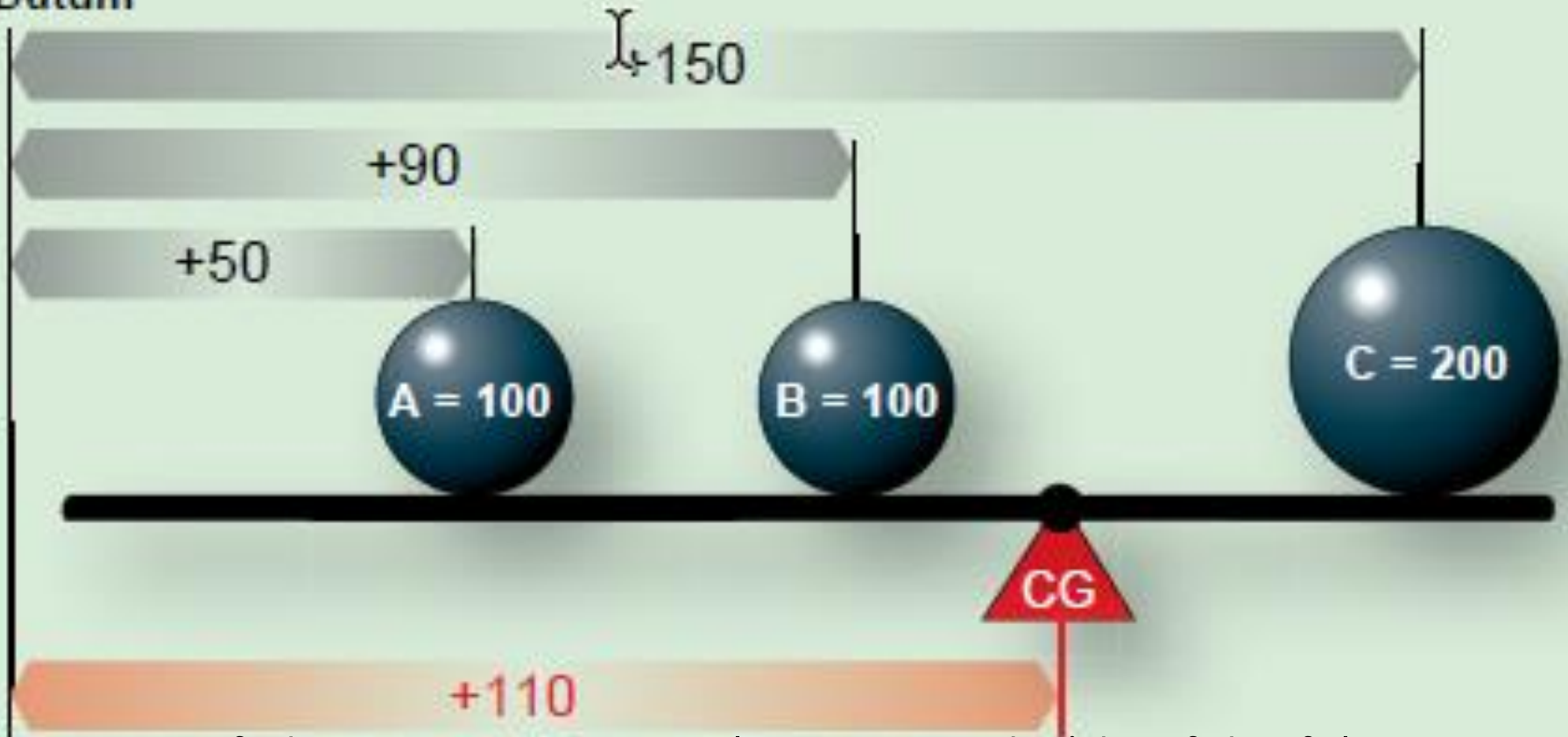
Item	Weight	*	Arm	=	Moment	CG
A	100		+50		5,000	
B	100		+90		9,000	
C	200		+150		30,000	
$\Sigma$ items	400				44,000	$\frac{\Sigma \text{ Moment}}{\Sigma \text{ Weight}}$

Datum



Item	Weight	*	Arm	=	Moment	CG
A	100		+50		5,000	
B	100		+90		9,000	
C	200		+150		30,000	
$\Sigma$ items	400				44,000	<b>+110</b>

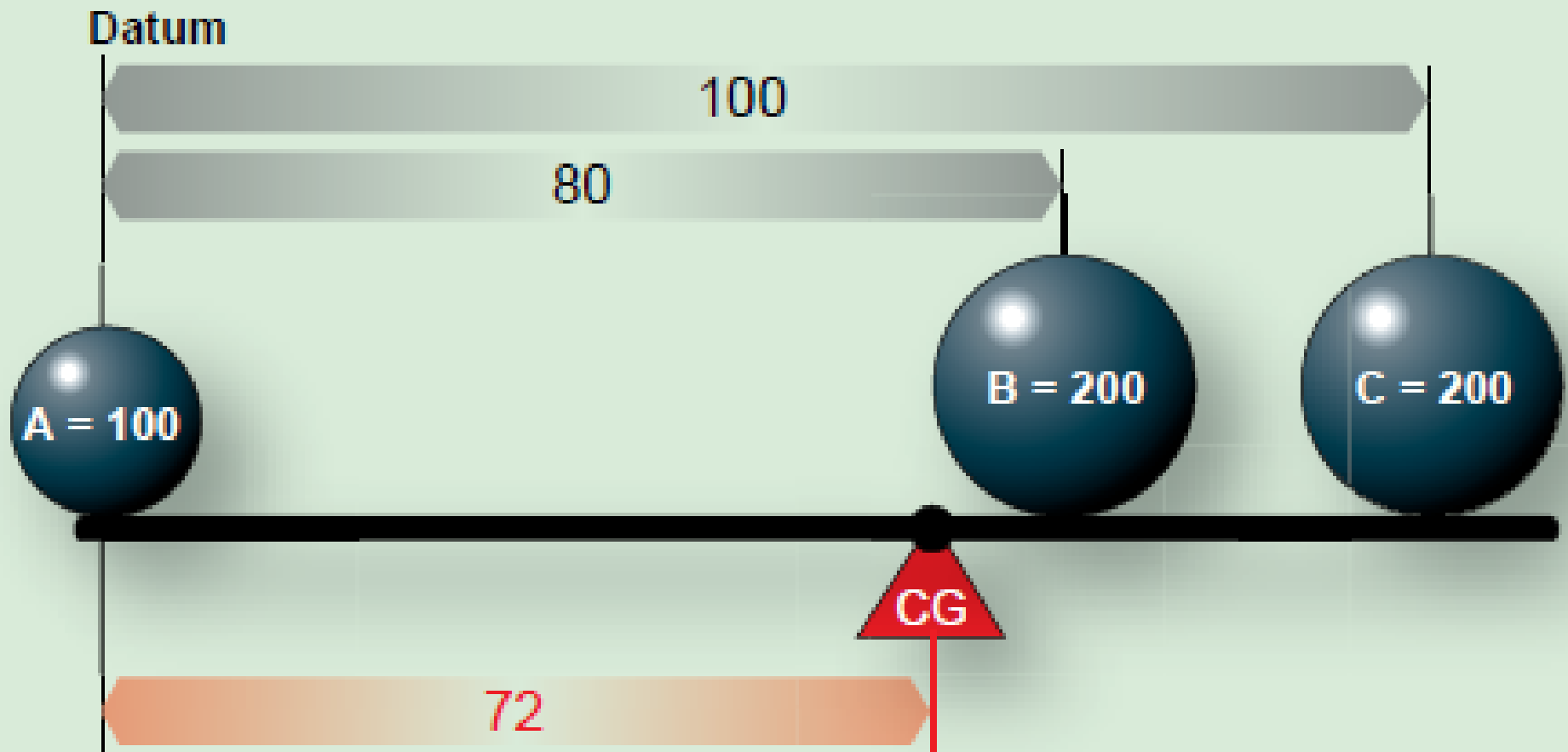
Datum



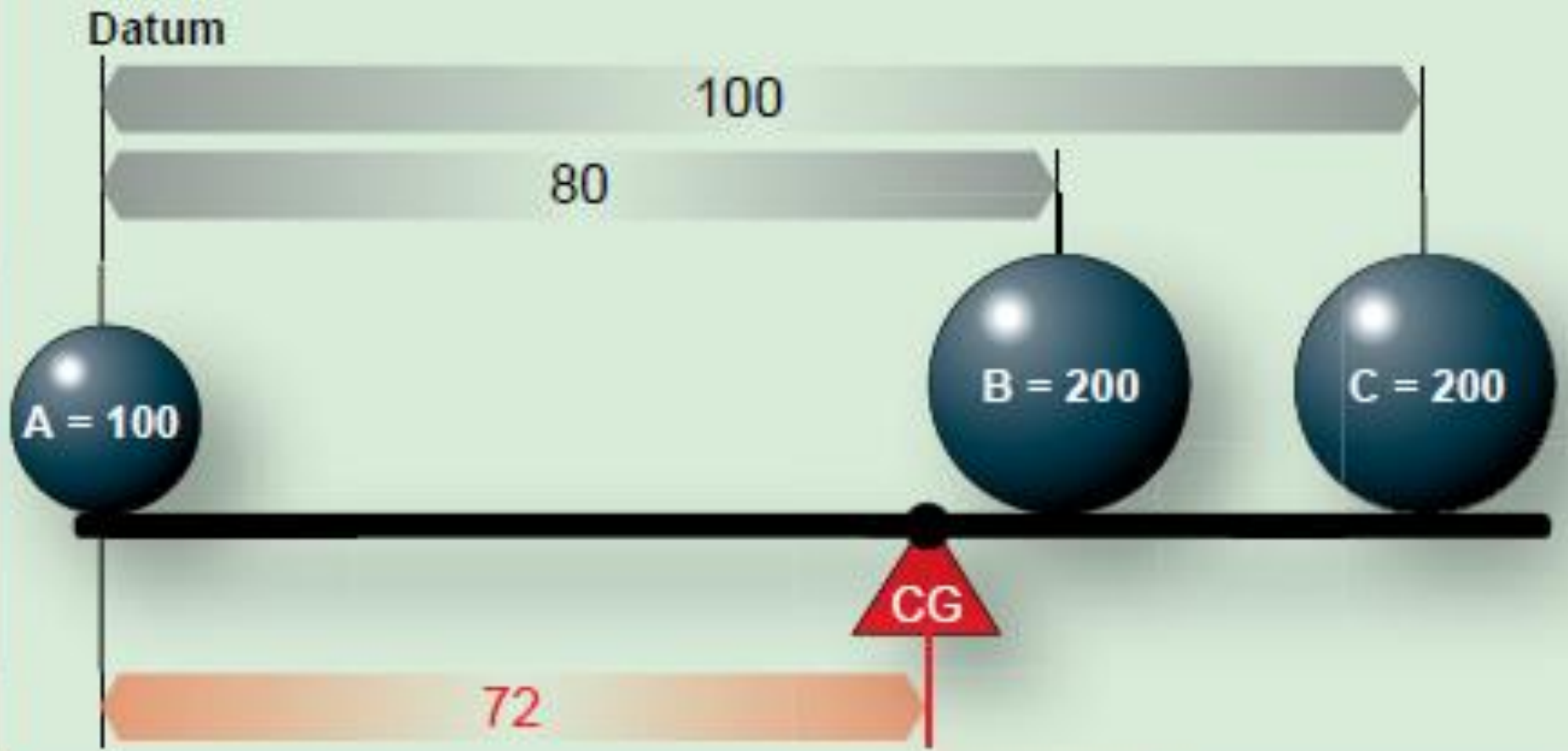
Proof: the moments cancel out on each side of the fulcrum:

Left: A (100 lbs) + B (100 lbs)	Right: C (200 lbs)
$[- (110'' - 50'') \times 100 \text{ lbs}] + [- (110'' - 90'') \times 100 \text{ lbs}]$	$(150'' - 110'') \times 200 \text{ lbs}$
$(-60'' \times 100 \text{ lbs}) + (-20'' \times 100 \text{ lbs})$	$(40'' \times 200 \text{ lbs})$
$(- 6000 \text{ inch-lbs}) + (- 2000 \text{ inch-lbs})$	
$- 8000 \text{ inch-lbs}$	$8000 \text{ inch-lbs}$

## Before Weight Shift



Here we have a plank of length 100". As currently distributed, the CG is 72" aft of the datum. How could we redistribute the weight (move Ball "B") so that the CG coincided with the midpoint of the plank (50" aft of datum)?



Let's start by demonstrating that the current CG is at 72":

Item	Weight	Arm	Moment	CG
A	100	0	0	
B	200	80	16000	
C	200	100	20000	
Sum	500		36000	72

# Basic Weight and Balance Equation

$$\frac{\text{Weight to be shifted}}{\text{Total weight}} = \frac{\text{Change in CG}}{\text{Distance weight is shifted}}$$

\*\* move "B" so that new CG = 50" aft of datum

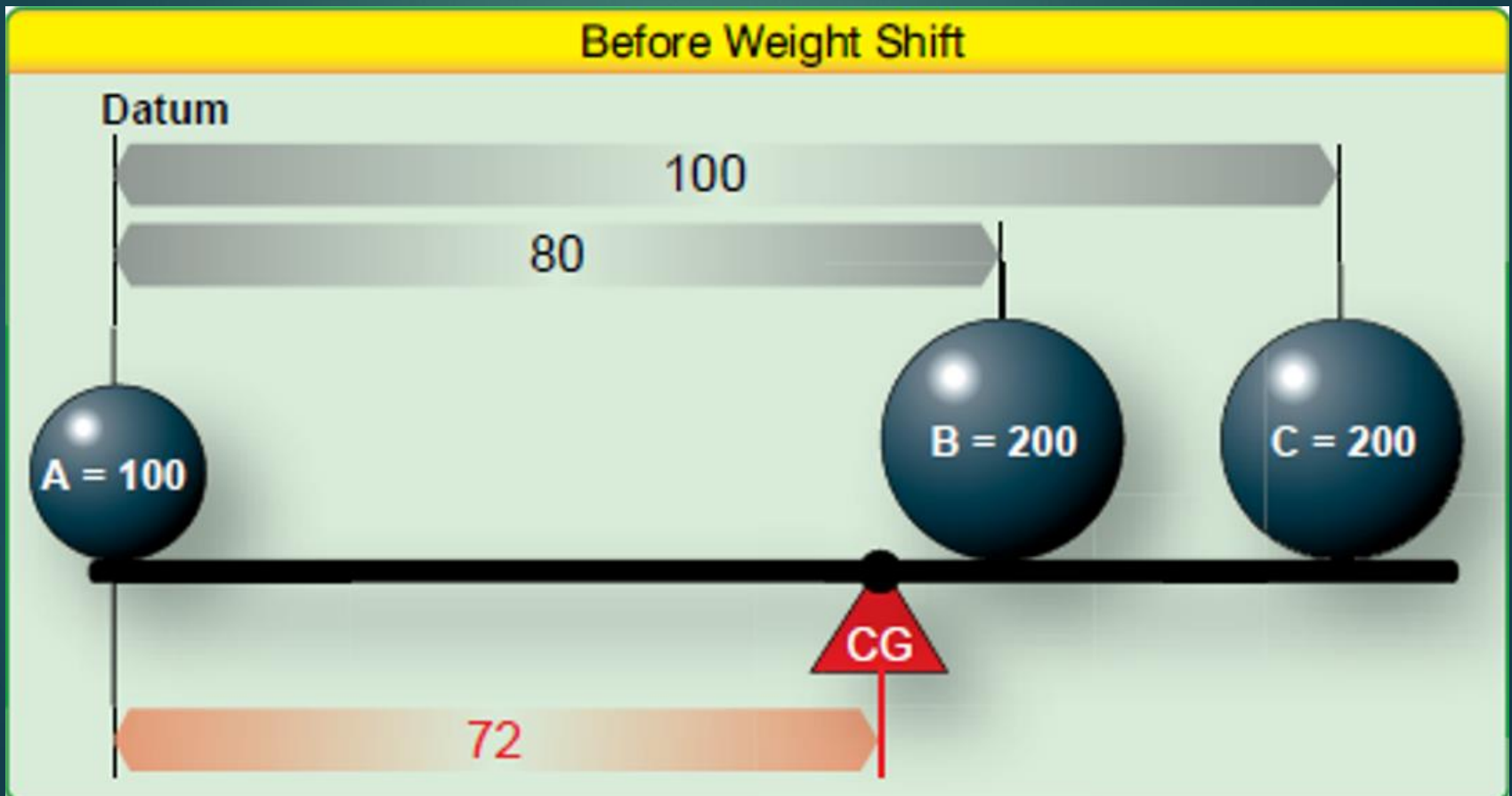
Weight to be shifted

Change in CG

=

Total weight

Distance weight is shifted



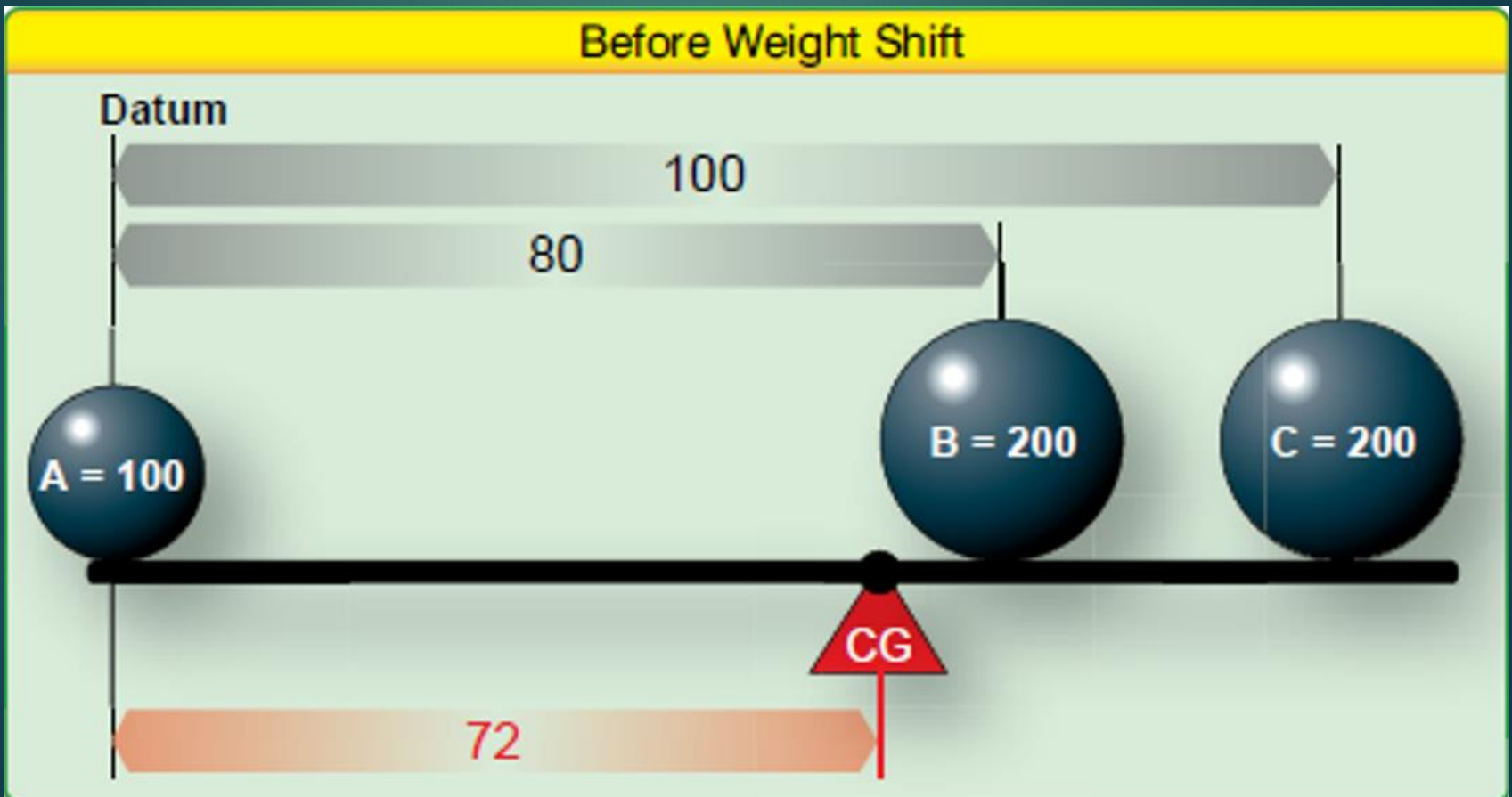
Weight to be shifted

Change in CG

=

Total weight

Distance weight is shifted



200 lbs

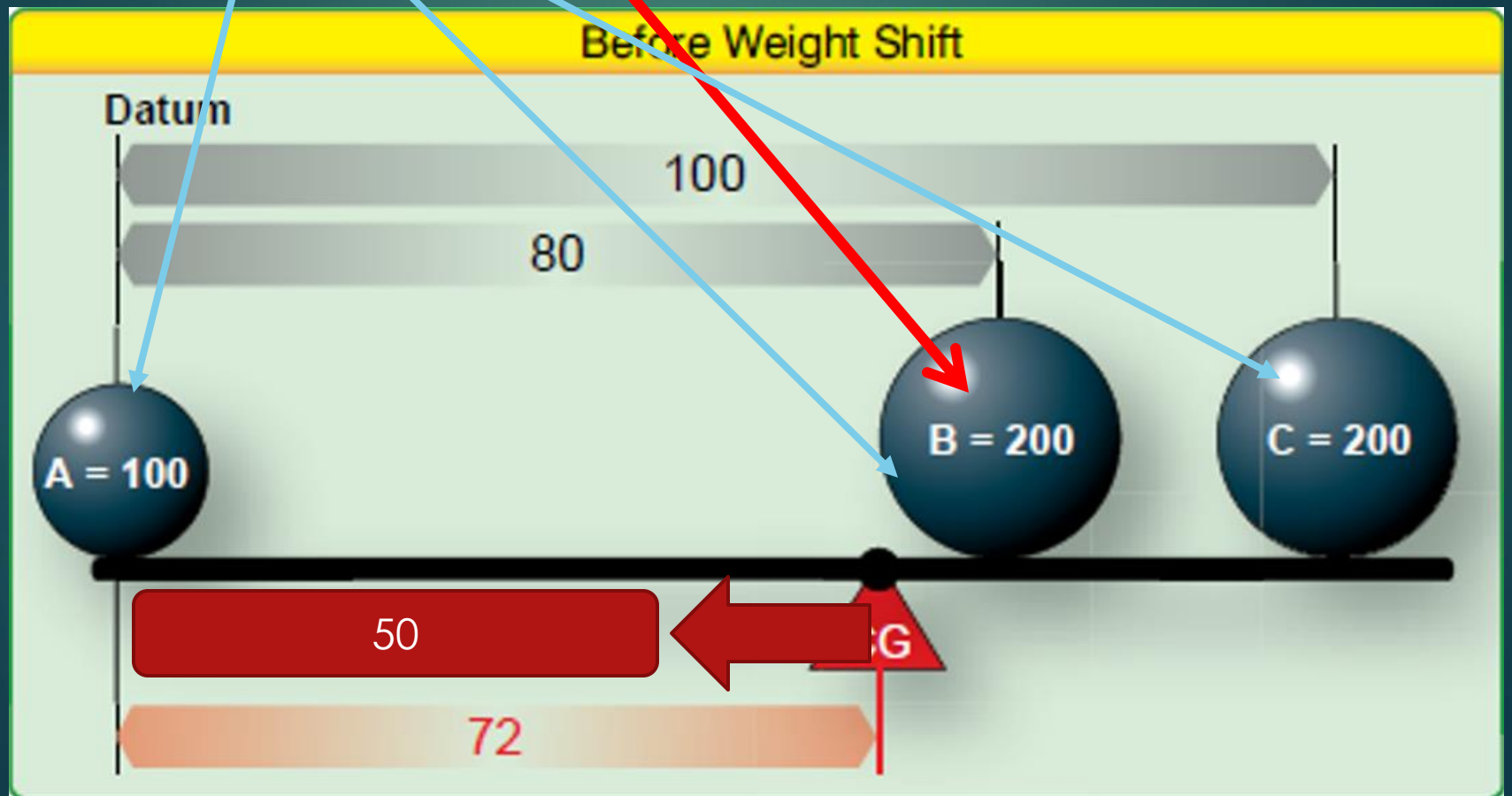
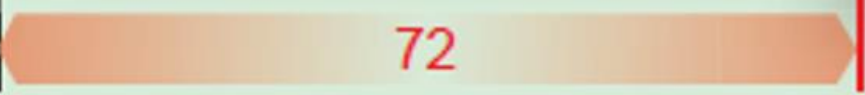
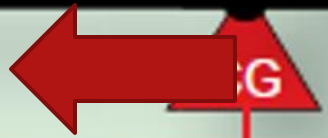
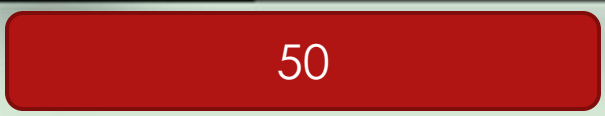
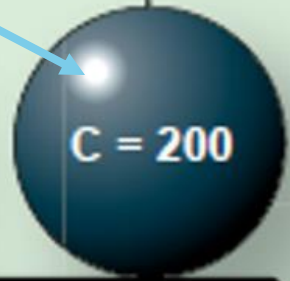
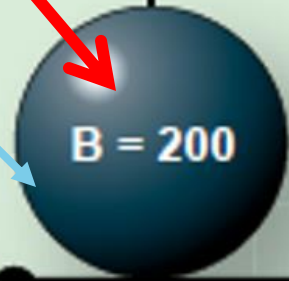
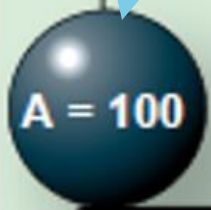
- 22 inches

500 lbs

Distance weight is shifted

### Before Weight Shift

Datum



200 lbs

- 22 inches

=

500 lbs

Distance weight is shifted

$$\frac{200}{500} = \frac{-22}{X}$$

\*\* move "B" so that new CG = 50" aft of datum

200 lbs

- 22 inches

=

500 lbs

Distance weight is shifted

$$\frac{200}{500} = \frac{-22}{X}$$

$$200 = \frac{(-22 \times 500)}{X}$$

\*\* move "B" so that new CG = 50" aft of datum

200 lbs

- 22 inches

=

500 lbs

Distance weight is shifted

$$\frac{200}{500} = \frac{-22}{X}$$

$$200 = \frac{(-22 \times 500)}{X}$$

$$200X = (-22 \times 500)$$

\*\* move "B" so that new CG = 50" aft of datum

200 lbs

- 22 inches

=

500 lbs

Distance weight is shifted

$$\frac{200}{500} = \frac{-22}{X}$$

$$200 = \frac{(-22 \times 500)}{X}$$

$$200X = (-22 \times 500)$$

$$X = \frac{(-22 \times 500)}{200}$$

\*\* move "B" so that new CG = 50" aft of datum

200 lbs

- 22 inches

=

500 lbs

Distance weight is shifted

$$\frac{200}{500} = \frac{-22}{X}$$

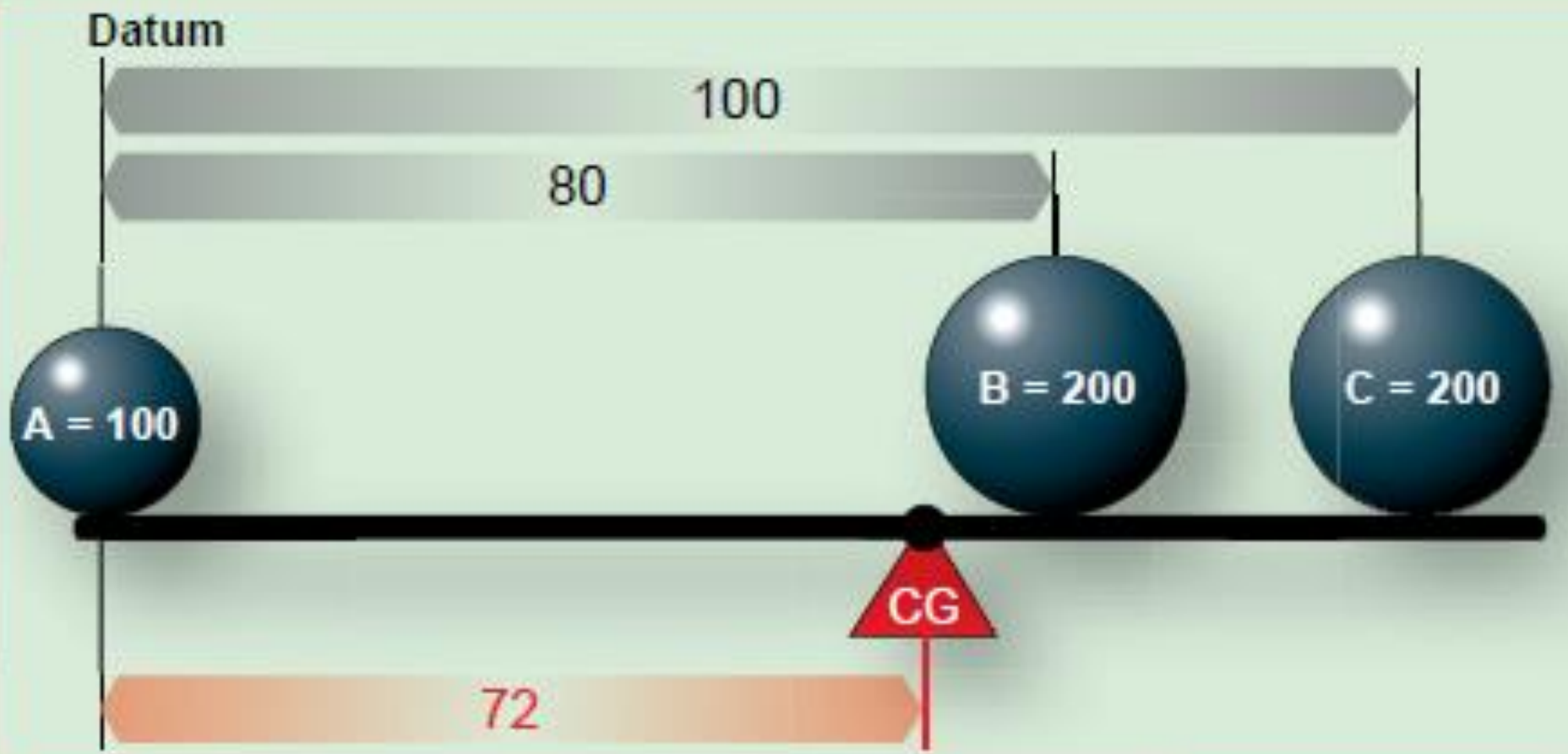
$$200 = \frac{(-22 \times 500)}{X}$$

$$200X = (-22 \times 500)$$

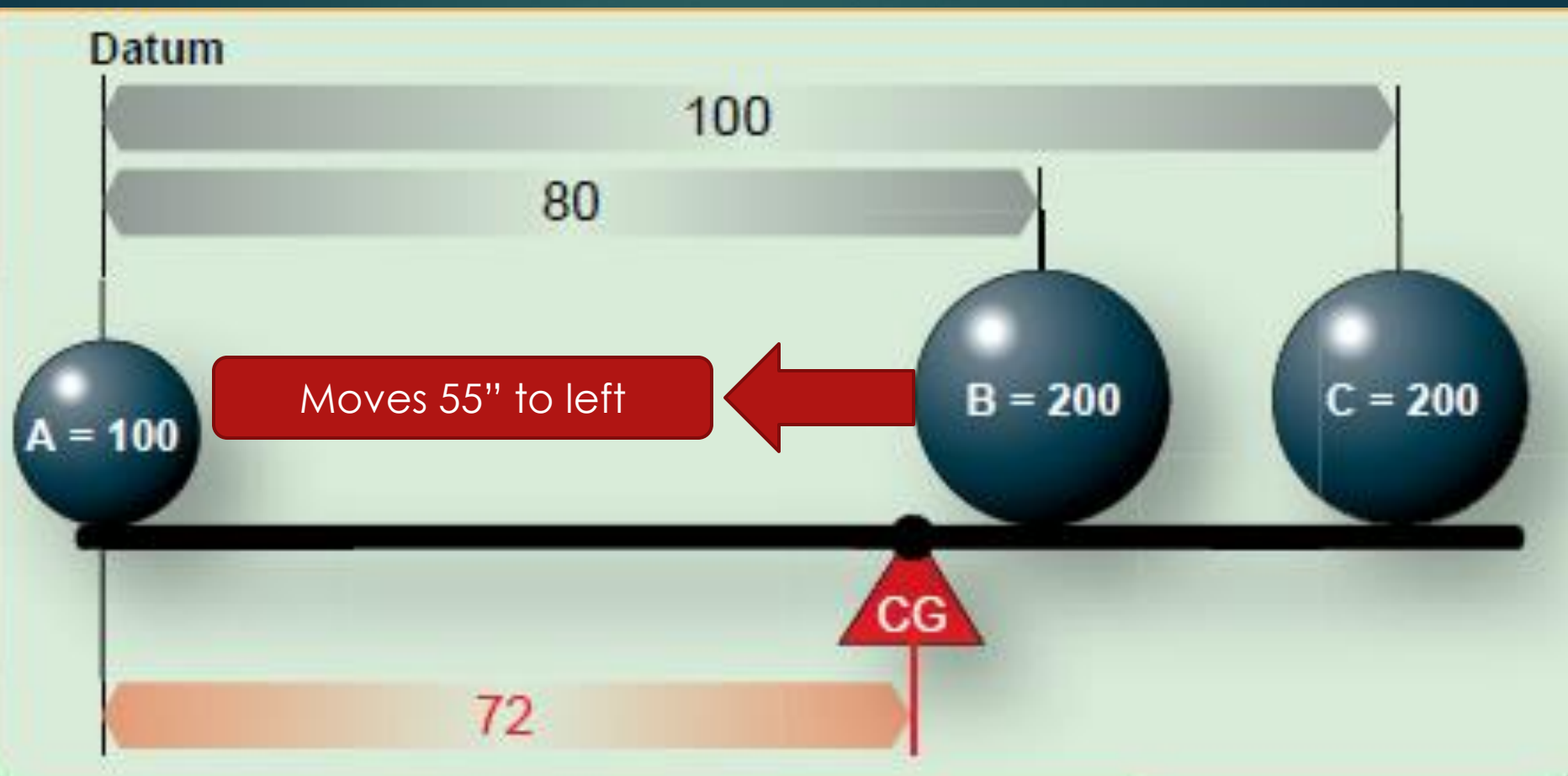
$$X = \frac{(-22 \times 500)}{200}$$

$$X = -55 \text{ inches}$$

\*\* move "B" so that new CG = 50" aft of datum

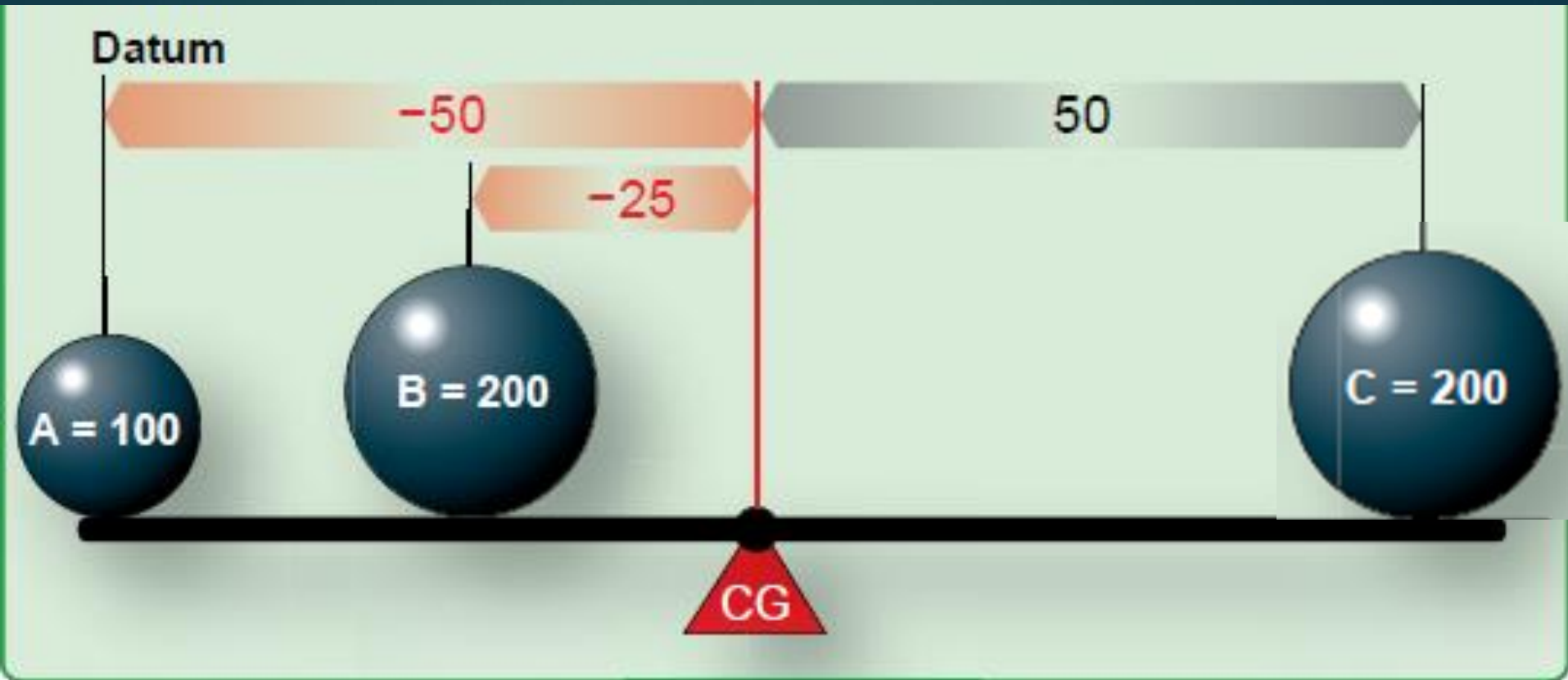


Item	Weight	Arm	Moment
A	100	0	0
B			
C	200	100	20,000



Item	Weight	Arm	Moment
A	100	0	0
B	200	$80 - 55 = 25$	5,000
C	200	100	20,000
Sum	500		25,000

New CG:  
 $25000 / 500$   
 $= 50!$



Item	Weight	Distance from Fulcrum	Moment
A	100	- 50	- 5000
B	200	- 25	- 5000
C	200	+ 50	+ 10000
Sum			0

Applying to Aircraft

# Some parameters

- ▶ Maximum takeoff weight (MTOW)
- ▶ Empty weight
- ▶ Number and position of seats
- ▶ Maximum baggage
- ▶ Fuel capacity
- ▶ Usable fuel in gallons
- ▶ Oil capacity in quarts (usually)

## Useful load weights and moments

### 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

**Empty weight**~2,015

**MOM/100**~1,554

#### 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
2,950 lb (takeoff or landing)	82.1	84.7
2,525 lb	77.5	85.7
2,475 lb or less	77.0	85.7

### 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

### 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.

Weight	Minimum Moment 100	Maximum Moment 100	Weight	Minimum Moment 100	Maximum Moment 100
2,100	1,617	1,800	2,500	1,932	2,143
2,110	1,625	1,808	2,510	1,942	2,151
2,120	1,632	1,817	2,520	1,953	2,160
2,130	1,640	1,825	2,530	1,963	2,168
2,140	1,648	1,834	2,540	1,974	2,176
2,150	1,656	1,843	2,550	1,984	2,184
2,160	1,663	1,851	2,560	1,995	2,192
2,170	1,671	1,860	2,570	2,005	2,200
2,180	1,679	1,868	2,580	2,016	2,208
2,190	1,686	1,877	2,590	2,026	2,216
2,200	1,694	1,885	2,600	2,037	2,224
2,210	1,702	1,894	2,610	2,048	2,232
2,220	1,709	1,903	2,620	2,058	2,239
2,230	1,717	1,911	2,630	2,069	2,247
2,240	1,725	1,920	2,640	2,080	2,255
2,250	1,733	1,928	2,650	2,090	2,263
2,260	1,740	1,937	2,660	2,101	2,271
2,270	1,748	1,945	2,670	2,112	2,279
2,280	1,756	1,954	2,680	2,123	2,287
2,290	1,763	1,963	2,690	2,133	2,295
2,300	1,771	1,971	2,700	2,144	2,303
2,310	1,779	1,980	2,710	2,155	2,311
2,320	1,786	1,988	2,720	2,166	2,319
2,330	1,794	1,997	2,730	2,177	2,326
2,340	1,802	2,005	2,740	2,188	2,334
2,350	1,810	2,014	2,750	2,199	2,342
2,360	1,817	2,023	2,760	2,210	2,350
2,370	1,825	2,031	2,770	2,221	2,358
2,380	1,833	2,040	2,780	2,232	2,366
2,390	1,840	2,048	2,790	2,243	2,374
2,400	1,848	2,057	2,800	2,254	2,381
2,410	1,856	2,065	2,810	2,265	2,389
2,420	1,863	2,074	2,820	2,276	2,397
2,430	1,871	2,083	2,830	2,287	2,405
2,440	1,879	2,091	2,840	2,298	2,413
2,450	1,887	2,100	2,850	2,309	2,421
2,460	1,894	2,108	2,860	2,320	2,428
2,470	1,902	2,117	2,870	2,332	2,436
2,480	1,911	2,125	2,880	2,343	2,444
2,490	1,921	2,134	2,890	2,354	2,452
2,900	2,365	2,460	2,910	2,377	2,468
2,920	2,388	2,475	2,930	2,399	2,483
2,940	2,411	2,491	2,950	2,422	2,499

FIGURE 32.—Airplane Weight and Balance Tables.

### Useful load weights and moments

#### 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

#### 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

#### 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~2,015  
MOM/100~1,554

#### 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
2,950 lb (takeoff or landing)	82.1	84.7
2,525 lb	77.5	85.7
2,475 lb or less	77.0	85.7

Weight	Minimum Moment	Maximum Moment	Weight	Minimum Moment	Maximum Moment
	100	100		100	100
2,100	1,617	1,800	2,500	1,932	2,143
2,110	1,625	1,808	2,510	1,942	2,151
2,120	1,632	1,817	2,520	1,953	2,160
2,130	1,640	1,825	2,530	1,963	2,168
2,140	1,648	1,834	2,540	1,974	2,176
2,150	1,656	1,843	2,550	1,984	2,184
2,160	1,663	1,851	2,560	1,995	2,192
2,170	1,671	1,860	2,570	2,005	2,200
2,180	1,679	1,868	2,580	2,016	2,208
2,190	1,686	1,877	2,590	2,026	2,216
2,200	1,694	1,885	2,600	2,037	2,224
2,210	1,702	1,894	2,610	2,048	2,232
2,220	1,709	1,903	2,620	2,058	2,239
2,230	1,717	1,911	2,630	2,069	2,247
2,240	1,725	1,920	2,640	2,080	2,255
2,250	1,733	1,928	2,650	2,090	2,263
2,260	1,740	1,937	2,660	2,101	2,271
2,270	1,748	1,945	2,670	2,112	2,279
2,280	1,756	1,954	2,680	2,123	2,287
2,290	1,763	1,963	2,690	2,133	2,295
2,300	1,771	1,971	2,700	2,144	2,303
2,310	1,779	1,980	2,710	2,155	2,311
2,320	1,786	1,988	2,720	2,166	2,319
2,330	1,794	1,997	2,730	2,177	2,326
2,340	1,802	2,005	2,740	2,188	2,334
2,350	1,810	2,014	2,750	2,199	2,342
2,360	1,817	2,023	2,760	2,210	2,350
2,370	1,825	2,031	2,770	2,221	2,358
2,380	1,833	2,040	2,780	2,232	2,366
2,390	1,840	2,048	2,790	2,243	2,374
2,400	1,848	2,057	2,800	2,254	2,381
2,410	1,856	2,065	2,810	2,265	2,389
2,420	1,863	2,074	2,820	2,276	2,397
2,430	1,871	2,083	2,830	2,287	2,405
2,440	1,879	2,091	2,840	2,298	2,413
2,450	1,887	2,100	2,850	2,309	2,421
2,460	1,894	2,108	2,860	2,320	2,428
2,470	1,902	2,117	2,870	2,332	2,436
2,480	1,911	2,125	2,880	2,343	2,444
2,490	1,921	2,134	2,890	2,354	2,452
2,900	2,365	2,460	2,910	2,377	2,468
2,920	2,388	2,475	2,930	2,399	2,483
2,940	2,411	2,491	2,950	2,422	2,499

FIGURE 32.—Airplane Weight and Balance Tables.

## Useful load weights and moments

### 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

### 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

### 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

Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

Empty weight~2,015

MOM/100~1,554

Moment limits vs weight

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

\*Included in basic empty weight.

## Useful load weights and moments

### 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

### 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

### 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~2,015

MOM/100~1,554

Moment limits vs weight

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

Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

Answer weight question first because it is easier; if it's too heavy you'll have to remove some weight before you calculate the balance anyway.

Maximum take off weight (MTOW) will be indicated in the Pilot's Operating Handbook/Operating Limitations.

Weight condition	Forward CG limit	AFT CG limit
<b>2,950 lb (takeoff or landing)</b>	<b>82.1</b>	<b>84.7</b>
<b>2,525 lb</b>	<b>77.5</b>	<b>85.7</b>
<b>2,475 lb or less</b>	<b>77.0</b>	<b>85.7</b>

## Useful load weights and moments

### 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

### 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

### 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~2,015

MOM/100~1,554

Moment limits vs weight

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

Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

Front seat occupants	415
Rear seat occupants	110
Fuel main tanks 44 gal	?
Fuel aux tanks 19 gal	?
Baggage	32

## Useful load weights and moments

### 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

### 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

### 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~2,015

MOM/100~1,554

Moment limits vs weight

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

Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

Front seat occupants	415
Rear seat occupants	110
Fuel main tanks 44 gal	264
Fuel aux tanks 19 gal	114
Baggage	32

Fuel weighs 6 lbs per gallon

## Useful load weights and moments

### 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

### 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

### 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~2,015**

**MOM/100~1,554**

**Moment limits vs weight**

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

**Determine if the airplane weight and balance is within limits.**

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

Front seat occupants	415
Rear seat occupants	110
Fuel main tanks 44 gal	264
Fuel aux tanks 19 gal	114
Baggage	32

What about oil?

Sometimes it is included in empty weight, sometimes not. This will be indicated on the chart. In this case, it is included.

## Useful load weights and moments

### 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

### 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

### 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.

Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

Front seat occupants	415
Rear seat occupants	110
Fuel main tanks 44 gal	264
Fuel aux tanks 19 gal	114
Baggage	32
Empty weight	2015
Total weight	

**Empty weight~2,015**

MOM/100~1,554

**Moment limits vs weight**

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

## Useful load weights and moments

### 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
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220	308
230	322
240	336
250	350
260	364
270	378

### 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

### 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.

## Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

Front seat occupants	415
Rear seat occupants	110
Fuel main tanks 44 gal	264
Fuel aux tanks 19 gal	114
Baggage	32
Empty weight	2015
Total weight	2950

### Weight condition

### Forward CG limit

### AFT CG limit

2,950 lb (takeoff or landing)  
2,525 lb  
2,475 lb or less

82.1  
77.5  
77.0

84.7  
85.7  
85.7

Empty weight~2,015

### MOMENT LIMITS vs WEIGHT

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

## Useful load weights and moments

### 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

### 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

### 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

## Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

	Lbs	Arm	Moment
Front seat occupants	415		
Rear seat occupants	110		
Fuel main tanks 44 gal	264		198
Fuel aux tanks 19 gal	114		107
Baggage	32		
Empty weight	2015		1554
Total weight	2950		

Empty weight ~ 2,015

MOM/100 ~ 1,554

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

\*Included in basic empty weight.

## Useful load weights and moments

### 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
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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

### 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

### 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.

## Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

	Lbs	Arm	Moment
Front seat occupants	415	85	
Rear seat occupants	110	121	
Fuel main tanks 44 gal	264		198
Fuel aux tanks 19 gal	114		107
Baggage	32	140	
Empty weight	2015		1554
Total weight	2950		

Empty weight~2,015

MOM/100~1,554

Moment limits vs weight

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

## Useful load weights and moments

### 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

### 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

### 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.

## Determine if the airplane weight and balance is within limits.

- Front seat occupants: 415 lb
- Rear seat occupants: 110 lb
- Fuel, main tanks: 44 gal
- Fuel, aux tanks: 19 gal
- Baggage: 32 lb

	Lbs	Arm	Moment
Front seat occupants	415	85	353
Rear seat occupants	110	121	133
Fuel main tanks 44 gal	264		198
Fuel aux tanks 19 gal	114		107
Baggage	32	140	45
Empty weight	2015		1554
Total weight	2950		

Empty weight~2,015

MOM/100~1,554

Moment limits vs weight

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

## Useful load weights and moments

### 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
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**Empty weight~2,015**

**MOM/100~1,554**

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**Determine if the airplane weight and balance is within limits.**

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CG = Moment/Weight			81.01

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<b>CG = Moment/Weight</b>			<b>81.01</b>

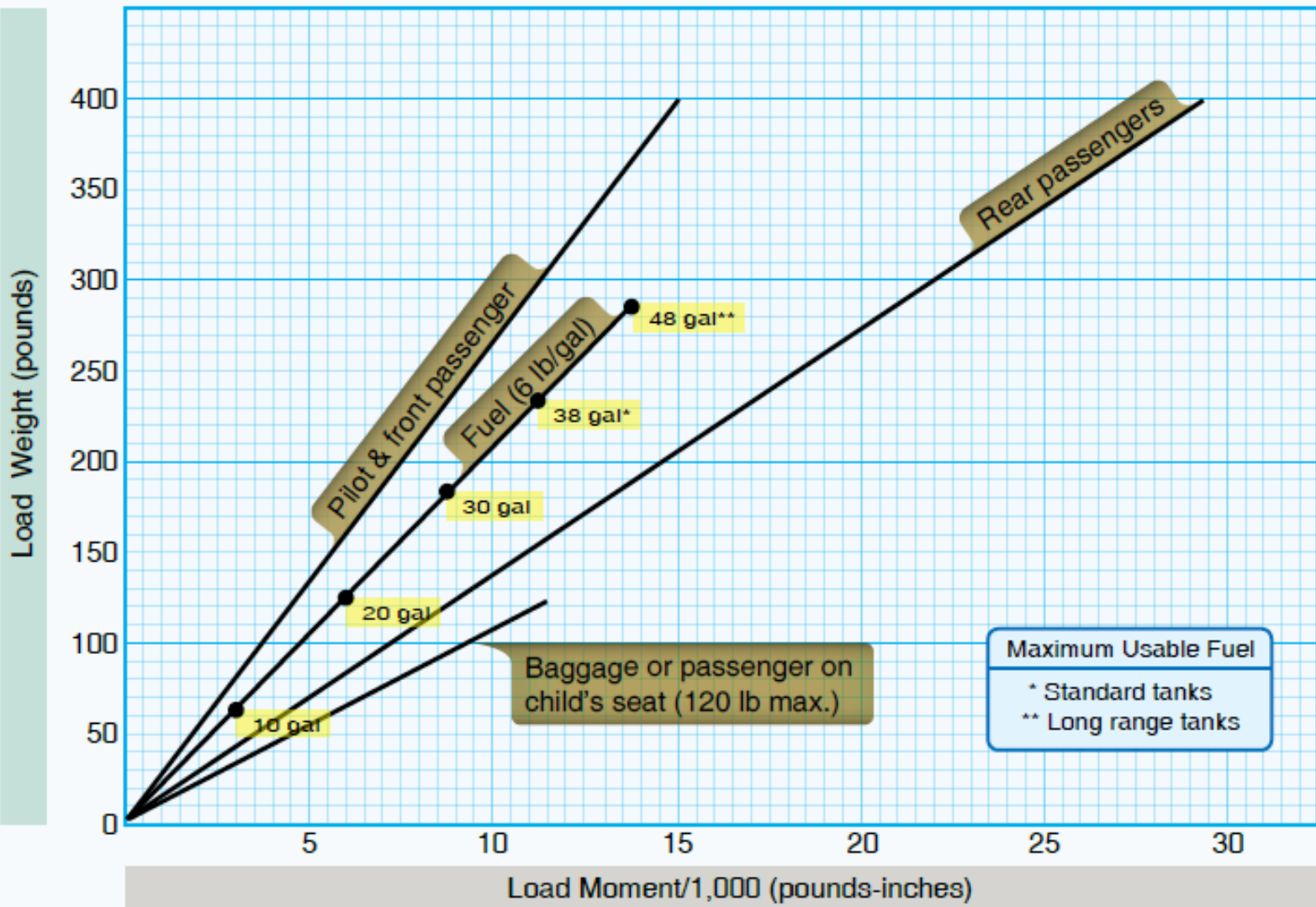
Moment limits vs weight (continued)					
Weight	Minimum Moment	Maximum Moment	Weight	Minimum Moment	Maximum Moment
	100	100		100	100
2,900	2,365	2,460	2,910	2,377	2,468
2,920	2,388	2,475	2,930	2,399	2,483
2,940	2,411	2,491	2,950	2,422	2,499

FIGURE 33.—Airplane Weight and Balance Tables.

Weight condition	Forward CG limit	AFT CG limit
2,950 lb (takeoff or landing)	82.1	84.7
2,525 lb	77.5	85.7
2,475 lb or less	77.0	85.7

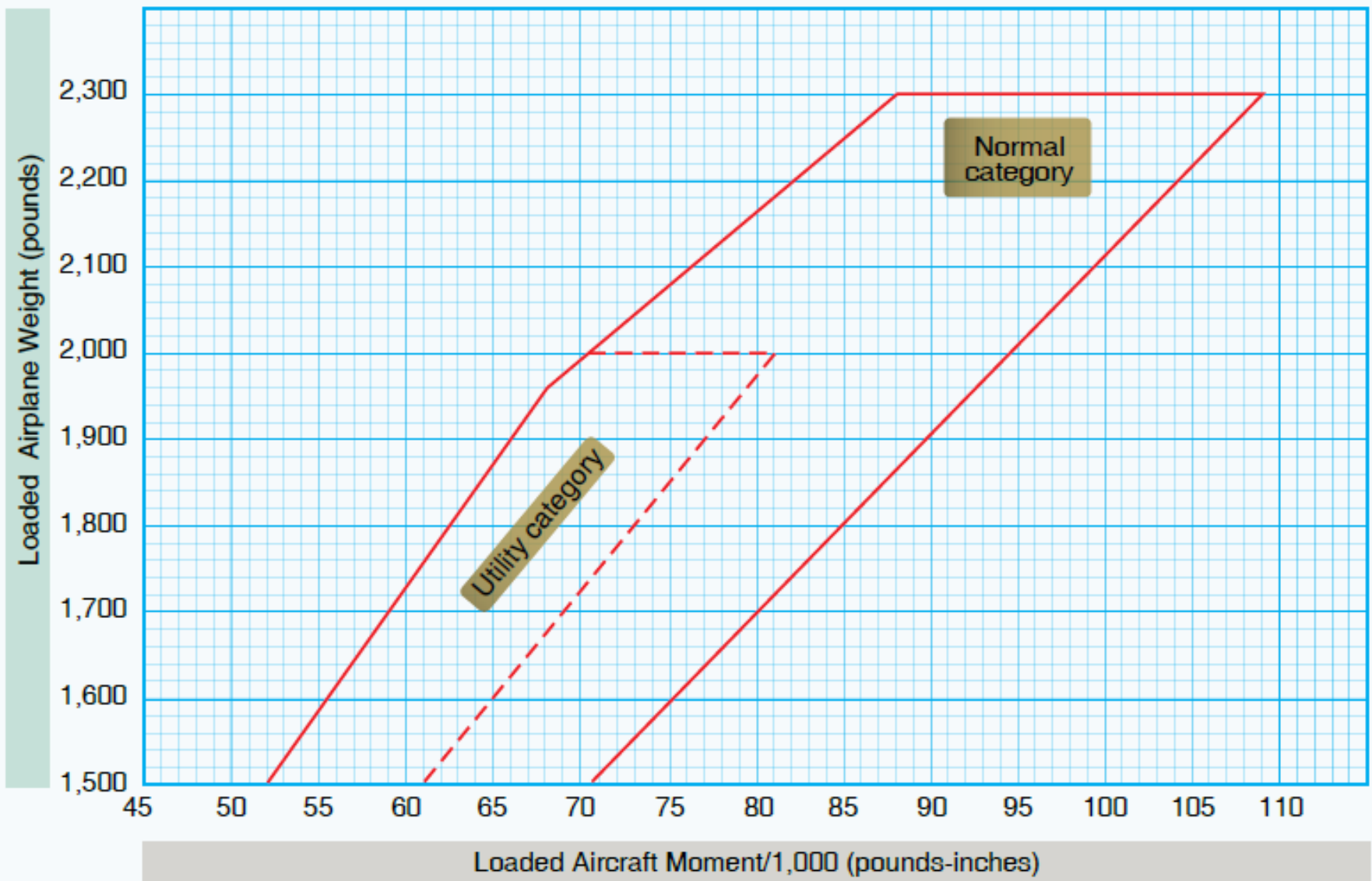
At current weight, this aircraft is not within CG limits – it is too far forward.

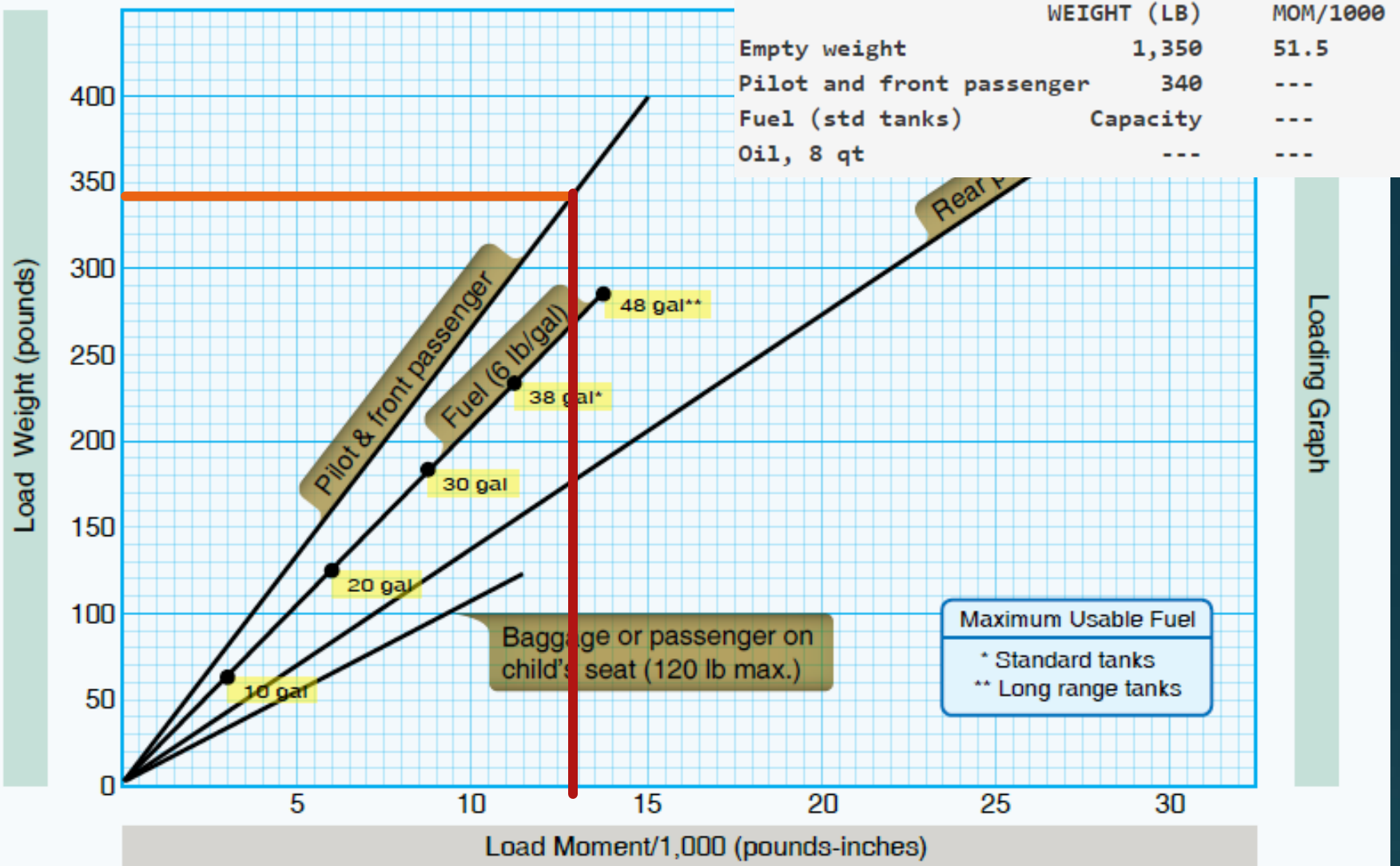




- Notes:
1. Lines representing adjustable seats show the pilot or passenger center of gravity on adjustable seats positioned for an average occupant. Refer to the Loading Arrangements diagram for forward and aft limits of occupant CG range.
  2. Engine Oil: 8 qt = 15 lb at  $-0.2$  Moment/1,000

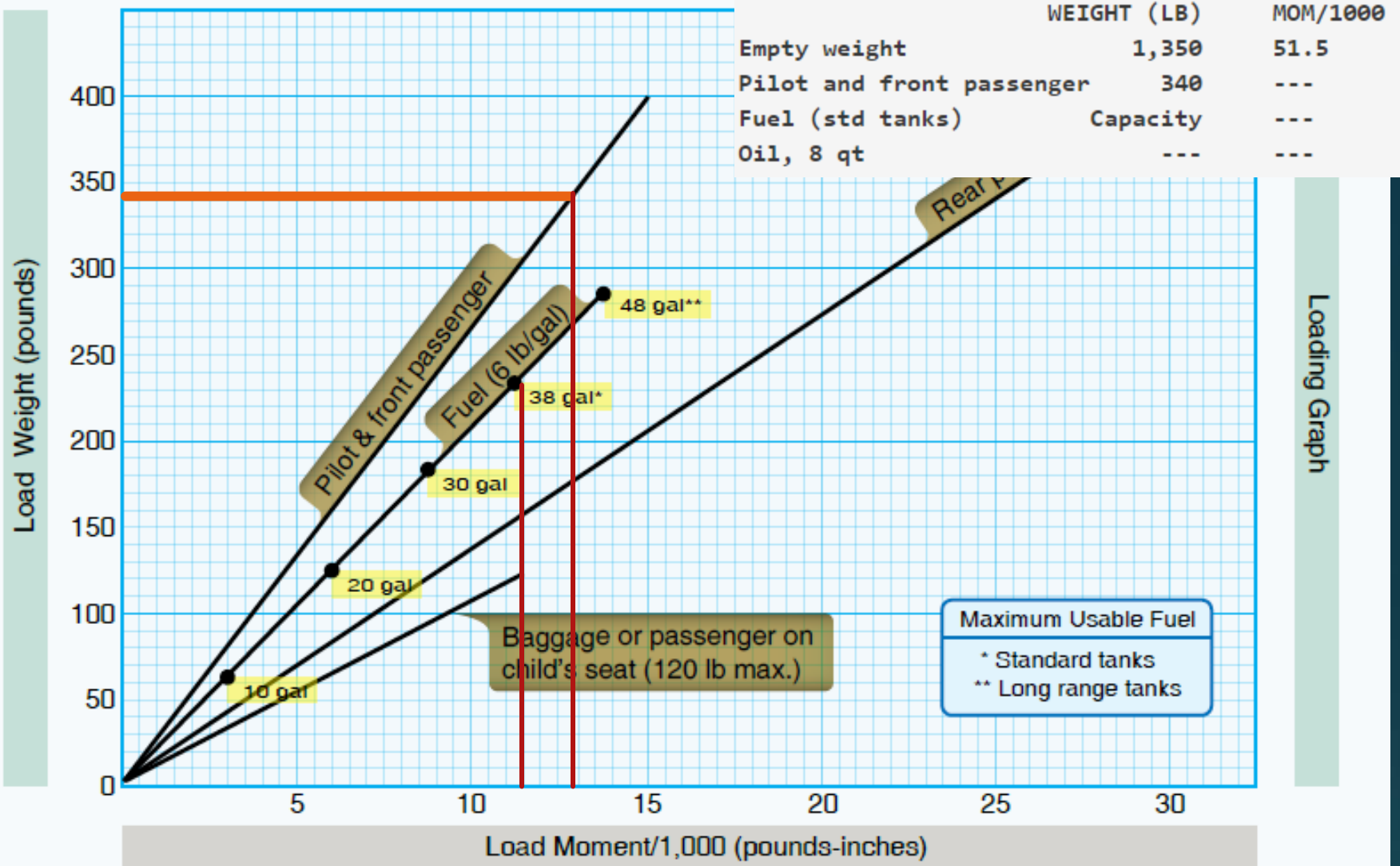
*Note: The empty weight of this airplane does not include the weight of the oil.*





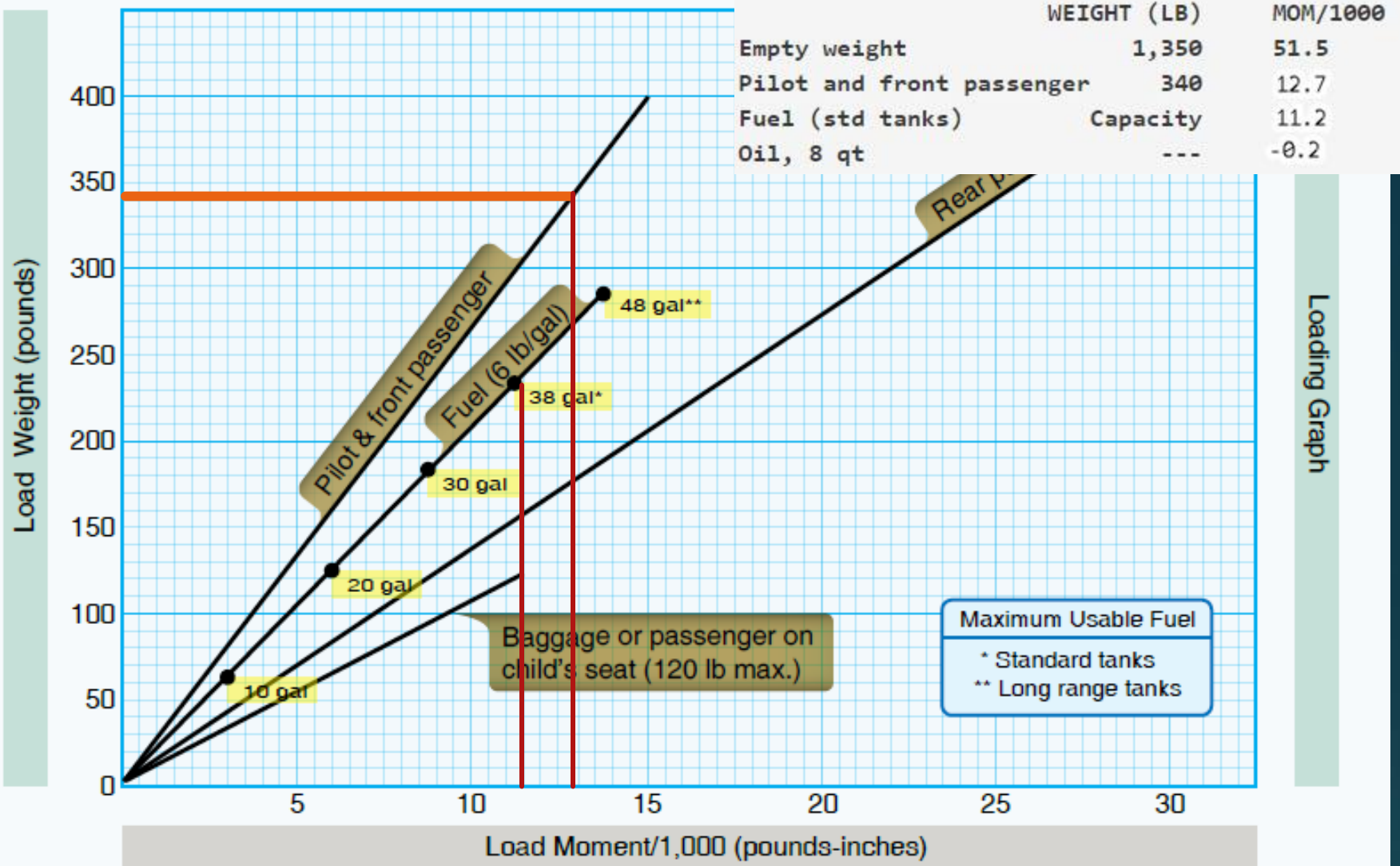
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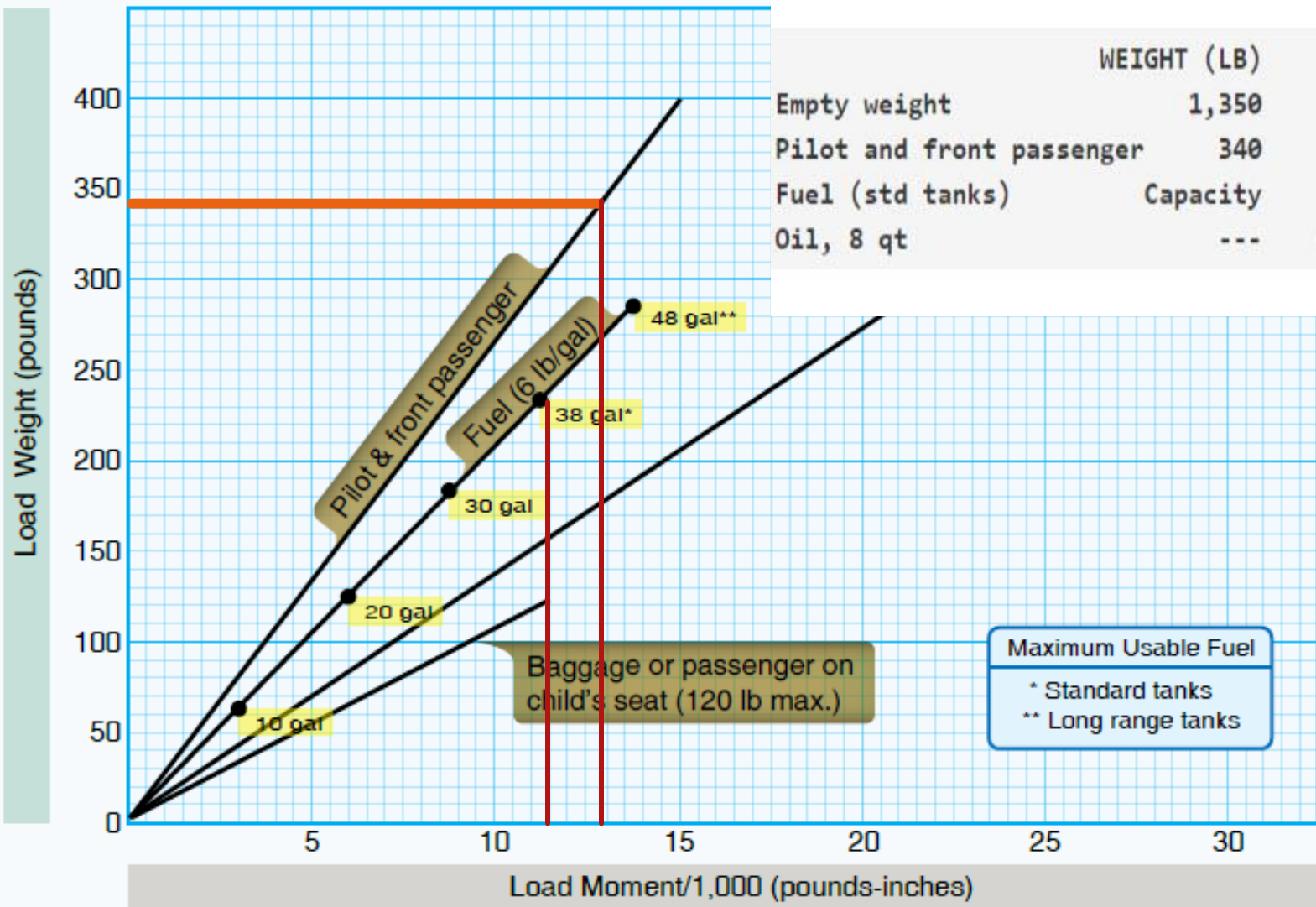
*Note: The empty weight of this airplane does not include the weight of the oil.*



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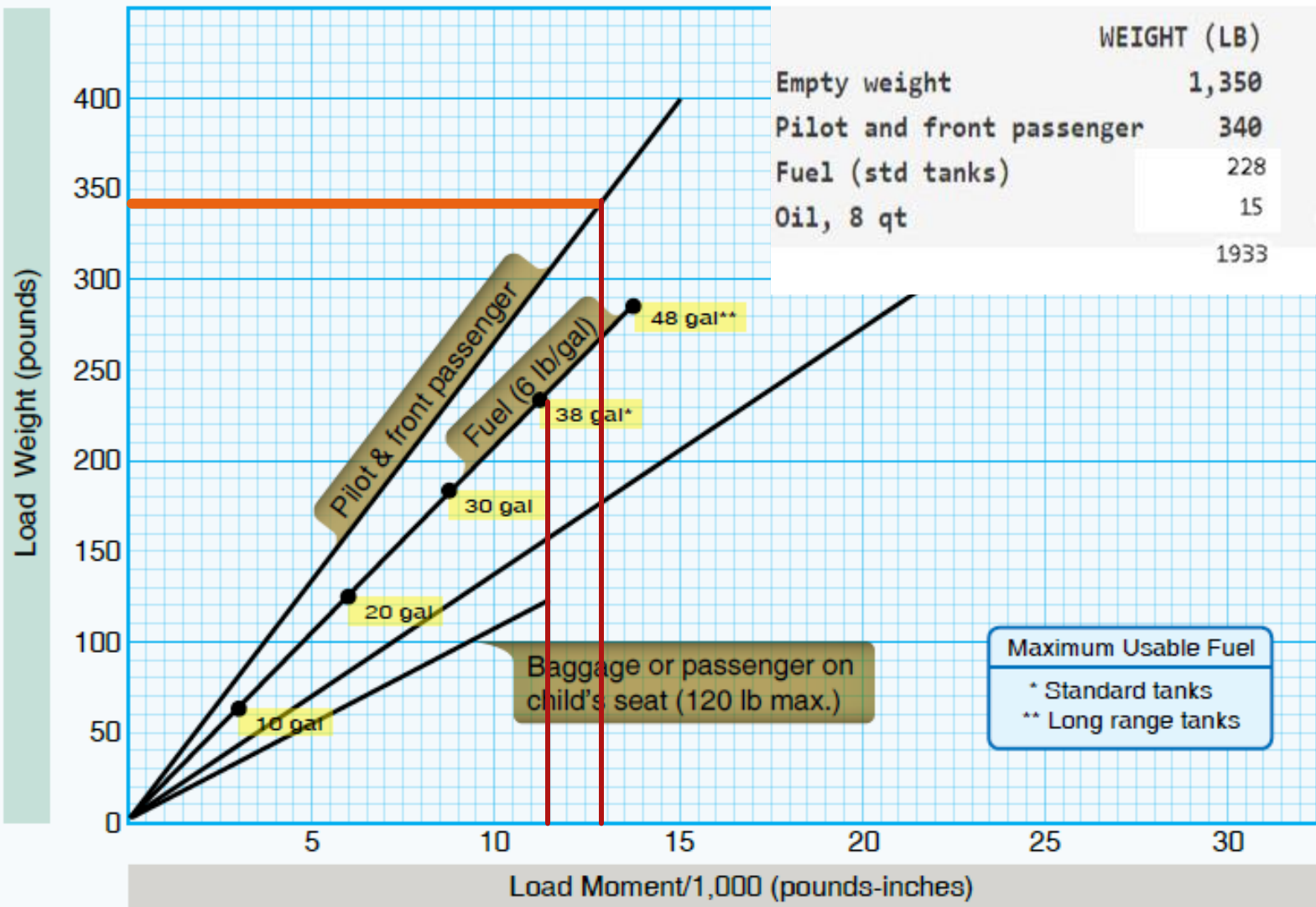
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Note: The empty weight of this airplane does not include the weight of the oil.

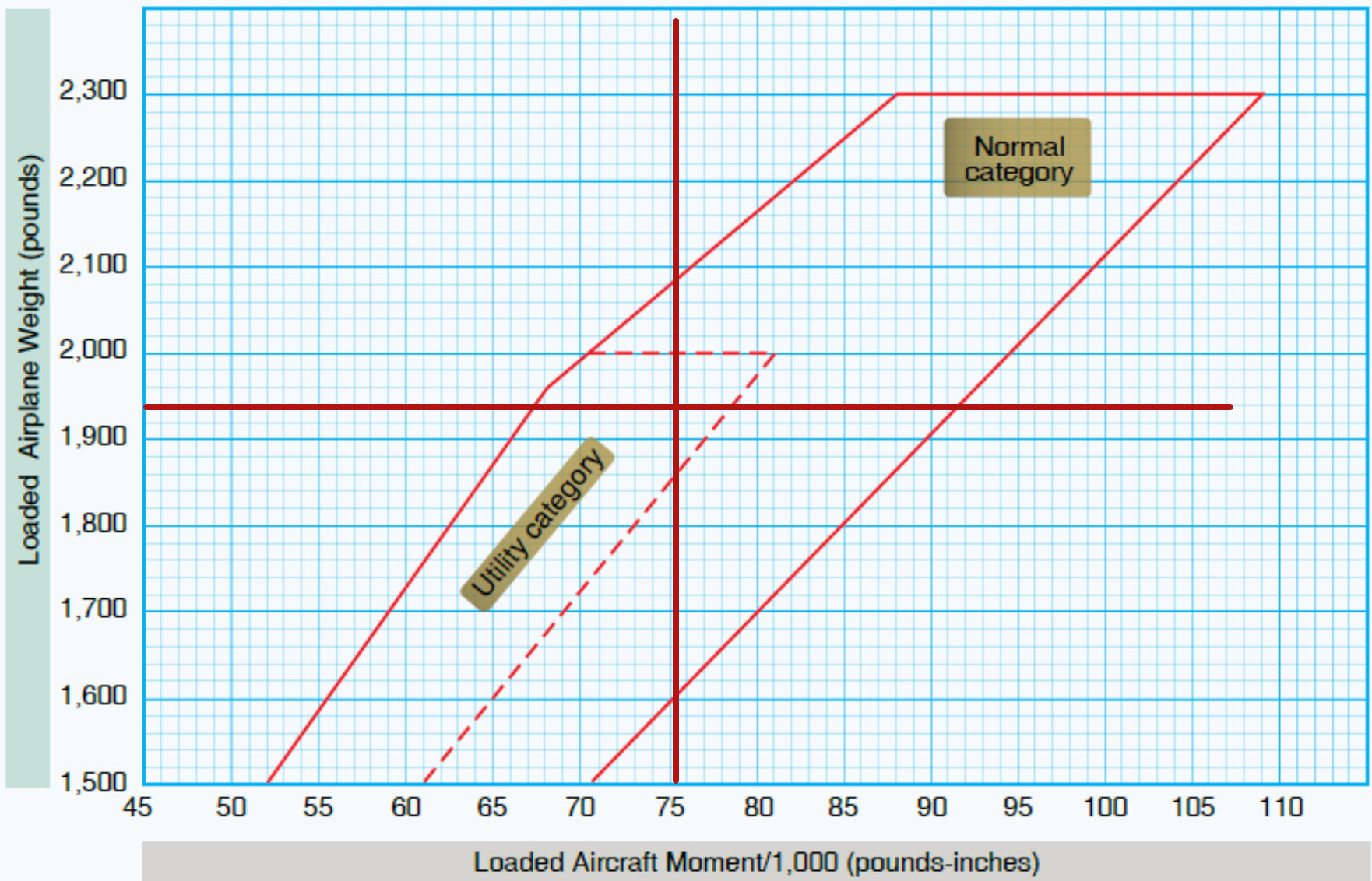


Loading Graph

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2. Engine Oil: 8 qt = 15 lb at -0.2 Moment/1,000

Note: The empty weight of this airplane does not include the weight of the oil.



## OPERATING WEIGHTS &amp; LOADING

Category	Max Weight	Center of Gravity Range
Light Sport	1320 lb	80.49" to 85.39" (18.4 to 27% Chord)

## NOTE

All measurements are aft of the datum line which is 70 inches forward of the wing leading edge.

Baggage 50 lb maximum

Maximum pilot / passenger weight 300lbs per seat, weight and balance permitting.

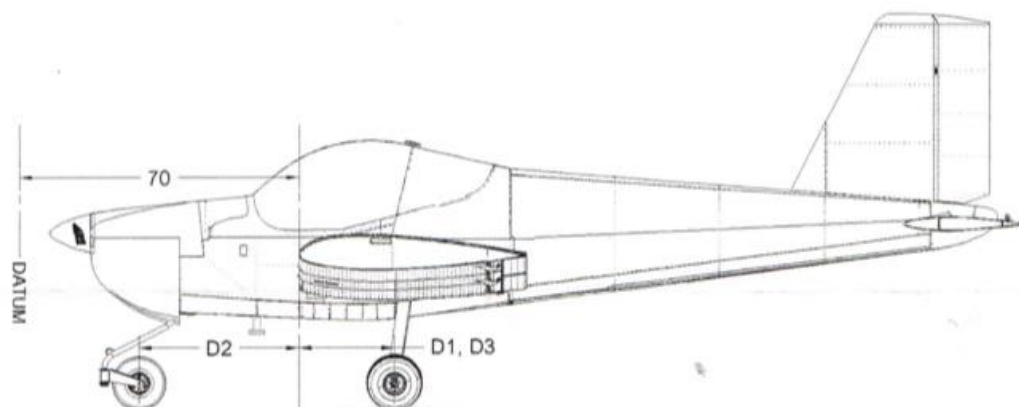


TABLE 1

	LEFT WHEEL	NOSE WHEEL	RIGHT WHEEL
WEIGHT	$\frac{304.5}{(W1)}$ lb	$\frac{159.0}{(W2)}$ lb	$\frac{322.0}{(W3)}$ lb
DISTANCE FROM AXLE CENTER TO LEADING EDGE	$\frac{23.50}{(D1)}$ inches	$\frac{46.50}{(D2)}$ inches	$\frac{23.50}{(D3)}$ inches

TABLE 2

	WEIGHT	ARM	MOMENT
LEFT WHEEL	$\frac{304.5}{(W1)}$ lb	$(70 + \frac{23.5}{(D1)}) = \frac{93.5}{(A1)}$ inches	$(\frac{304.5}{(W1)}) * (\frac{93.5}{(A1)}) = \frac{28,470.75}{(M1)}$ in-lb
NOSE WHEEL	$\frac{159.0}{(W2)}$ lb	$(70 - \frac{46.5}{(D2)}) = \frac{29.5}{(A2)}$ inches	$(\frac{159.0}{(W2)}) * (\frac{29.5}{(A2)}) = \frac{4,690.50}{(M2)}$ in-lb
RIGHT WHEEL	$\frac{322.0}{(W3)}$ lb	$(70 + \frac{23.5}{(D3)}) = \frac{93.5}{(A3)}$ inches	$(\frac{322.0}{(W3)}) * (\frac{93.5}{(A3)}) = \frac{30,107.00}{(M3)}$ in-lb

EMPTY WEIGHT =  $\frac{785.5}{(W1 + W2 + W3)}$  lb    EMPTY ARM =  $\frac{80.5452}{(\text{Empty Moment} / \text{Empty Weight})}$  inches

EMPTY MOMENT =  $\frac{63,268.25}{(M1 + M2 + M3)}$  in-lb

## YOUR AIRPLANE

ITEM	ARM (IN.) (LIMITS 80.49-85.39)	WEIGHT (LB)	MOMENT (IN-LB)
EMPTY WEIGHT WITH OIL & COOLANT			
PILOT	78.85		
PASSENGER	78.85		
BAGGAGE	110.81		
FUEL (6 LB/GAL)	110.28		
TAKEOFF WEIGHT & MOMENT			

CG - TOTAL MOMENT / WEIGHT

# Van's RV-12 W&B worksheet

Item	Weight	Arm	Moment		Maximum
Empty Weight (lbs)	785.5	80.54	63264.17		
Pilot (lbs)		78.85	0	<-----	300 lbs
Passenger (lbs)		78.85	0	<-----	300 lbs
Baggage (lbs)		110.81	0	<-----	50 lbs
Fuel (gals)		110.28	0	<-----	22 gals
Total Weight	785.5			<-----	1320 lb
Total Moment	63264.17				
CG	80.54			forward limit	80.49
				aft limit	85.39

- ▶ Next time: cross country flight planning
- ▶ Machado Chapter 14
- ▶ Pilot's Handbook Chapter 16
  
- ▶ Homework: work on aircraft performance and weight and balance problems. We will go over these next Monday (3/16)