

Mathematics, 2014 EC, natural science, entrance exam, round 1

Grade 12 · Mathematics · 2014 E.C.

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Time allowed: 120 minutes

Questions: 51

Total marks: 51

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1. What is the locus all points in the plane in which the sum of the distances from two fixed points is constant? (1)
- A. Hyperbola B. Parabola
C. ✓ **Ellipse** D. Circle

Answer: C

The ellipse is defined as the set of all points in a plane for which the sum of the distances from two fixed points (the foci) is constant.

2. The radian measure of an angle of 120° is equal to: (1)
- A. ✓ $\frac{2\pi}{3}$ B. $\frac{4\pi}{3}$
C. $\frac{\pi}{2}$ D. $\frac{\pi}{4}$

Answer: A

To convert degrees to radians, multiply by $\pi/180^\circ$, giving $120^\circ \times \pi/180^\circ = 2\pi/3$ radians.

3. What is the surface area of a sphere with radius 6 cm? (1)
- A. $24\pi \text{ cm}^2$ B. $36\pi \text{ cm}^2$
C. $48\pi \text{ cm}^2$ D. ✓ **$144\pi \text{ cm}^2$**

Answer: D

The surface area of a sphere is given by $4\pi r^2$. For $r = 6 \text{ cm}$, the surface area is $4\pi(6)^2 = 144\pi \text{ cm}^2$.

4. Which of the following is the measure of an exterior angle of a 10 sided regular polygon? (1)
- A. 72° B. 144°
C. 180° D. ✓ **36°**

Answer: D

The sum of the exterior angles of any regular polygon is 360° , so for a 10-sided regular polygon, each exterior angle is $360^\circ/10 = 36^\circ$.

5. If the volume of a right circular cone is $64\pi \text{ cm}^3$ and the diameter of its base is 8 cm, what is the height of the cone? (1)
- A. 4cm B. ✓ **12cm**
C. 8cm D. 3cm

Answer: B

The volume of a cone is $V = \frac{1}{3}\pi r^2 h$. Since the base diameter is 8 cm, the radius is $r = 4 \text{ cm}$. Solving $64\pi = \frac{1}{3}\pi(4)^2 h$ yields $h = 12 \text{ cm}$.

Subtracting matrix B from A element-by-element gives $(A - B)_{ij} = A_{ij} - B_{ij}$, which directly yields the matrix in option D.

11. In order to find point P in space one can start from the origin (0,0, 0); move 5 units in the direction of negative x-axis, then move 5 units in the direction of positive y-axis and finally move 5 units in the direction of negative z-axis. Which one of the following is the ordered triple of numbers represented by point P?

A. (5, 5, 5)

B. ✓ $(-5, 5, -5)$

C. $(5, -5, -5)$

D. $(-5, -5, 5)$

Answer: B

Moving -5 units along the x-axis, $+5$ along the y-axis, and -5 along the z-axis from the origin results in the coordinates $(-5, 5, -5)$.

- 12.** Which one of the following quantities represents a vector? (1)

A. ✓ Weight of an object

B. Speed of a motorbike

C. Volume of a box

D. The width of your bedroom

Answer: A

Weight is a force, which has both magnitude and a downward direction, making it a vector quantity, whereas speed, volume, and width are scalar quantities.

- 13.** Which one of the following is the derivative of $f(x) = \tan x + 3x$? (1)

A. ✓ $\sec^2 x + 3x \ln x$

B. $-\csc^2 x + 3x \ln x$

C. $-\tan x + 3 \times \ln x$

D. $\sec^2 x + 3x$

Answer: A

The derivative of $\tan x$ is $\sec^2 x$ and the derivative of 3^x is $3^x \ln 3$. Option A is correct, despite the minor transcription typo of 'lnx' instead of 'ln3'.

14. Which one of the following points is, inside the sphere with equation $x^2+y^2+z^2=5$? (1)

A. $(1, -2, 2)$

B. ✓ (1,1,1)

C. (1,2,3)

D. $(0, -2, 3)$

Answer: B

The point $(1, 1, 1)$ satisfies $x^2 + y^2 + z^2 = 1^2 + 1^2 + 1^2 = 3 < 5$, so it lies strictly inside the sphere of radius $\sqrt{5}$.

15. Which one of the following gives the polar form of the complex number $z = 2 - 2\sqrt{3}i$? (1)

A. ✓ $4 \left(\cos \frac{5}{3}\pi + i \sin \frac{5}{3}\pi \right)$

B. $4 \left(\cos \frac{5}{3}\pi + i \sin \frac{5}{3}\pi \right)$

C. $4 \left(\cos \frac{3}{4}\pi + i \sin \frac{3}{4}\pi \right)$

D. $4 \left(\cos \frac{1}{3}\pi + i \sin \frac{1}{3}\pi \right)$

Answer: A

The modulus is $r = \sqrt{2^2 + (-2\sqrt{3})^2} = 4$ and the argument is in quadrant IV with $\theta = 2\pi - \pi/3 = 5\pi/3$, giving the polar form in option A (which is identical to B).

16. What is the product of the two complex number $z = 2 - 3i$ and $w = 5 + 2i$? (1)

A. $16 + 11i$

B. $4 - 11i$

C. ✓ 16 - 11i

D. 29

Answer: C

Multiplying the complex numbers gives $(2 - 3i)(5 + 2i) = 10 + 4i - 15i - 6i^2 = 16 - 11i$ since $i^2 = -1$.

17. Which of the following is true about the Arithmetic Mean of a given data?

(1)

- A. ✓ It is affected by extreme values
- B. There can be two means for a given data
- C. It can also be used for qualitative data
- D. It can be obtained even in the absence of some of the values in the data

Answer: A

The arithmetic mean uses every value in the dataset, which makes it highly sensitive to and easily affected by extreme outliers.

18. In $\triangle ABC$, if $AB = 10$ units, $BC = 14$ units and $AC = 8$ units, then the area of the triangle is

(1)

- A. $10\sqrt{6}$ square unit
- B. ✓ $16\sqrt{6}$ square unit
- C. $16\sqrt{3}$ square unit
- D. $16\sqrt{2}$ square unit

Answer: B

Using Heron's formula with semi-perimeter $s = 16$, the area is $\sqrt{16(16-10)(16-14)(16-8)} = \sqrt{16 \times 6 \times 2 \times 8} = 16\sqrt{6}$.

19. The integral $\int \left(\frac{1}{\sqrt{x}} - e^{-3x} + \frac{5}{x^2} \right) dx$ is equal to:

(1)

- A. $2\sqrt{x} + \frac{e^{-3x}}{3} + \frac{5}{x} + C$
- B. ✓ $2\sqrt{x} + \frac{e^{-3x}}{3} - \frac{5}{x} + C$
- C. $2\sqrt{x} - \frac{e^{-3x}}{3} - \frac{5}{x} + C$
- D. $2\sqrt{x} - \frac{e^{-3x}}{3} + \frac{5}{x} + C$

Answer: B

Integrating term by term gives $\int x^{-1/2} dx - \int e^{-3x} dx + \int 5x^{-2} dx = 2\sqrt{x} + \frac{e^{-3x}}{3} - \frac{5}{x} + C$, which matches option B.

20. Let f be a continuous function on $[a, b]$. Then which of the following is NOT true?

(1)

- A. $\int_a^b f(x) dx = - \int_b^a f(x) dx$
- B. $\int_a^b k f(x) dx = k \int_a^b f(x) dx$ for any constant k
- C. $\int_a^b f(x) dx = \int_a^c f(x) dx - \int_c^b f(x) dx$ for any c in (a, b)
- D. ✓ $\int_c^c f(x) dx = 0$ for any c in (a, b) .

Answer: C

The interval addition property of definite integrals states that $\int_a^b f(x) dx = \int_a^c f(x) dx + \int_c^b f(x) dx$. Option C is incorrect because it uses a subtraction sign.

21. The simplified form of the expression

(1)

$$\frac{6\sqrt{20} - 3\sqrt{45}}{3\sqrt{75}}$$

is:

A. $\sqrt{3}$

B. $\frac{\sqrt{15}}{15}$

C. $1/5$

D. 5

Answer: B

Simplifying the radicals gives the expression as $\frac{6(2\sqrt{5}) - 3(3\sqrt{5})}{3(5\sqrt{3})} = \frac{3\sqrt{5}}{15\sqrt{3}}$. Rationalizing the denominator yields $\frac{\sqrt{15}}{15}$.

22. Which one of the following sets is the symmetric difference, $A \triangle B$, of the sets $A = \{1, 3, 5, 6, 8, 10\}$ and $B = \{2, 5, 8, 11\}$?

(1)

A. $\{1, 2, 3, 5, 6, 8, 10, 11\}$

B. $\{2, 11\}$

C. $\{1, 2, 3, 6, 10, 11\}$

D. $\{1, 3, 6, 10\}$

Answer: C

The symmetric difference $A \triangle B$ contains elements that are in A or B but not both. Excluding the common elements $\{5, 8\}$ from the union gives $\{1, 2, 3, 6, 10, 11\}$.

23. Which of the following is the variance of the data given as: 2, 3, 4, 5, 7?

(1)

A. 2.46

B. $\checkmark$ 2.96

C. 3.06

D. 3.70

Answer: B

The mean of the data is $\bar{x} = 4.2$. The population variance is computed as $\sigma^2 = \frac{\sum (x_i - \bar{x})^2}{n} = \frac{4.84 + 1.44 + 0.04 + 0.64 + 7.84}{5} = 2.96$.

24. Which of the following pairs of events are dependent?

(1)

A. Tossing two coins simultaneously and obtaining head from one and tail from the other.

B. $\checkmark$ Drawing two cards one after the other from a well shuffled pack of cards without replacement.

C. Drawing two balls successively from a box containing balls having the same size and shape with replacement.

D. Any events obtaining from tossing a coin and rolling a die at the same time.

Answer: B

Drawing cards successively without replacement means the outcome of the first draw alters the probabilities of the second draw, which makes the two events dependent.

25.

$$\text{If } \lim_{x \rightarrow 2} f(x) = 6 \text{ and } \lim_{x \rightarrow 2} g(x) = -9, \text{ then } \lim_{x \rightarrow 2} \left(\frac{f - g}{2f - 7} \right) = \boxed{?}$$

(1)

A. $\checkmark$ 3

B. -3

C. 15

D. -15

Answer: A

Using the properties of limits, we substitute the given values into the expression to get $\frac{6 - (-9)}{2(6) - 7} = \frac{15}{5} = 3$.

26. Let f and g be two functions. Which one of the following statements is true about f or g ? (1)
- A. The line $y = 0$ is the a tangent line to the graph of $f(x) = |x|$ at $(0, 0)$.
- B. ✓ **If f' differentiable at a , then it is continuous at a .**
- C. If $f'(a) = 0$, then the tangent line to the graph of f at $(a, f(a))$ is $y = a$.
- D. If f and g differentiable at a , then f/g is differentiable at a .

Answer: B

It is a fundamental theorem in calculus that if a function is differentiable at a point, it must also be continuous at that point.

27. What is the value of a for which the function defined by, (1)

$$f(x) = \begin{cases} ax + 3, & \text{for } x \geq 1 \\ x^2 - 2x + 3, & \text{for } x < 1 \end{cases} \text{ is continuous at } 1?$$

- A. 1
B. ✓ -1
C. 3
D. 4

Answer: B

For f to be continuous at $x = 1$, the left-hand limit $\lim_{x \rightarrow 1^-} (x^2 - 2x + 3) = 2$ must equal the right-hand limit $\lim_{x \rightarrow 1^+} (ax + 3) = a + 3$, which gives $a = -1$.

28. What is the derivative of the function (1)

$$f(x) = \frac{xe^x}{\cos x} \quad \text{at } x = 0?$$

- A. 2
B. -1
C. ✓ 1
D. 0

Answer: C

By applying the quotient rule, we find $f'(x) = \frac{(e^x + xe^x) \cos x + xe^x \sin x}{\cos^2 x}$. Evaluating this at $x = 0$ yields 1.

29. Which of the following is true about bounded sequence? (1)
- A. Every bounded sequence is convergent.
- B. Every increasing bounded sequence converges to the greatest lower bound of the sequence.
- C. Every decreasing bounded sequence converges to the least upper bound of the sequence.
- D. ✓ **Every monotone bounded sequence converges.**

Answer: D

According to the Monotone Convergence Theorem, any sequence that is both monotone (either entirely non-increasing or non-decreasing) and bounded is guaranteed to converge.

30. If f and g are continuous functions at a , then which of the following functions may NOT be continuous at a ? (1)
- A. $2f + 3g$
B. fg
C. ✓ **f/g**
D. $f - 2g$

Answer: C

The quotient of two continuous functions, f/g , fails to be continuous at any point a where the denominator $g(a) = 0$.

31. Let f be a continuous function on $\mathbb{R}$ and c be a number in the domain of f . Which one of the following must be true about the function? (1)
- A. **An absolute maximum value of f which is attained at a critical number is also a local maximum value of f .** ✓
- B. If $f'(c) = 0$, then $(c, f(c))$ is an inflection point of f .
- C. If $f(c)$ is a local minimum value of f , then $f'(c) = 0$.
- D. If c is a critical number of f , then $f(c)$ is a local extreme value of f .

Answer: A

Since the domain of f is the entire set of real numbers $\mathbb{R}$ (which has no boundary points), any absolute maximum is also a local maximum, which must occur at a critical point.

32. If the perimeter of a rectangle is 120 m, what are the length l and width w of the rectangle that maximizes its area? (1)
- A. $l = 50$ m and $w = 10$ m
- B. ✓ **$l = 30$ m and $w = 30$ m**
- C. $l = 35$ m and $w = 25$ m
- D. $l = 40$ m and $w = 20$ m

Answer: B

For a fixed perimeter, the rectangle that maximizes the area is a square. Thus, the length and width must both be equal to $120/4 = 30$ m.

33. The sum of the first 8 terms of a geometric sequence with first term 0.3 and common ratio $1/10$ is equal to: (1)
- A. $\frac{3}{10} \left(\frac{10^8 - 1}{10^8} \right)$
- B. ✓ $\frac{1}{3} \left(\frac{10^8 - 1}{10^8} \right)$
- C. $\frac{1}{3} \left(\frac{10^8 - 1}{10^7} \right)$
- D. $\frac{3}{10} \left(\frac{10^8 - 1}{10^9} \right)$

Answer: B

Using the geometric series sum formula $S_n = a_1 \frac{1-r^n}{1-r}$ with $a_1 = 0.3$ and $r = 0.1$ gives $S_8 = \frac{3}{10} \cdot \frac{1-10^{-8}}{9/10} = \frac{1}{3} \left(\frac{10^8-1}{10^8} \right)$.

34. Suppose f is a continuous function on an interval $[a, b]$ and differentiable on (a, b) with the property $f(a) = f(b)$. Which one of the following must be true? (1)
- A. The function has a zero in (a, b) .
- B. The function has minimum value in (a, b) .
- C. The function has maximum value in (a, b) .
- D. ✓ **The graph of f has horizontal tangent line at $(c, f(c))$ for some $c \in (a, b)$.**

Answer: D

This is a direct application of Rolle's Theorem, which guarantees that there is at least one point $c \in (a, b)$ where $f'(c) = 0$, representing a horizontal tangent line.

35. The distance from the point $P(3, 4)$ to the line L with equation $3x + 4y - 5 = 0$ is: (1)
- A. 5 units
- B. 6 units
- C. ✓ **4 units**
- D. 7 units

Answer: C

The distance is given by the formula $d = \frac{|Ax_0 + By_0 + C|}{\sqrt{A^2 + B^2}} = \frac{|3(3) + 4(4) - 5|}{\sqrt{3^2 + 4^2}} = \frac{20}{5} = 4$ units.

36. A line segment chord in an ellipse which passes through the center and perpendicular to the major axis is called: (1)
- A. Semi-major axis
B. ✓ **Minor axis**
C. Eccentricity
D. Latus rectum

Answer: B

By definition, the minor axis of an ellipse is the chord that passes through the center of the ellipse and is perpendicular to its major axis.

37. If A is a 3×3 matrix with $\det(A) = 5$, then what is the determinant of $2A$? (1)
- A. 10
B. $2/5$
C. ✓ **40**
D. 30

Answer: C

For an $n \times n$ matrix A and a scalar k , $\det(kA) = k^n \det(A)$. For this 3×3 matrix, we have $\det(2A) = 2^3(5) = 40$.

38. Which one of the following is the augmented matrix associated to the system of equations: (1)

$$\begin{cases} 2x + y + 3z = 4 \\ x - z = 1 \\ -4x + y = 3 \end{cases}$$

- A. $\begin{pmatrix} 3 & 2 & 1 & 1 \\ -1 & 1 & -1 & 3 \\ -1 & -4 & 1 & 4 \end{pmatrix}$
B. $\begin{pmatrix} 3 & 1 & 2 & 4 \\ -1 & 0 & 1 & 1 \\ -4 & 1 & -3 & 0 \end{pmatrix}$
C. $\begin{pmatrix} 1 & 2 & 3 & 4 \\ -1 & 1 & -1 & 1 \\ 1 & -4 & -1 & 3 \end{pmatrix}$
D. ✓ $\begin{pmatrix} 2 & 1 & 3 & 4 \\ 1 & 0 & -1 & 1 \\ -4 & 1 & 0 & 3 \end{pmatrix}$

Answer: D

The augmented matrix is formed by aligning the coefficients of x , y , and z as columns, alongside the constant vector on the right, which matches option D.

39. Which one of the following compound statements has a converse with truth value False? (1)
- A. ✓ **If 6 is a prime integer, then 4 is an even number.**
B. If man is immortal, then the earth does not rotate around the sun.
C. If athlete Derartu Tulu was born on October 21, 1971, then 6 is prime.
D. If man is mortal, then the earth does not rotate around the sun.

Answer: A

The converse of statement A is 'If 4 is an even number, then 6 is a prime integer.' Since the hypothesis is True and the conclusion is False, this converse is False.

40. The solution set of the equation given by $\log(x^2 - 3) = 2 \log(x - 1)$ is: (1)
- A. $\{1\}$
B. ✓ **$\{2\}$**
C. $\{4\}$
D. $\emptyset$

Answer: B

Solving the equation yields $x^2 - 3 = (x - 1)^2 \implies -3 = -2x + 1 \implies x = 2$. This is a valid solution as it satisfies the domain requirement $x > \sqrt{3}$.

41. Which of the following is true about the trigonometric values of the given pairs of angles? (1)

- A. $\tan(75^\circ) = \tan(105^\circ)$ B. $\sin(75^\circ) = \cos(105^\circ)$
C. $\cos(120^\circ) = \cos(60^\circ)$ D. ✓ **$\sin(120^\circ) = \sin(60^\circ)$**

Answer: D

Using the trigonometric identity $\sin(180^\circ - \theta) = \sin \theta$, we have $\sin(120^\circ) = \sin(180^\circ - 60^\circ) = \sin(60^\circ)$.

42. Which one of the following intervals is the solution set of the inequality $x^2 - 5x + 6 \leq 0$? (1)

- A. $[0, 2]$ B. ✓ **$[2, 3]$**
C. $(3, \infty)$ D. $(-\infty, 2]$

Answer: B

Factoring the quadratic inequality gives $(x - 2)(x - 3) \leq 0$. The product is non-positive between its roots, which corresponds to the closed interval $[2, 3]$.

43. What are the coordinates of a point that divides the line segment with endpoints $P(0, 1)$ and $Q(5, 6)$ in the ratio 2:3 from P? (1)

- A. ✓ **$(2, 3)$** B. $(0, 2)$
C. $(3, 2)$ D. $(0, 3)$

Answer: A

The coordinates of the point dividing the segment from $P(0, 1)$ to $Q(5, 6)$ in the ratio 2 : 3 are given by $x = \frac{2(5)+3(0)}{2+3} = 2$ and $y = \frac{2(6)+3(1)}{2+3} = 3$, resulting in $(2, 3)$.

44. Which one of the following trigonometric values is correct? (1)

- A. $\sin(-120^\circ) = 0.5$ B. ✓ **$\cos(-120^\circ) = -0.5$**
C. $\tan(-120^\circ) = -1$ D. $\cos(-60^\circ) = \sqrt{3}/2$

Answer: B

Using the properties of trigonometric functions, $\cos(-120^\circ) = \cos(120^\circ) = -0.5$, which is correct. The other options are incorrect because $\sin(-120^\circ) = -\sqrt{3}/2$, $\tan(-120^\circ) = \sqrt{3}$, and $\cos(-60^\circ) = 0.5$.

45. Which one of the following is an onto function from $\mathbb{R}$ on to $[0, \infty)$? (1)

- A. ✓ **$f(x) = \sqrt{x^2}$** B. $f(x) = |x| + 2$
C. $f(x) = x^2 + 1$ D. $f(x) = 2^x$

Answer: A

A function is onto if its range equals its codomain $[0, \infty)$. The range of $f(x) = \sqrt{x^2} = |x|$ is $[0, \infty)$, so it is onto, whereas the other options have ranges that do not equal $[0, \infty)$.

46. Which one of the following is the simplified form of $\frac{4x^4 - 64}{2 - x}$ for $x \neq 2$? (1)

- A. $4(x + 2)(x^2 + 4)$ B. $4(x - 2)(x^2 - 4)$
C. ✓ **$-4(x + 2)(x^2 + 4)$** D. $-4(x - 2)(x^2 + 4)$

Answer: C

The numerator can be factored as $4(x^4 - 16) = 4(x^2 - 4)(x^2 + 4) = 4(x - 2)(x + 2)(x^2 + 4)$. Dividing this by the denominator $2 - x = -(x - 2)$ yields $-4(x + 2)(x^2 + 4)$.

47. If Btu 20,000 is deposited in a Bank at a rate of 12% interest compounded monthly, how long will it take to double the amount? (1)
- A. 7.59 years
B. 6 years
C. ✓ **5.81 years**
D. 5 years

Answer: C

Using the compound interest formula $A = P(1 + r/n)^{nt}$, we set $2 = (1 + 0.12/12)^{12t} = (1.01)^{12t}$. Solving for t gives $t = \frac{\ln 2}{12 \ln 1.01} \approx 5.81$ years.

48. Which one of the following is true about the matrix $\begin{pmatrix} 1 & 3 & 5 \\ 6 & 4 & 2 \\ 9 & 7 & 0 \end{pmatrix}$? (1)
- A. The minor of the entry 3 is 18.
B. The cofactor of the entry 5 is -6.
C. The minor of the entry 0 is 14.
D. ✓ **The cofactor of the entry 1 is -14.**

Answer: D

The cofactor of the entry 1 (located at position $(1, 1)$) is given by $(-1)^{1+1} \det \begin{pmatrix} 4 & 2 \\ 7 & 0 \end{pmatrix} = 1 \cdot (0 - 14) = -14$, which is correct.

49. What is the image of the circle with equation $(x + 2)^2 + (y - 2)^2 = 1$, when it is rotated through $\pi/6$ about the origin? (1)
- A. $(x + (\sqrt{3} - 1))^2 + (y - (\sqrt{3} - 1))^2 = 1$
B. $(x - (\sqrt{3} + 1))^2 + (y + (\sqrt{3} - 1))^2 = 1$
C. ✓ **$(x + (\sqrt{3} + 1))^2 + (y - (\sqrt{3} - 1))^2 = 1$**
D. $(x - (\sqrt{3} - 1))^2 + (y + (\sqrt{3} + 1))^2 = 1$

Answer: C

The original circle has center $C(-2, 2)$ and radius $r = 1$. Rotating the center counterclockwise by $\pi/6$ about the origin gives the new center $C'(-\sqrt{3} - 1, \sqrt{3} - 1)$, leading to the equation $(x + (\sqrt{3} + 1))^2 + (y - (\sqrt{3} - 1))^2 = 1$.

50. What is the dot (scalar) product of the vectors $u = i + 2j$ and $v = -2i + 4j$? (1)
- A. -8
B. 5
C. ✓ **6**
D. 7

Answer: C

The dot product of $u = (1, 2)$ and $v = (-2, 4)$ is computed as $u \cdot v = 1(-2) + 2(4) = -2 + 8 = 6$.

51. The following is the distribution of the marks of students obtained in Mathematics test out of 50: Range of marks Frequency 20 - 25 15 26 - 31 25 32 - 37 25 38 - 43 20 44 - 50 10 (1)
- A. The first quartile of the distribution is 28.
B. The first quartile of the distribution is 26.
C. The first quartile of the distribution is 26.5.
D. ✓ **The first quartile of the distribution is 27.5**

Answer: D

The first quartile Q_1 corresponds to the cumulative frequency of 23.75 (which lies in the class 26 - 31). Using the quartile formula with class boundary $L = 25.5$ and class width $w = 5$ gives $Q_1 = 25.5 + \frac{23.75 - 15}{25} \times 5 = 27.25$, which is closest to the option of 27.5.

END OF THE MARKING KEY

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