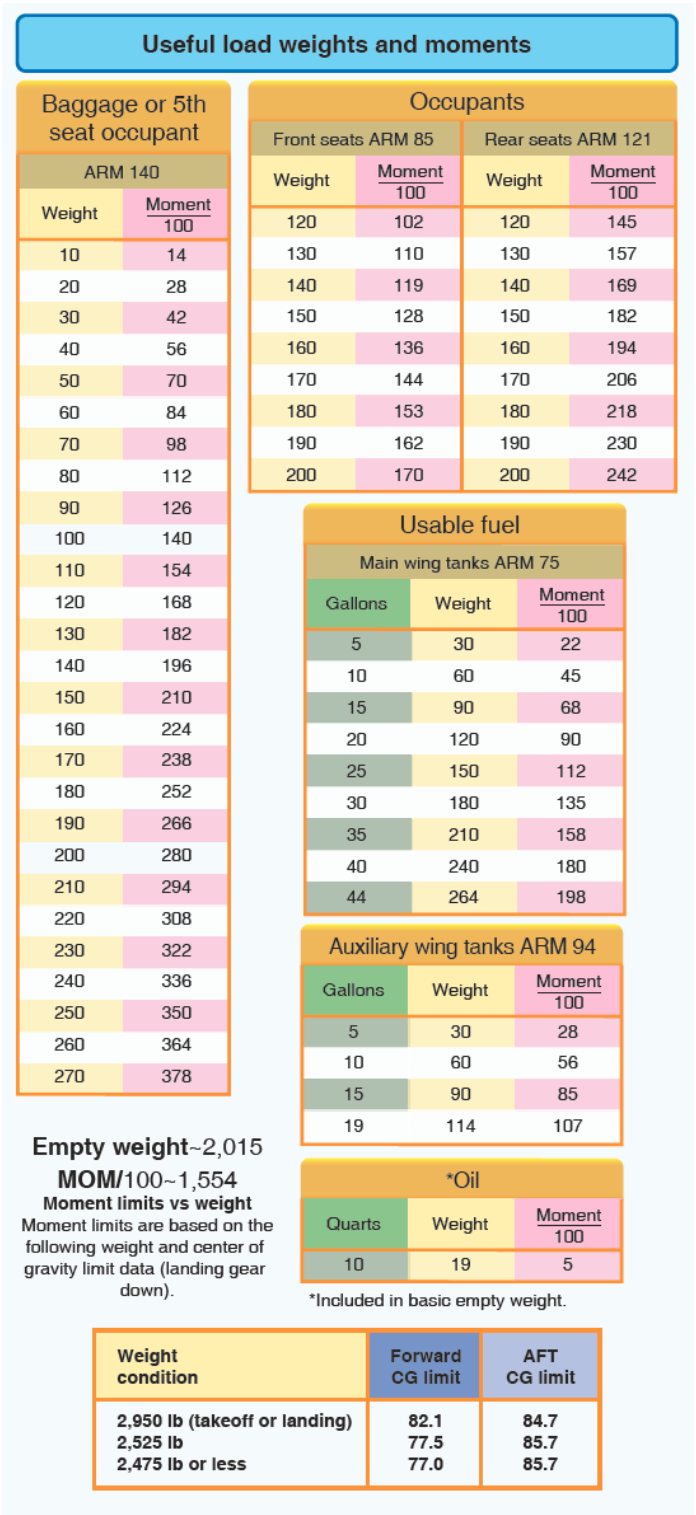
1.	Calculate the weight and balance and determine if the CG and the weight of the airplane are within limits.

Front seat occupants: 350 lbs	On the exam, the answer choices are
Rear seat occupants: 325 lbs	A: CG 83.4, within limits
Baggage: 27 lbs	B: CG 81.7, out of limits forward
Fuel: 35 gallons	C: CG 84.1, within limits
	The correct answer is A: CG 83.4 within limits



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

FIGURE 32.—Airplane Weight and Balance Tables.

To solve this question, you need to recall the two fundamental formulas used in weight and balance problems:

$$Weight \times Arm = Moment$$

and

$$CG = \frac{Total\ Moment}{Total\ Weight}$$

Additionally, you need to recall that the weight of AvGas is 6 pounds per US Gallon.

Get the basic empty weight and moment of the empty aircraft from Figure 32. Get the arms for each item also from this figure. Then, create a table as follows to calculate the CG:

	Weight	x	Arm	=	Moment
Empty Weight	2015				155400
Front Occupants	350	x	85	=	29750
Rear Occupants	325	x	121	=	39325
Baggage	27	x	140	=	3780
Fuel	210	x	75	=	15750
Totals	2927	x	CG	=	244005
			CG =		83.36
CG = Sum of Moments / Sum of Weights					
Fuel	35	gallons @ 6lb/gal =		210	lbs

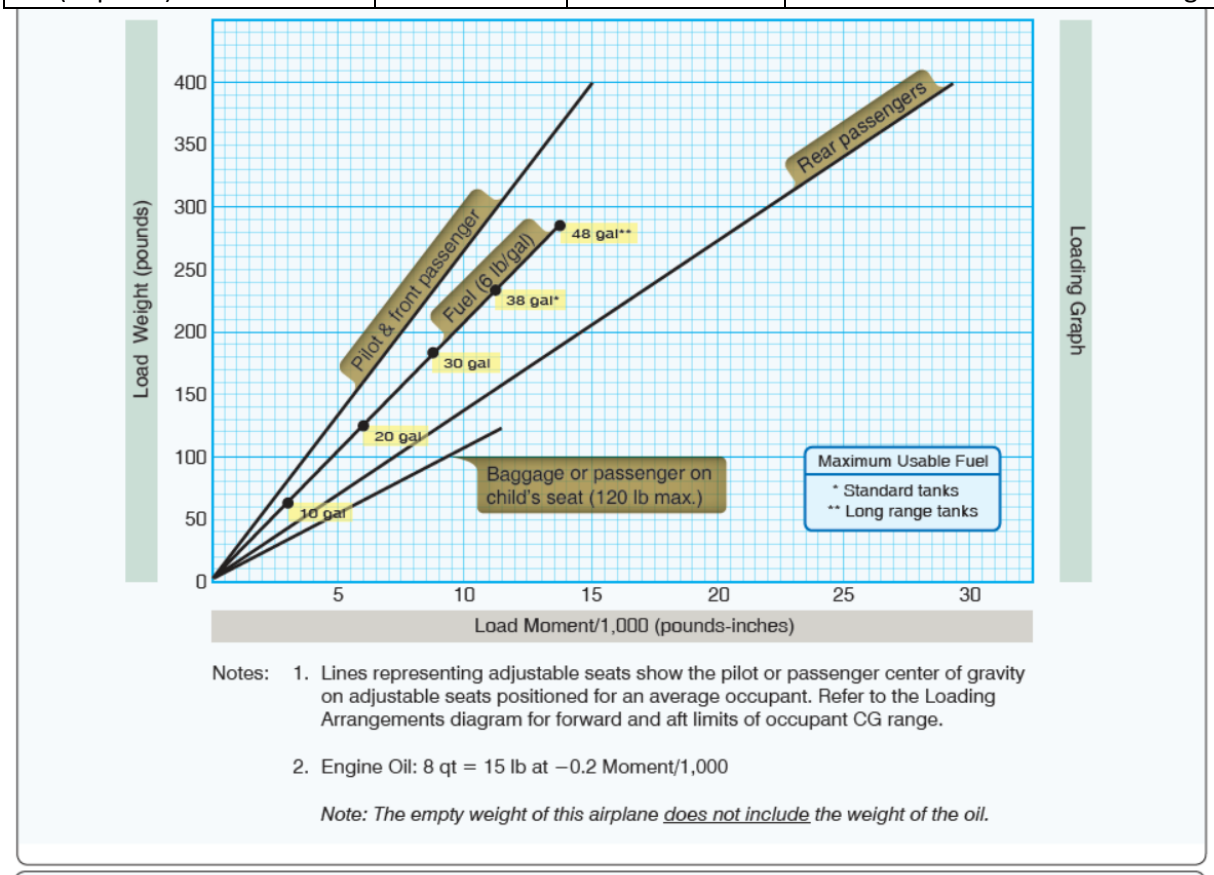
Based on a calculation of 83.4 for the CG, you know that "83.4 ...." is indeed the correct answer. You can verify that this is in limits by confirming the a CG of 83.4 is acceptable for all weight conditions (because it is between the forward and aft limits for all weight conditions.)

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

83.4

2. What is the maximum amount of fuel that may be aboard the airplane on takeoff, if loaded as follows?

	Weight (lbs)	Moment/1000	On the exam, the answer choices are:
Empty weight	1,350	51.5	A: 32 gallons
Pilot and front passenger	340		B: 40 gallons
Rear passengers	310		C: 24 gallons
Baggage	45		
Oil (8 quarts)			The correct answer is B: 40 gallons



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.

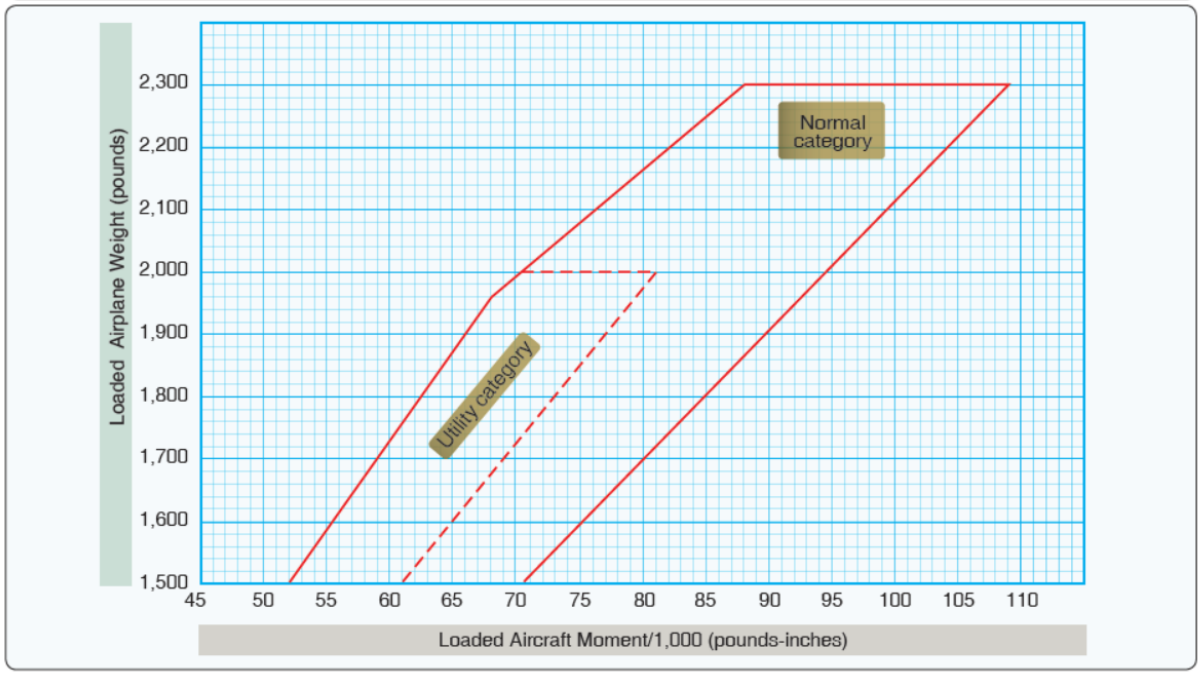
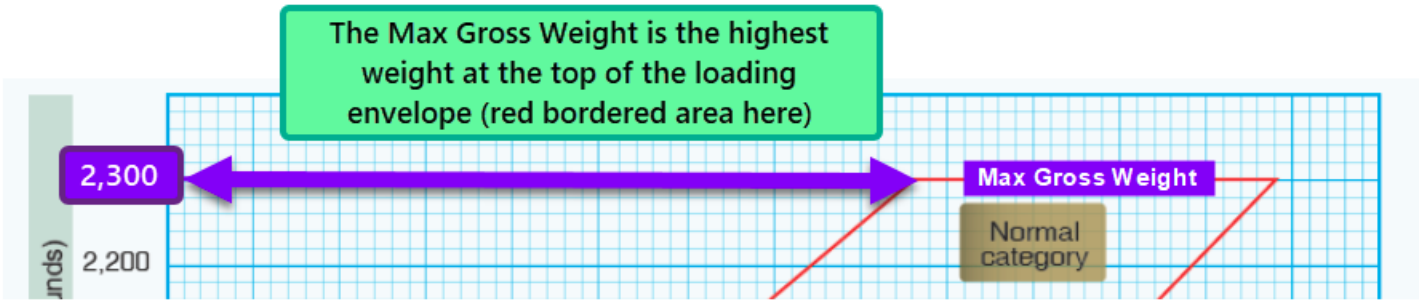


FIGURE 34.—Airplane Weight and Balance Graphs.

First, let's get the (normal category) Max Gross Weight of the aircraft from the lower chart:



2,300 pounds represents the absolute maximum total gross weight of the aircraft as there is nowhere in the red "envelope" greater than 2,300 pounds.

Let's also be aware of the oil note accompanying this question:

2. Engine Oil: 8 qt = 15 lb at -0.2 Moment/1000

Now, let's add up the weight of everything except for usable fuel, subtract that from the max gross weight, and then divide what's left by the standard 6pounds/gallon to see the maximum number of gallons that we could theoretically load if we're considering weight only.

	Weight	
Empty Weight	1350	
Pilot / Co-Pilot	340	
Rear Passengers	310	
Baggage	45	
Fuel	0	
Oil	15	pounds
Weight Except Fuel	2060	pounds

Fuel 0 Gallons @ 6lb/gal = 0 lbs

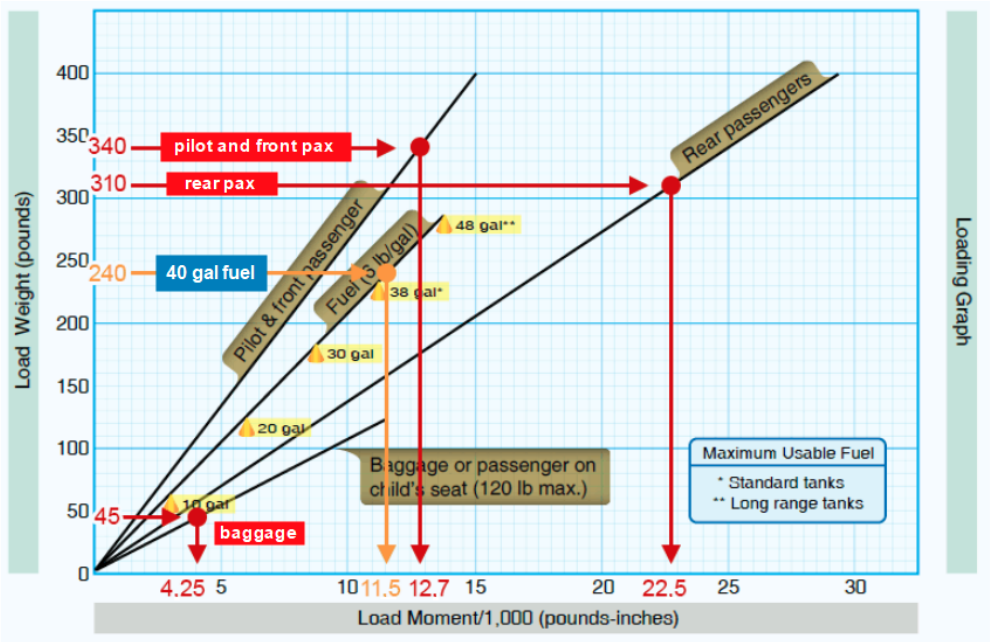
Oil values come from the note on the figure

	Weight	
Max Gross Weight	2300	pounds
Weight Except Fuel	-2060	pounds
Max Fuel Weight	240	max pounds of fuel that maybe can be loaded

Max Fuel Weight	240	pounds
	divided by	
Av Fuel Weight	6	pounds per gallon
	equals	
	40	max gallons of fuel that maybe can be loaded

2300 (max gross weight, from the lower chart) - 2060 implies an upper limit of 240 pounds of fuel that can be loaded. 240 lb / (6 lb / gal) = 40 possible gallons can be loaded, considering only weight.

But is this consistent with CG (moment) considerations? Put another way the question is: "sure, if we think about max gross weight only, we can load 40 gallons. However, will this put the center of gravity too far fore or aft (forward or backward) for safe and legal operation?



Let's compute the total moment given 40 gallons of fuel. For many of the numbers, we reference the moment from the upper graph: 51500 (airplane) + 12750 (front Pax) + 22500 (rear Pax) + 4250 (baggage) - 200 (oil) + 11500 (40 gal fuel) = 102300.

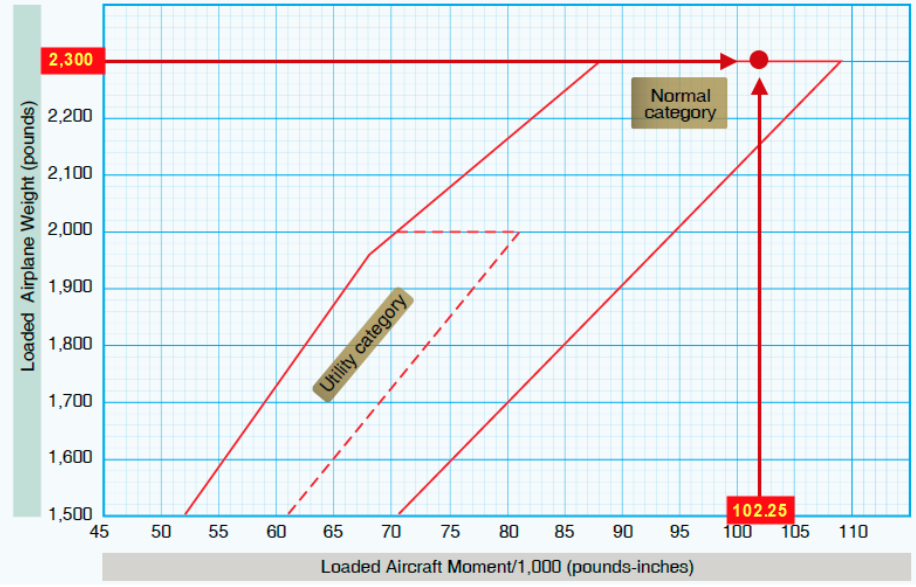
Referencing the bottom graph, we see that this is within moment limits.

	Weight	Moment/1000
Empty Weight	1350	51.5
Pilot / Co-Pilot	340	12.7
Rear Passengers	310	22.5
Baggage	45	4.25
Fuel	240	11.5
Oil	15	-0.2
Total	2300	102.25

Fuel 40 Gallons @ 6lb/gal = 240 lbs

Oil values come from the note on the figure

Moments determined by graph lookup



3. How could the 500 lb weight be shifted to balance the plank on the fulcrum?

The exam answer choices are:

A: 1 inch to the right
B: 4.5 inches to the right
C: 1 inch to the left

The correct answer is: C: 1 inch to the left

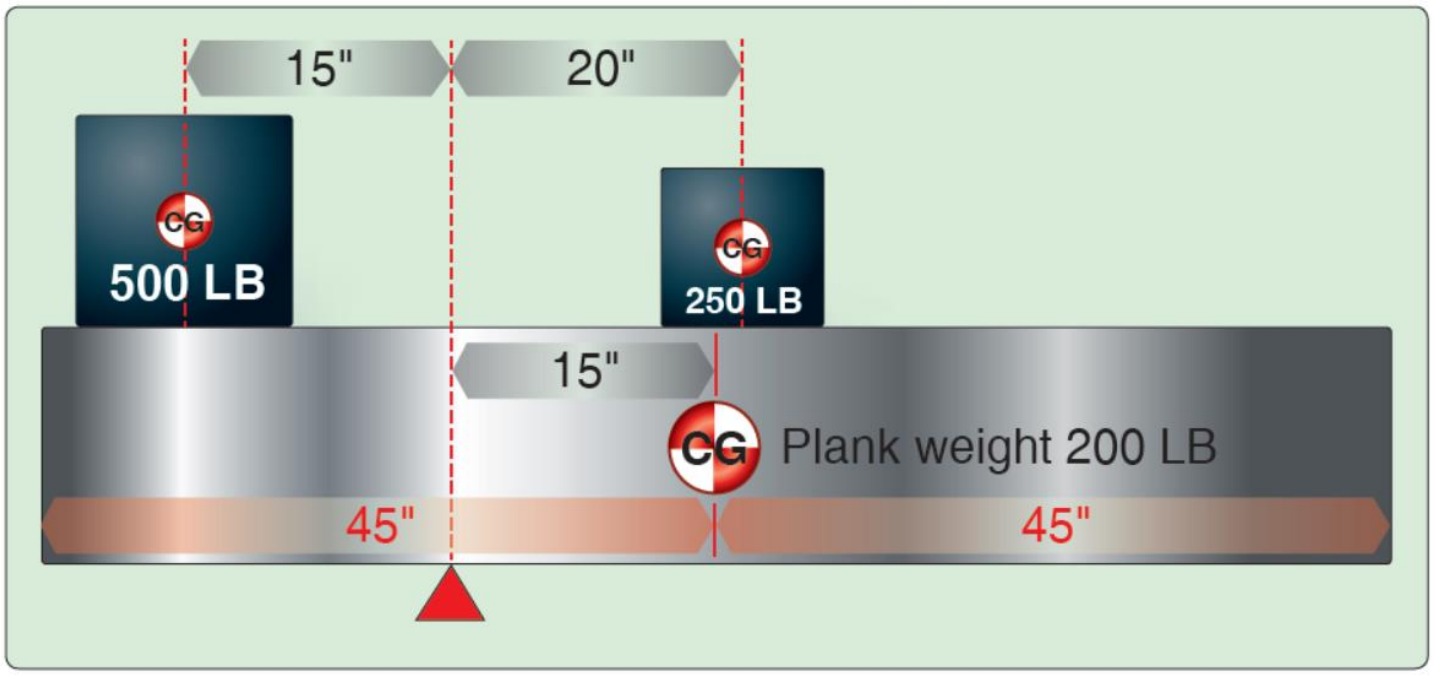


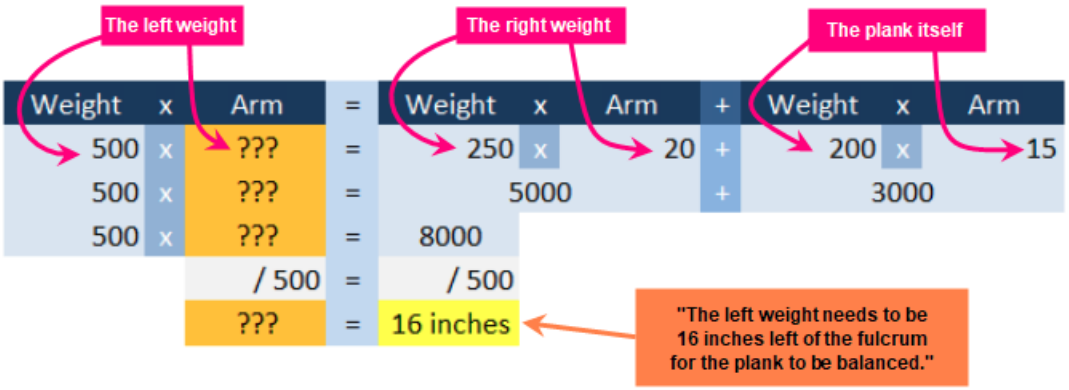
FIGURE 60.—Weight and Balance Diagram.

First, remember all weight and balance questions use the basic formula:

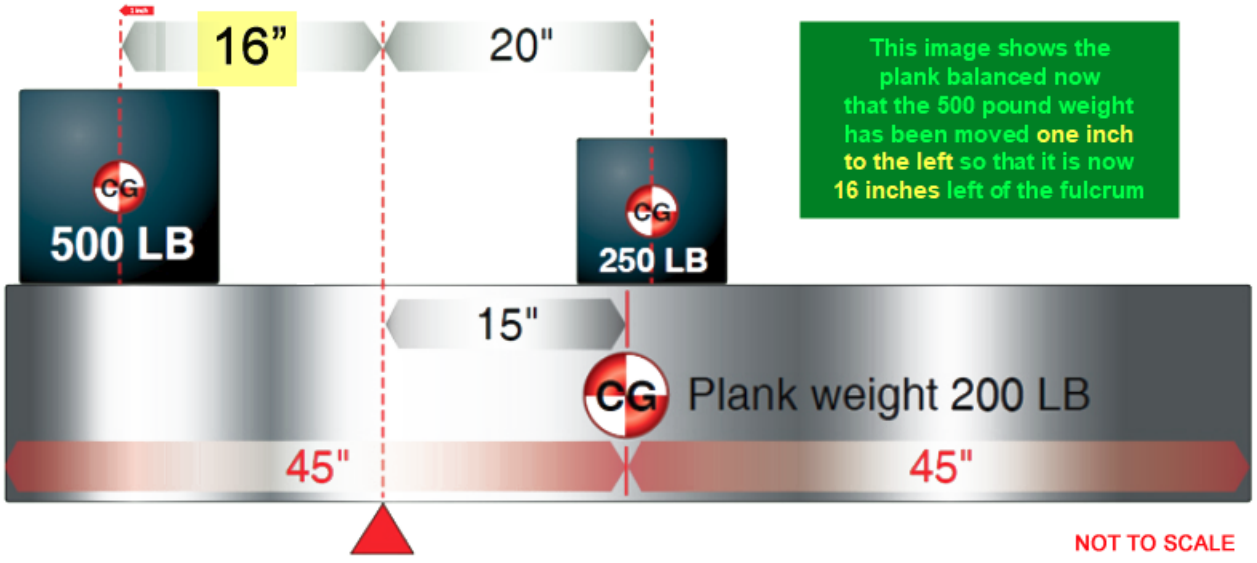
$$Weight \times Arm = Moment$$

The easiest way to solve this is to set up an equation with the item that has a CG left of the fulcrum (500 pound weight) equal to the items (250 pound weight and the plank) to the right of the fulcrum. We'll set '???' equal to the distance the 500 pound weight must be from the fulcrum for it to balance.

So,



Since the 500 pound weight was 15 inches left of the fulcrum, and it needs to be 16 inches left, the 500-pound weight should be shifted **1 inch to the left.**



In considering the plank itself, it is important to realize that even though the plank goes both to the left and right of the fulcrum point, we can still consider it as a point object with the arm at its center of gravity. If that's confusing, think about one of the two weights - let's say the right weight. It's drawn there as a rectangular box. But in reality we don't need to care about the shape of the box nor do we need to care about the internal loading of whatever is in the box - for example, it could be all steel ball bearings towards the right and and cotton balls on the left. All that matters to us is that in total the weight of the box is 250 and its center of gravity is 20 inches right of the fulcrum. That is to say, we are reducing a complex object - a box - down to a single "point object" having only a weight and an arm. Likewise, we don't care about the specifics of the shape of the plank itself - we just care about its total weight and that its center of gravity is 15 inches right of the fulcrum. We're very lucky about the fact that complex objects can be reduced to simple "point objects" when calculating weight and balance. Imagine how difficult it would be to do weight and balance questions otherwise of something as irregularly shaped and with such varying densities as a human body!

You can verify the correct answer by computing the resulting CG using a standard weight and balance table. Notice how we give the 500 pound weight an arm of negative 16 (-16) as it is "left" of the fulcrum while the arms of the 250 pound weight and plank get positive values.

	Weight	x	Arm	=	Moment
500 lb weight	500	x	-16	=	-8000
250 lb weight	250	x	20	=	5000
Plank	200	x	15	=	3000
End Total	950	x	CG	=	0
			CG = 0.00		
CG = Sum of Moments / Sum of Weights					

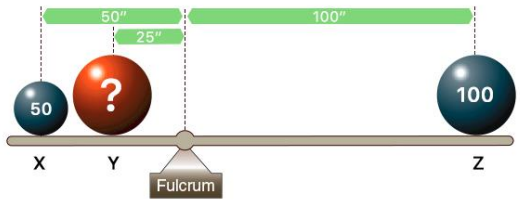
The resulting CG of 0 tells us that the plank is indeed balanced in this condition. You could repeat the calculation above with arms of "-14" and "-10.5" corresponding to the incorrect answer choices to see that they result in non-zero CGs.

4. If 50 lbs of weight is located at Point X and 100 lbs at Point Z, how much weight must be located at Point Y to balance the plank?

The exam answer choices are:
A: 300 pounds
B: 50 pounds
C: 150 pounds

The correct answer is: A: 300 pounds.

Let's draw out the situation that the question describes:



Recall our basic weight and balance formula:

$$Weight \times Arm = Moment$$

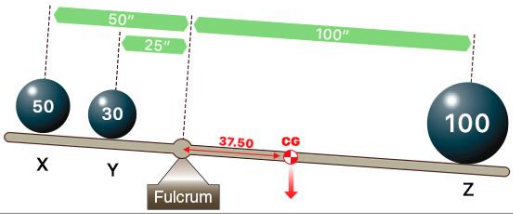
Putting this question in a traditional weight and balance table style, we can clarify what it is that we need to solve for.

	Weight	x	Arm	=	Moment
Weight X	50	x	-50	=	-2500
Weight Y	???	x	-25	=	???
Weight Z	100	x	100	=	10000
End Total	???	x	CG	=	???
		CG =	0.00		

CG = Sum of Moments / Sum of Weights

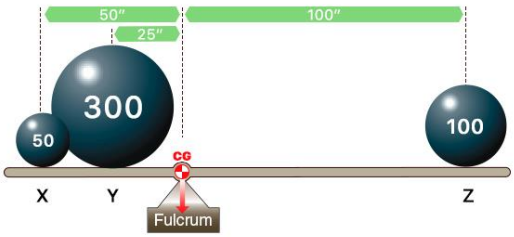
	Weight	x	Arm	=	Moment
Weight X	50	x	-50	=	-2500
Try 30 for Weight Y	30	x	-25	=	-750
Weight Z	100	x	100	=	10000
End Total	180	x	CG	=	6750
		CG =	37.50		

CG = Sum of Moments / Sum of Weights



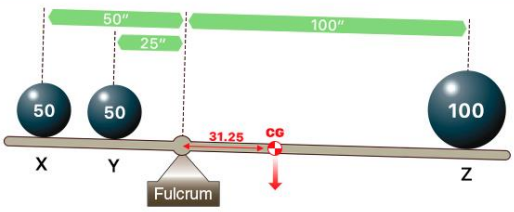
	Weight	x	Arm	=	Moment
Weight X	50	x	-50	=	-2500
Try 300 for Weight Y	300	x	-25	=	-7500
Weight Z	100	x	100	=	10000
End Total	450	x	CG	=	0
		CG =	0.00		

CG = Sum of Moments / Sum of Weights



	Weight	x	Arm	=	Moment
Weight X	50	x	-50	=	-2500
Try 50 for Weight Y	50	x	-25	=	-1250
Weight Z	100	x	100	=	10000
End Total	200	x	CG	=	6250
		CG =	31.25		

CG = Sum of Moments / Sum of Weights



5. With the airplane loaded as follows, what action could be taken to balance the airplane?

Front occupants: 411 lbs Rear occupants: 100 lbs Main wing tanks: 44 gallons	Answer choices are: A: Add a 100 lb weight to the baggage compartment B: Fill the auxiliary wing tanks C: Transfer 10 gallons of fuel from the main tanks to the auxiliary tanks.
The correct answer is A: Add a 100-pound weight to the baggage compartment.	

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

FIGURE 32.—Airplane Weight and Balance Tables.

For most weight and balance questions, including this one, the two fundamental formulas that you must know are:

$$Weight \times Arm = Moment$$

and

$$CG = \frac{Total\ Moment}{Total\ Weight}$$

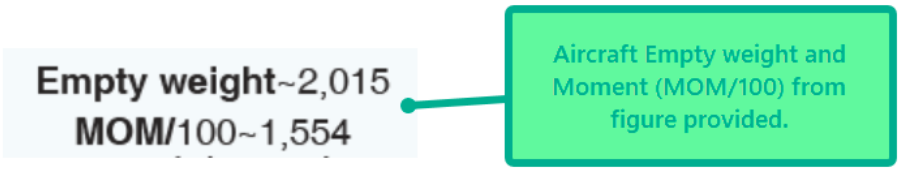
To answer this question, we need to recall also that AvGas weight 6 pounds per US gallon.

Armed with all of this, we can set up a weight and balance table to see where we are initially:

	Weight	x	Arm	=	Moment
Empty Weight	2015				155400
Front Occupants	411	x	85	=	34935
Rear Occupants	100	x	121	=	12100
Baggage	0	x	140	=	0
Fuel (Main Tanks)	264	x	75	=	19800
Fuel (Aux tanks)	0		94		0
Totals	2790	x	CG	=	222235
			CG = 79.65		
CG = Sum of Moments / Sum of Weights					

Main Tank Fuel	44	gallons @ 6lb/gal =	264	lbs
Auxiliary Wing Tank Fuel	0	gallons @ 6lb/gal =	0	lbs

Before we go on, a few notes about the above table:



- The "Arm" values come from Figure 32.
- The Empty weight of the aircraft comes from the bottom left of Figure 32.
- As the question is phrased, the baggage compartment and auxiliary fuel tanks are empty (hence 0 weight).
- We calculate the Center of Gravity here. However, on figure 33, the balance limits are given not as CG values, but as MOM/100 values for given weights. So, in this case we calculated CG needlessly as far as solving the problem goes, though we include this to show you how it's done and for completeness.

From Figure 33, we see that at 2790 pounds, the minimum and maximum permissible moments (MOM/100) are 2,243 and 2,374, respectively. As stated in the question, we have a resultant MOM/100 of 2,222.4. So, we are out of limits. What should we do?

The first thing we need to notice is that because 2,222.4 is less than 2,243, the problem is that our CG is forward of the forward limit. We therefore need to move the center of gravity rearwards. Unfortunately, the FAA makes this question hard as all 3 answer choices can indeed move the CG rearward. Thus, the best and realistically only way to solve this problem is try each variation and see which one results in a MOM/100 within limits for the resultant weights.

When we do this, we see that adding a 100 pound weight to the baggage compartment brings us into limits.

Add 100 pounds to baggage

	Weight	x	Arm	=	Moment
Empty Weight	2015				155400
Front Occupants	411	x	85	=	34935
Rear Occupants	100	x	121	=	12100
Baggage	100	x	140	=	14000
Fuel (Main Tanks)	264	x	75	=	19800
Fuel (Aux tanks)	0		94		0
Totals	2890	x	CG	=	236235
			CG =	81.74	
CG = Sum of Moments / Sum of Weights					

Main Tank Fuel	44	gallons @ 6lb/gal =	264	lbs
Auxiliary Wing Tank Fuel	0	gallons @ 6lb/gal =	0	lbs

Transfer 10 Gals from Main to Aux Tanks

	Weight	x	Arm	=	Moment
Empty Weight	2015				155400
Front Occupants	411	x	85	=	34935
Rear Occupants	100	x	121	=	12100
Baggage	0	x	140	=	0
Fuel (Main Tanks)	204	x	75	=	15300
Fuel (Aux tanks)	60		94		5640
Totals	2790	x	CG	=	223375
			CG =	80.06	
CG = Sum of Moments / Sum of Weights					

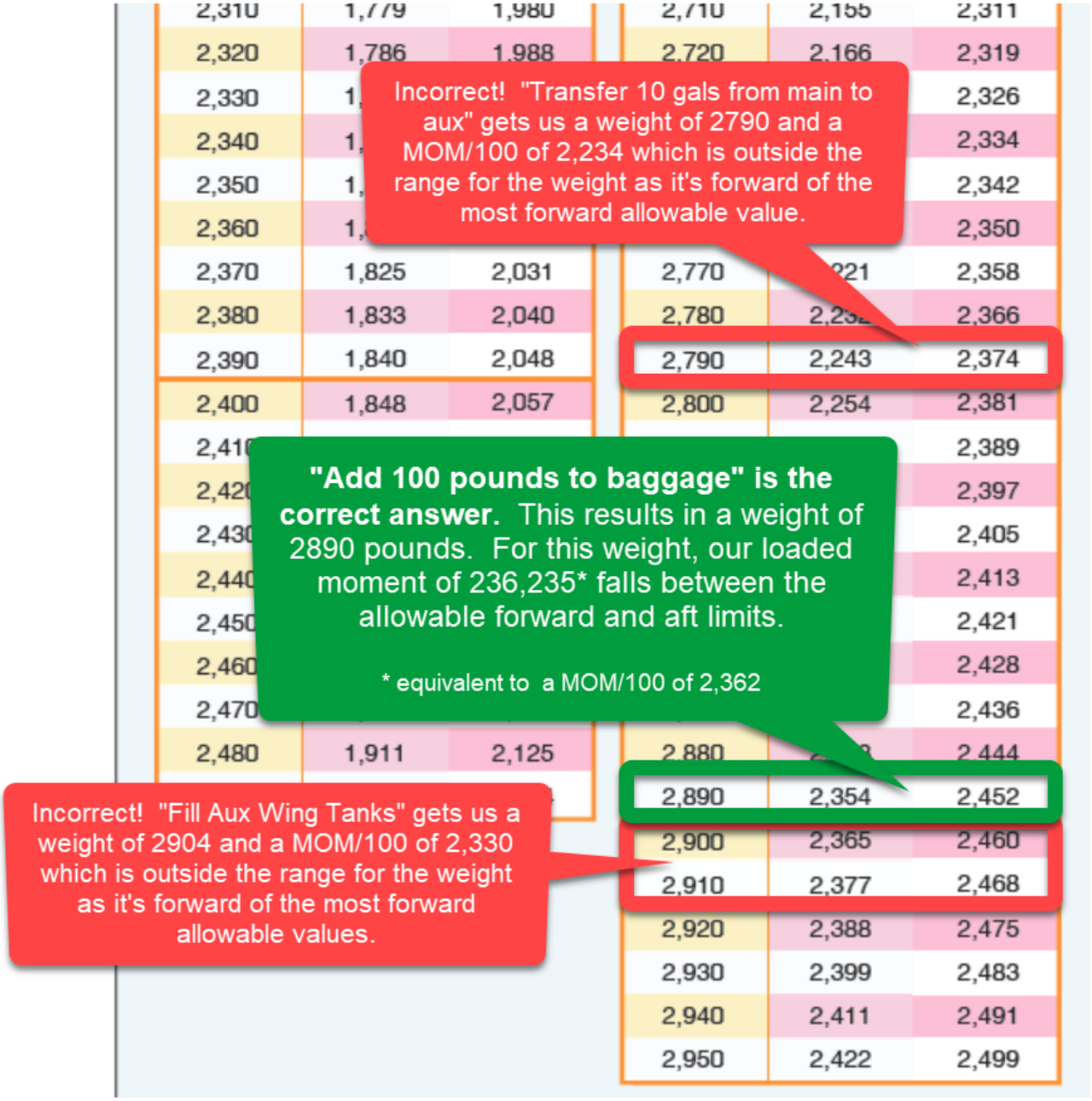
Main Tank Fuel	34	gallons @ 6lb/gal =	204	lbs
Auxiliary Wing Tank Fuel	10	gallons @ 6lb/gal =	60	lbs

Fill Aux Wing Tanks

	Weight	x	Arm	=	Moment
Empty Weight	2015				155400
Front Occupants	411	x	85	=	34935
Rear Occupants	100	x	121	=	12100
Baggage	0	x	140	=	0
Fuel (Main Tanks)	264	x	75	=	19800
Fuel (Aux tanks)	114		94		10716
Totals	2904	x	CG	=	232951
			CG =	80.22	
CG = Sum of Moments / Sum of Weights					

Main Tank Fuel	44	gallons @ 6lb/gal =	264	lbs
Auxiliary Wing Tank Fuel	19	gallons @ 6lb/gal =	114	lbs

The best way for this question to see whether we are within fore and aft CG limits is to use the Figure 33 table excerpted from below. There is a also a highly abbreviated W&B table on figure 32 that has allowable CG limits for 3 different configurations, but that one does not provide enough detail for us to use for this question.



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,				2,326
2,340	1,				2,334
2,350	1,				2,342
2,360	1,				2,350
2,370	1,825	2,031	2,770	221	2,358
2,380	1,833	2,040	2,780	2,23	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
2,41					2,389
2,42					2,397
2,43					2,405
2,44					2,413
2,45					2,421
2,46					2,428
2,47					2,436
2,480	1,911	2,125	2,880		2,444
			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

6. Given the following loading condition, what is the CG of the airplane?

	Weight (lbs)	Arm (inches)	Moment (Lb-inches)	The answer choices are
Empty weight	1,495	101.4	151,593.0	A: 92.44
Pilot and passengers	380.0	64.0		B: 119.8
Fuel (30 gallons usable)		96.0		C: 94.01
The correct answer is C: 94.01				

As with most weight and balance questions, we need to remember two basic formulas:

$$Weight \times Arm = Moment$$

and

$$CG = \frac{Total\ Moment}{Total\ Weight}$$

Now, let's solve the problem:

First, determine the weight of the fuel on board. 30 gallons of fuel * 6 lb / gallon = 180 lbs.

Next, compute the moments for both the (pilot and passengers) and the fuel by multiplying their weights by their arms.

- **Pilot and Passengers:** 380 lb * 64 inches = 24320 lb inches.
- **Fuel:** 180 lb * 96 inches = 17280 lb inches.

Next, compute the total weight and total moments:

- **Total weight** = 1495 lb + 380 lb + 180 lb = 2055 lb
- **Total moment** = 151593 + 24320 + 17280 = 193193 lb-inches

Finally, divide the total moment by the total weight to get the center of gravity.

193193 lb-inches / 2055 lbs = approximately 94.01 (any inaccuracy due to rounding, etc).

Hence 94.01 is the right answer.

	Weight	x	Arm	=	Moment
Empty Weight	1495	x	101.4	=	151593
Pilot and Passengers	380	x	64	=	24320
Fuel	180	x	96	=	17280
Totals	2055	x	CG	=	193193
		CG =	94.01		
CG = sum of moments / sum of weight					
Fuel	30	gallons @ 6lb/gal =	180	lbs	

It is important to remember that the "datum" can be located anywhere--at the nose of the airplane, at the firewall, or even an imaginary point three miles ahead of the airplane! While usually specified by the manufacturer, the actual location of the datum is just a tool of mathematical convenience (though, of course, by seeing that the pilots and baggage sit 64 inches from the datum plane, it might not be too far fetched to assume that the datum in this example is the firewall).