Box-and-Whisker Plots

Name: _____ Date: _____ Score: _____ / 33

Quick Review

A **box-and-whisker plot** (boxplot for short) is a five-point summary of a numeric data set drawn over a number line. The five points are the **five-number summary**: minimum, first quartile Q_1, median, third quartile Q_3, and maximum.

Build it in steps. Sort the data. The *median* is the middle value (or the average of the two middle values for even n). Split the data into the lower half and the upper half (don't include the median in either half when n is odd). Q_1 is the median of the lower half; Q_3 is the median of the upper half. The **IQR** is $Q_3 - Q_1$ – the spread of the middle 50%.

What the picture shows. The box runs from Q_1 to Q_3 with a line through the median inside it. Whiskers stretch from the box out to the minimum and maximum (or out to the *outlier fences* when there are outliers). The box always covers the middle 50%, so its length *is* the IQR.

Outlier rule (the 1.5 IQR rule). Any value below $Q_1 - 1.5 \cdot \text{IQR}$ or above $Q_3 + 1.5 \cdot \text{IQR}$ is flagged as an outlier and usually drawn as a separate dot beyond the whisker.

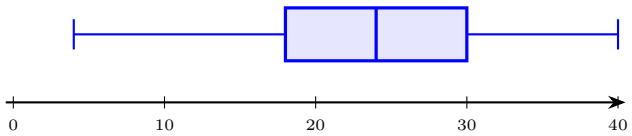
Reading two boxplots side by side – the most common test task. Compare medians (which group is typically higher), compare IQRs (which group is more spread out), check for outliers, and note overlap. Don't confuse a wider box with a higher median: width is spread, the median line is location.

Common slips. Putting the mean line on a boxplot (the line inside the box is the *median*, not the mean). Saying the whiskers reach the quartiles (they reach the min/max or the fences). Reporting $Q_3 - Q_1$ as the range (range is max − min).

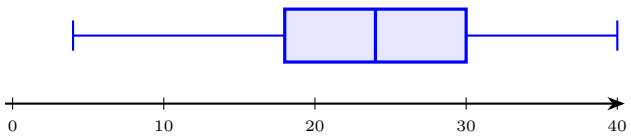
PRACTICE

Compute the five-number summary, IQR, or read values from a boxplot.

1. Five-number summary of $\{4, 7, 8, 11, 12, 13, 18, 21, 25\}$ _____
2. IQR of $\{12, 15, 18, 20, 22, 25, 28, 30, 35\}$ _____
3. Median of $\{3, 5, 7, 8, 10, 12, 14, 16, 45\}$ _____
4. IQR of $\{3, 5, 7, 8, 10, 12, 14, 16, 45\}$ _____
5. Outlier check for $\{3, 5, 7, 8, 10, 12, 14, 16, 45\}$ using $Q_1 = 6, Q_3 = 15$ _____
6. Range of $\{2, 5, 7, 9, 11, 13, 15, 17, 18\}$ _____
7. Median of $\{2, 5, 7, 9, 11, 13, 15, 17, 18\}$ _____
8. IQR of $\{2, 5, 7, 9, 11, 13, 15, 17, 18\}$ _____
9. Read the median (the line inside the box) from the boxplot below. _____



10. In the boxplot below, read off Q_1 (the left edge of the box). _____



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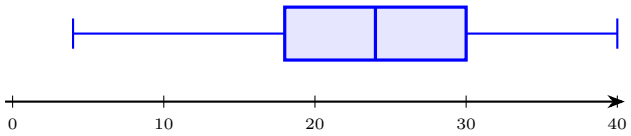
11. Find the IQR (the width of the box) from the boxplot below. _____



12. Five-number summary of $\{1, 2, 3, 4, 5, 6, 7, 8\}$ _____

13. Median of $\{10, 10, 10, 10, 10\}$ _____

14. IQR of $\{10, 10, 10, 10, 10\}$ _____

15. True or false: the whiskers in a boxplot always reach Q_1 and Q_3. _____

16. Class A has $Q_1 = 65$, $Q_3 = 82$. Class B has $Q_1 = 70$, $Q_3 = 90$. Which has the larger IQR? _____

17. Find Q_1 of $\{1, 3, 5, 7, 9, 11, 13, 15, 17, 19\}$. _____

18. Range of $\{18, 22, 25, 29, 31, 35, 40\}$ _____

19. If the IQR is 0, what does that tell you? _____

20. Five-number summary of $\{4, 4, 4, 4, 4, 4, 4\}$ _____

♦ Word Problems

21. A data set is $\{3, 5, 7, 8, 10, 12, 14, 16, 45\}$. Using the 1.5 IQR rule with $Q_1 = 6$ and $Q_3 = 15$, determine which value is an outlier. ____

22. Two classes took the same test. Class A's boxplot shows $Q_1 = 65$, median $= 75$, $Q_3 = 82$. Class B's boxplot shows $Q_1 = 70$, median $= 78$, $Q_3 = 90$. Which class has a higher median, and which has a greater IQR? Explain. ____

23. A coach times 11 swimmers in a 50-meter freestyle and records the times in seconds: $28, 29, 30, 31, 32, 33, 35, 36, 37, 40, 55$. Find the five-number summary and identify any outliers using the 1.5 IQR rule. ____

24. A retailer compares two stores' weekly sales (in thousands of dollars) using boxplots. Store X has median 42 and IQR 8. Store Y has median 45 and IQR 20. Which store has more consistent weekly sales, and which is typically higher? ____

Additional Practice

25. Find the mean of $4, 6, 8, 10$. _____

26. Find the median of $3, 9, 4, 10, 7$. _____

27. Find the range of $12, 5, 9, 20$. _____

28. Find the mode of $2, 3, 3, 5, 8$. _____

29. Find z for $x = 72$, mean 60, standard deviation 6. _____

30. Interpret $z = -1.5$. _____

31. Predicted y for $\hat{y} = 2x + 5$ at $x = 6$. _____

32. Residual if actual $= 20$ and predicted $= 17$. _____

33. Positive association: slope sign? _____

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Answer Keys

1. min 4, $Q_1 = 7.5$, median 12, $Q_3 = 19.5$, max 25
2. 12.5
3. 10
4. 9
5. 45 is an outlier
6. 16
7. 11
8. 10
9. 24
10. $Q_1 = 18$
11. 12
12. 1, 2.5, 4.5, 6.5, 8
13. 10
14. 0
15. False
16. Class B
17. 5
18. 22
19. the middle 50% are all the same value
20. 4, 4, 4, 4, 4
21. 45
22. Class B has both a higher median and a greater IQR
23. (28, 30, 33, 37, 55); 55 is an outlier
24. X consistent; Y higher median

Additional Practice Answers

25. 7
26. 7
27. 15
28. 3
29. 2
30. 1.5 SD below mean
31. 17
32. 3
33. positive

Additional Practice: Answers for all numbered items, including the added practice, are shown in the grid above.

Step-by-Step Explanations

1. There are 9 values, so the median is the 5th (12). Lower half is $\{4, 7, 8, 11\}$: $Q_1 = \frac{7+8}{2} = 7.5$. Upper half is $\{13, 18, 21, 25\}$: $Q_3 = \frac{18+21}{2} = 19.5$.

2. Keep the rule visible: 9 values, median is the 5th (22). Lower half $\{12, 15, 18, 20\}$ gives $Q_1 = \frac{15+18}{2} = 16.5$; upper half $\{25, 28, 30, 35\}$ gives $Q_3 = \frac{28+30}{2} = 29$. IQR $= 29 - 16.5 = 12.5$. That gives a quick check on the answer.

3. Sort (already sorted). With 9 values, the median is the 5th: 10. The big value 45 doesn't shift the median – only its *position* matters.

4. Lower half $\{3, 5, 7, 8\}$: $Q_1 = \frac{5+7}{2} = 6$. Upper half $\{12, 14, 16, 45\}$: $Q_3 = \frac{14+16}{2} = 15$. IQR $= 15 - 6 = 9$. (The 45 sits in the upper half but doesn't make it into the Q_3 calculation.)

5. A careful way to see it: IQR $= 9$. Upper fence: $15+1.5(9) = 15+13.5 = 28.5$. Since $45 > 28.5$, it's an outlier. Lower fence: $6-13.5 = -7.5$; nothing falls below it. That gives a quick check on the answer.

6. Keep the rule visible: Range = max − min $= 18 - 2 = 16$. (Don't confuse with IQR.) This is the part to check before moving on, because it keeps the answer tied to the original question.

7. One steady path is: Nine values, middle position is the 5th: 11. This is the part to check before moving on, because it keeps the answer tied to the original question.

8. Start with the key idea: Lower half $\{2, 5, 7, 9\}$: $Q_1 = 6$. Upper half $\{13, 15, 17, 18\}$: $Q_3 = 16$. IQR $= 16 - 6 = 10$. That gives a quick check on the answer.

9. The vertical line inside the box always marks the median. Here it sits at 24 – not the mean, which a standard boxplot doesn't show.

10. The left edge of the box marks the first quartile, $Q_1 = 18$. The right edge marks $Q_3 = 30$, and the line in between is the median.

11. One steady path is: IQR $= Q_3 - Q_1 = 30 - 18 = 12$. That's just the width of the box, read straight off the picture. That gives a quick check on the answer.

12. Even $n = 8$: median $= \frac{4+5}{2} = 4.5$. Lower half $\{1, 2, 3, 4\}$: $Q_1 = \frac{2+3}{2} = 2.5$. Upper half $\{5, 6, 7, 8\}$: $Q_3 = \frac{6+7}{2} = 6.5$. Min 1, max 8.

13. Every value is 10, so the middle value is 10. The IQR would be 0 – no spread inside the box.

14. Keep the rule visible: $Q_1 = Q_3 = 10$, so IQR $= 0$. A perfectly flat data set has no spread. That gives a quick check on the answer.

15. Whiskers reach the minimum and maximum (or the outlier fences when outliers are present). Q_1 and Q_3 are the box *edges*, not the whisker tips.

16. Class A: IQR $= 82 - 65 = 17$. Class B: IQR $= 90 - 70 = 20$. Class B's middle 50% is more spread out.

17. Ten values ⇒ median splits between the 5th and 6th values: $\frac{9+11}{2} = 10$. The lower half is $\{1, 3, 5, 7, 9\}$. With an odd five entries, Q_1 is just their middle (3rd) value: $Q_1 = 5$.

18. Keep the rule visible: $40 - 18 = 22$. Range uses only the two extreme values. This is the part to check before moving on, because it keeps the answer tied to the original question.

19. One steady path is: $Q_1 = Q_3$ means there's no spread between them – the middle half of the data is collapsed to a single value. That gives a quick check on the answer.

20. Every value is 4, so the min, Q_1, median, Q_3, and max are all 4. The box collapses to a single line on the boxplot.

21. A careful way to see it: IQR $= 15 - 6 = 9$. Upper fence: $15 + 1.5(9) = 28.5$. Lower fence: $6 - 1.5(9) = -7.5$. Any value outside $[-7.5, 28.5]$ is flagged. Only 45 qualifies, so 45 is the outlier. On a boxplot it would appear as a separate dot to the right of the whisker. That gives a quick check on the answer.

22. Compare medians directly: Class A median is 75, Class B median is 78, so Class B has the higher median (it's typically higher overall). For spread: Class A's IQR is $82 - 65 = 17$; Class B's IQR is $90 - 70 = 20$. So Class B is also more spread out in the middle 50%. (Note: you cannot conclude every Class B student outscored every Class A student from boxplots alone.)

23. Sorted, $n = 11$, so the median is the 6th value: 33. Lower half (first five): $\{28, 29, 30, 31, 32\}$, $Q_1 = 30$. Upper half (last five): $\{35, 36, 37, 40, 55\}$, $Q_3 = 37$. IQR $= 37 - 30 = 7$. Upper fence: $37 + 1.5(7) = 47.5$. Lower fence: $30 - 1.5(7) = 19.5$. The time 55 is above 47.5, so it's an outlier – probably a swimmer who had a rough heat that day.

24. Consistency goes with a smaller spread. Store X's IQR of 8 is much smaller than Store Y's IQR of 20, so X's middle 50% of weeks are bunched closer together – more consistent. Store Y has a higher median (45 vs. 42), so its typical week brings in more sales. So Y wins on the average week, but X wins on predictability.

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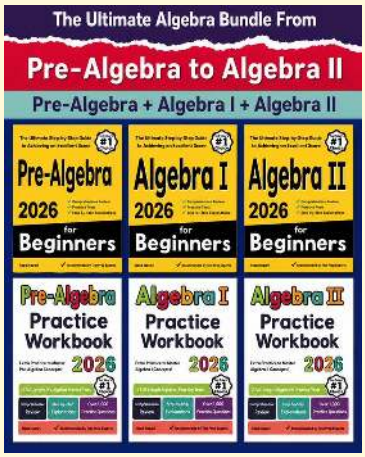

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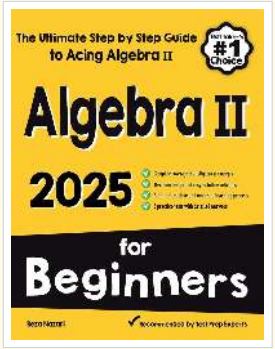

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