These marking guidelines are prepared for use by examiners and sub-examiners, all of whom are required to attend a standardisation meeting to ensure that the guidelines are consistently interpreted and applied in the marking of candidates' scripts.

The IEB will not enter into any discussions or correspondence about any marking guidelines. It is acknowledged that there may be different views about some matters of emphasis or detail in the guidelines. It is also recognised that, without the benefit of attendance at a standardisation meeting, there may be different interpretations of the application of the marking guidelines.
MODULE 1  CALCUlus AND ALGEBRA

QUESTION 1

Step 1: Let $n = 1$

$LHS = 1^2 = RHS$

Step 2: Assume true for $n = k$

then $1 + 3 + 5 + \ldots + (2k - 1) = k^2$

Step 3: For $n = k + 1$

$1 + 3 + 5 + \ldots + (2k - 1) + (2k + 1)$

$= k^2 + 2k + 1$

$= (k + 1)^2$

∴ by the P.M.I. the statement is true for $n \in \mathbb{N}$ [12]

QUESTION 2

2.1 (a)

(b) $4e^{1-x} > 7$

$e^{1-x} > 1.75$

$ln1.75 < 1 - x$

$0.56 < 1 - x$

$x < 0.44$ (6)
2.2 (a) 

(b) For \( g(x) \neq f(x) \) require \(-1 \leq k \leq 3\) 
\(\text{(note change of inequality)}\)
QUESTION 3

3.1 \[2(5 - 2i) - i(6i - 1)\]
\[= 10 - 4i - 6i^2 + i\] (note change of mark allocations)
\[= 16 - 3i\] (6)

3.2 \[\frac{x - 10}{(2x - 1)(x + 3)} = \frac{A}{2x - 1} + \frac{B}{x + 3} = \frac{Ax + 3A + 2Bx - B}{(2x - 1)(x + 3)}\] (note change of mark allocations)
\[\therefore x: A + 2B = 1\]
Const: \(+3A - B = -10\)
\[\therefore A = -\frac{19}{7} \quad B = \frac{13}{7}\] thus
\[\frac{x - 10}{(2x - 1)(x + 3)} = \frac{-\frac{19}{7}}{2x - 1} + \frac{\frac{13}{7}}{x - 3}\] (10)

3.3 \[\lim_{n \to \infty} \frac{4\Sigma k - 3\Sigma 1}{n^2} = \lim_{n \to \infty} \frac{1}{n^2} \left(\frac{4n(n+1)}{2} - 3n\right)\]
\[= \lim_{n \to \infty} \left(2 - \frac{1}{n}\right) = 2\] (8)

[24]

QUESTION 4

4.1 Since \(f'(x) > 0\) \(\therefore f\) is always increasing
(a) Greatest value of \(f(x)\) is at \(x = F\) (4)

(b) \(f''(x) = 0\) \(\therefore\) points of inflection at (and \(f(x) \neq 0\)) (note change of mark allocations)
\(x = B; C; E\) (6)

4.2 No. We have no indication of what the y-values are for the graph. (No given points) (4)

4.3 \(f'(x) \neq 0\) thus \(f(x)\) has no turning points. (4)
[18]
QUESTION 5

5.1 \[ y = (\sin 2x)(2-x)^{-3} \]  
(note change of mark allocations)

\[ \frac{dy}{dx} = 2 \cos 2x (2-x)^{-3} + 3(2-x)^{-4} \cdot \sin 2x \]

OR \[ y = \frac{\sin 2x}{(2-x)^3} \]

\[ \frac{dy}{dx} = \frac{2 \cos 2x (2-x)^3 + 3(2-x)^2 \cdot \sin 2x}{(2-x)^6} \]  \hspace{1cm} (6)

5.2 (a) \[ 1^3 + 2^3 - 1 \times 2^2 = 1 + 8 - 4 = 5 \]

\[ \therefore \text{point (1 ; 2) lies on curve.} \]  \hspace{1cm} (2)

(b) \[ 3x^2 + 3y^2 \frac{dy}{dx} - \left( 1 \cdot y^2 + 2y \frac{dy}{dx} \right) = 0 \]

\[ 3x^2 + 3y^2 \frac{dy}{dx} - y^2 - 2xy \frac{dy}{dx} = 0 \]

\[ \therefore \frac{dy}{dx} \left( 3y^2 - 2xy \right) = y^2 - 3x^2 \]

\[ \therefore \frac{dy}{dx} = \frac{y^2 - 3x^2}{3y^2 - 2xy} \]  \hspace{1cm} (10)

(c) at (1 ; 2) \[ \frac{dy}{dx} = \frac{4 - 3}{12 - 4} = \frac{1}{8} \]

\[ \therefore y = \frac{1}{8} x + c \]

\[ 2 = \frac{1}{8} + c \]

\[ c = \frac{7}{8} \]

\[ \therefore \text{tangent } y = \frac{1}{8} x + \frac{7}{8} \]  \hspace{1cm} (4)
5.3 (a) \[ y = (bx + c)^{-1} \]
\[ \therefore \frac{dy}{dx} = -1(bx + c)^{-2} \]
\[ \frac{d^2y}{dx^2} = 2b(bx + c)^{-3} \cdot b = 2b^2(bx + c)^{-3} \]
\[ \frac{d^3y}{dx^3} = -6b^2(bx + c)^{-4} \cdot b = -6b^3(bx + c)^{-4} \]  
(6)

(b) \[ \frac{d^n y}{dx^n} = (-1)^n n! b^n (bx + c)^{-(n+1)} \]  
(6)

QUESTION 6

6.1 \[ SA = 2rh + r\alpha h + 2 \times \frac{1}{2} r^2 \alpha \] but \( r = h \)  \[ \therefore A = 2r^2 + r^2 \alpha + r^2 \alpha \] (note change of mark allocations)
\[ = 2r^2(\alpha + 1) \]  
(8)

6.2 \[ Vol = \frac{1}{2} r^2 \alpha h \] 
If \( r = h \) and total volume 1000 cm\(^3\)
Then \[ 1000 = \frac{1}{2} r^3 \alpha \] (note change of mark allocations)
Thus \[ \alpha = \frac{2000}{r^3} \]  
(4)

6.3 \[ \therefore A = 2r^2 \left(1 + \frac{2000}{r^3}\right) = 2r^2 + \frac{4000}{r} \]
\[ \therefore \frac{dSA}{dr} = 4r - \frac{4000}{r^2} = 0 \] for minimum SA
\[ \therefore 4r^3 - 4000 = 0 \]
\[ \therefore r = 10 \] and thus \( \alpha = 2 \)  
(8)

[34]

[20]
QUESTION 7

7.1 (a) Vertical asymptotes: \((x + 5)(x + 1) = 0\)
\[
\therefore \quad x = -5 \quad \text{or} \quad x = -1
\]

(b) \(2x^3 + 6x^2 - 25x - 39 = (x^2 + 6x + 5)(2x - 6) + x - 9\)
\[
\therefore \quad \frac{2x^3 + 6x^2 - 25x - 39}{x^2 + 6x + 5} = 2x - 6 + \frac{x - 9}{x^2 + 6x + 5} \quad \text{(this step not necessary)}
\]
\[
\therefore \quad \text{oblique asymptote} = y = 2x - 6
\]

7.2 (a) \(f(x) = \cos x - 0,25x\) initial estimate
\[
f'(x) = -\sin x - 0,25
\]
\[
\therefore \quad x_{n+1} = x_n + \frac{\cos x - 0,25x}{\sin x + 0,25}
\]
\[
x = -2,1333 \quad \text{(8)}
\]

(b) If \(f'(x) = 0\) i.e. \(\sin x = -0,25\)
\[
or \quad x = \sin^{-1}\left(-\frac{1}{4}\right)
\]
Algebraically ÷ by 0
OR Graphically will not cut \(x\)-axis

QUESTION 8

8.1 Let \(u = 3x\) \[
\therefore \quad \frac{du}{3} = dx
\]
\[
\therefore \quad \frac{1}{3} \int \cos^2 u du = \frac{1}{3} \left[ \frac{1}{2} (1 + \cos 2u) \right] du
\]
\[
= \frac{1}{6} \left( u + \frac{\sin 2u}{2} \right) + c
\]
\[
= \frac{x}{2} + \frac{\sin 6x}{12} + c
\]

(8)
8.2 \[ \int \cos 2\theta \sin 5\theta d\theta \]

\[ = \frac{1}{2} \int \sin(5\theta + 2\theta) + \sin(5\theta - 2\theta) d\theta \]

\[ = \frac{1}{2} \left[ \int \sin 7\theta + \sin 3\theta d\theta \right] \]

\[ = \frac{1}{2} \left[ -\frac{\cos 7\theta}{7} - \frac{\cos 3\theta}{3} \right] + c \]

\[ = -\frac{\cos 7\theta}{14} - \frac{\cos 3\theta}{6} + c \]  


8.3 Let \( u = 2 - x \) then \( x = 2 - u \)

\( du = -dx \)

\[ \therefore - \int \frac{10 - 5u}{u^2} \, du = -\int 10u^{-\frac{1}{2}} - 5u^{\frac{1}{2}} \, du \]

\[ = -10u^{\frac{1}{2}} + \frac{5u^{\frac{3}{2}}}{3} + c \]

(note changes of sign in last 3 steps)

\[ = -20u^{\frac{1}{2}} + \frac{10}{3}u^{\frac{3}{2}} + c \]

\[ = -20(2 - x)^{\frac{1}{2}} + \frac{10}{3}(2 - x)^{\frac{3}{2}} + c \]  


QUESTION 9

9.1 \[ \therefore V = \pi \left[ \left( \frac{x - 4}{4} \right)^2 \right]_{-8}^{8} = \pi \left[ \frac{1}{16} \left( x - 4 \right)^4 \right]_{-8}^{8} = \pi \left[ \frac{1}{16} \left( x - 4 \right)^4 \right]_{-8}^{8} = \pi \times \frac{1024}{5} = \frac{64}{5} \pi \, \text{units}^3 \]  

9.2 No The line \( y = x \), not an axis of symmetry \( \therefore \) rotation would be different. Or any other valid reason.

9.3 \[ \pi \int_{-8}^{8} \left( \frac{x + 4}{16} \right)^4 \, dx = \pi \left[ \frac{\left( x + 4 \right)^5}{5} \right]_{-8}^{8} = 10\pi \]

\[ = \pi \left[ \frac{\left( x + 4 \right)^5}{5} \right]_{-8}^{8} = 10\pi \]

\[ \therefore (a - 4)^5 = 800 - 1024 \]

\[ \therefore a - 4 = -2.9515 \]

\[ \therefore a = 1.0485 \]  


Total for Module 1: 200 marks
MODULE 2  STATISTICS

QUESTION 1

1.1  (a)  \[ X \sim N(38,4 ; 4,6^2) \]

\[ P(30 < x < 40) = P\left( \frac{30 - 38,4}{4,6} < z < \frac{40 - 38,4}{4,6} \right) \]

\[ = P(-1,83 < z < 0,35) \]

\[ = 0,4664 + 0,1368 \]

\[ = 0,6032 \quad (8) \]

(b)  \[ P(x > k) = 0,9 \]

\[ z = -1,28 \]

\[-1,28 = \frac{k - 38,4}{4,6} \]

\[ k = 32,512 \quad (8) \]

1.2  (a)  \[ 2,33 \left( \sqrt{\frac{(0,32)(0,68)}{n}} \right) \leq 0,1 \]

\[ \sqrt{\frac{0,2176}{n}} \leq 0,0429 \]

\[ n \geq 119 \quad (6) \]

(b)  A 98% CI for \( p \) is

\[ 0,32 \pm 2,33 \left( \sqrt{\frac{(0,32)(0,68)}{119}} \right) \]

\[ (0,2204 ; 0,4196) \quad (4) \]

[26]

QUESTION 2

2.1  (a)  False

(b)  True

(c)  False

(d)  True

(e)  True

(f)  False  (6)
2.2 \( H_0 : \mu = 8 \)
\( H'_1 : \mu < 8 \)

Rejection Region:
Reject \( H_0 \) if \( z < -1.75 \)

Test Statistic:
\[
z = \frac{7.92 - 8}{0.2} = -2.19
\]

Conclusion:
Since \( z < -1.75 \) we reject \( H_0 \) at the 4% level of significance and suggest sufficient evidence to support the claim. (10)

**QUESTION 3**

3.1 (a) A and B are independent. (2)

(b) \( P(A \cap B) = 0 \) \( \therefore \) A and B are mutually exclusive. (2)

3.2 \[P(A|B) = \frac{P(A \cap B)}{P(B)}\]
\[1 = \frac{P(A \cap B)}{P(B)}\]
\[P(B) = P(A \cap B)\] (4)

3.3 (a) \[
\frac{\binom{5}{4} \binom{4}{0}}{\binom{9}{4}} = \frac{5}{126} = 0.0400 \quad \text{or} \quad \frac{5 \times 4}{9 \times 8 \times 3 \times 2} \times \frac{2}{6} = \frac{5}{126} = 0.0400
\] (8)

(b) \[
\binom{5}{4} + \binom{5}{3} + \binom{5}{2} + \binom{5}{1} = 30
\] (8)

3.4 \( P(x > 4) = \binom{6}{5} (0.6)^5 (0.4)^1 + \binom{6}{6} (0.6)^6 (0.4)^0 = 0.2333 \) (8)
QUESTION 4

4.1 (a) 

\[
\begin{array}{c|c|c|c}
 x & 1^1 & 2 & 3 \\
\hline
 P(x) & \frac{7}{24} & \frac{8}{24} & \frac{9}{24} \\
\end{array}
\]

\[
\frac{7}{24} + \frac{8}{24} + \frac{9}{24} = 1
\]

\[\therefore P(X = x) \text{ is a probability mass function.}\] (4)

(b) 

\[
\bar{x} = 1 \left( \frac{7}{24} \right) + 2 \left( \frac{8}{24} \right) + 3 \left( \frac{9}{24} \right)
\]

\[
= \frac{25}{12}
\] (5)

4.2 (a) 

\[P(\text{correct}) = 1(0,65) + \frac{1}{5}(0,35)\]

\[= 0,72\] (4)

(b) 

\[P(\text{guesses / correct}) = \frac{\frac{1}{5}(0,35)}{0,65 + \frac{1}{5}(0,35)}\]

\[= \frac{7}{72} = 0,0972\] (4)

[17]

QUESTION 5

5.1 (a) Sub \(21; \bar{y}\) into \(y = -7x + 163\)

\[\bar{y} = -7(21) + 163\]

\[= 16\] (2)

(b) 

\[y = -7(5) + 163\]

\[= 128\] (2)

5.2 

\[r = -\frac{1}{7} = -0,1429\]

A correlation coefficient is negative and considered very weak. (3)

5.3 The estimate is unreliable as the correlation is too weak. (2)

[9]

Total for Module 2: 100 marks
MODULE 3  FINANCES AND MODELLING

QUESTION 1

1.1 \[ T_{n+1} = T_n \cdot \left(1 + \frac{0.09}{4}\right)^{11} = 11300, \quad T_0 = 150000 \]  

(5)

1.2 \[ 0.5 = (1 - c)^t \quad \therefore c = 15.91\% \]

\[ 0.1 = (1 - 0.1591)^n \quad \therefore n = 13.3 \quad \therefore n = 14 \text{ years} \]

(9)

[14]

QUESTION 2

2.1 \[ OB = \frac{8932.75 \left[ 1 - \left(1 + \frac{0.0648}{12}\right)^{-51}\right]}{0.0648} = 397290.48 \]

(6)

2.2 \[ 400000 \left(1 + \frac{0.0674}{12}\right)^3 = \frac{x \left[1 - \left(1 + \frac{0.0674}{12}\right)^{-48}\right]}{0.0674} \]

\[ x = 9691.81 \]

(8)

2.3 \[ 8932.75 \times 189 + 9691.81 \times 48 - 1200000 = 953496.63 \]

(6)

[20]

QUESTION 3

3.1 \[ \left(1 + \frac{0.058}{4}\right)^4 = \left(1 + \frac{i}{12}\right)^{12} \]

\[ 1 + \frac{i}{12} = 1.004810 \ldots \]

\[ i = 5.7722\% \text{ per annum, compound monthly} \]

(8)

3.2 \[ 850000 = \frac{7300 \left[ 1 - \left(1 + \frac{0.057722}{12}\right)^{-n}\right]}{0.057722} \]

\[ 0.43991 = 1.00481^{-n} \]

\[ n = 171,128 \]

\[ 180 - 172 = 8 \text{ months} \text{ earlier} \]

(10)

[18]
QUESTION 4

4.1  \(0.95 = 1 + 0.6 - x\)  \(x = 0.65\)
\(500 = -2 \times 500 + y\)  \(y = 3\ 000\)

4.2  \(F_{n+1} = 0.95 \times F_n + 500, \ F_0 = 5\ 000\)  \(F_{20} = 8\ 207 \text{ or } 8\ 208\)  (rounding)
Population increasing, but at slower rate as time goes on.

4.3  \(F_n = 0.95^{100} \times 5000 + \frac{500[0.95^{100} - 1]}{0.95 - 1}\)  
\[(k) \ (n) \ (c, \ K) = 9\ 970\]  (5)

QUESTION 5

5.1  (a) prey: accept 18\ 000 - 20\ 000\ predator: accept 700 - 1\ 000\  (2)
(b) 1\ 000 < prey < 94\ 000\  (accept 100 - 2\ 000; 93\ 000 - 94\ 000)\  (2)
(c) quadrant 3\  (2)
(d) rate of deadly interactions between predator and prey\  (2)
(e) Could lead to extinction of prey
at some time points in cycles prey population is already very low (1\ 000)
and now has a higher rate of fatalities per cycle

OR
prey decreases more rapidly per cycle
double amount of kills per cycle and hence potentially more predators

OR
Equilibrium point of prey half the original
\(R = c/(bf)\) so denom doubled, hence value halved \((4)\)
6.1 \( Q_{n+1} = 0.12P_n + 0.9Q_n + 400 000 \) (4)

6.2 For equilibrium, \( P_{n+1} = P_n \):
\(-0.2P + 0.06Q = -600 000.\)

For equilibrium, \( Q_{n+1} = Q_n \):
\(0.12P - 0.1Q = -400 000.\)

\[ P = 6562500, \quad Q = 11875000 \] (8)

Total for Module 3: 100 marks
MODULE 4: MATRICES AND GRAPH THEORY

QUESTION 1

1.1 (a) \[ 4a - (-2) = 0 \]
\[ a = -\frac{1}{2} \]  
(4)

(b) \[ \frac{1}{6} \begin{pmatrix} 4 & 1 \\ 2 & 2 \end{pmatrix} \]  
(4)

(c) \[ A - 2B = \begin{pmatrix} a & 2 \\ -1 & 4 \end{pmatrix} - \begin{pmatrix} 4 & -2 \\ -4 & 2b \end{pmatrix} \]
\[ a - 4 = -7 \quad a = -3 \]
\[ 4 - 2b = 4a = -12 \quad b = 8 \]  
(6)

1.2 (a) \( q \times p \)  
(2)

(b) \( p \times r \)  
(2)

(c) \( r \times r \)  
(2)

[20]

QUESTION 2

2.1 (a) \( \begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix} \)  
(2)

(b) \( \begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ 3 & 1 \end{pmatrix} \) (shear) (factor) (direction)  
\( = \begin{pmatrix} -3 & -1 \\ -1 & 0 \end{pmatrix} \)  
(6)

2.2 \( 360^\circ \div 8 = 45^\circ \)
\( \begin{pmatrix} \cos 45 & -\sin 45 \\ \sin 45 & \cos 45 \end{pmatrix} \cdot \begin{pmatrix} -1 \\ 2 \end{pmatrix} = \begin{pmatrix} -2.121 \\ 0.707 \end{pmatrix} \)  
(6)

2.3 \( \begin{pmatrix} \cos 2A & \sin 2A \\ \sin 2A & -\cos 2A \end{pmatrix} = \begin{pmatrix} -0.8 & -0.6 \\ -0.6 & 0.8 \end{pmatrix} \)
\[ \cos 2A = -0.8 \quad \text{AND} \quad \sin 2A = -0.6 \]
\[ 2A = 180^\circ + 36,87^\circ = 216,87 \]
\[ \tan A = -3 \quad \text{so} \quad A = 108,435^\circ \]
\[ y = -3x \]  
(10)

[24]
QUESTION 3  

3.1 \( \det = 16 \)  \(\text{(2)}\)

\[
\begin{pmatrix}
4 & 2 & 6 \\
-1 & 2 & 2 \\
0 & 1 & 3 \\
\end{pmatrix}
\]  \(\text{(2)}\)

3.2 \( a = 2 \times 2 - 2 \times 6 = -8 \)

\( b = 4 \times 3 - 0 \times 6 = 12 \)

\( c = 4 \times 2 - (-1) \times 2 = 10 \)  \(\text{(6)}\)

QUESTION 4  

4.1 Dijkstra  \(\text{(2)}\)

4.2 Prim  \(\text{(2)}\)

4.3 Fleury  \(\text{(2)}\)

4.4 Nearest Neighbour  \(\text{(2)}\)

QUESTION 5  

5.1

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\(\text{(6)}\)
5.2

A F E G H J L = 29

OR

A
AB  (8)  C,D,E,F,G,H,J,K,L
ABF  (12)  C,D,E,G,H,J,K,L
ABFC or ABFCE  (14)  D,G,H,J,K,L
ABFCEG  (17)  D,H,J,K,L
ABFCEGD  (20)  H,J,K,L
ABFCEGDH or ABFCEGDHK  (21)  J,L
ABFCEGDHKJ  (23)  L
ABFCEGDHKJL  (29)

5.3

EG  HJ  (4)

5.4

(a) 11 vertices, therefore each vertex must be connected to 5 other vertices.
True only of G.  (2)

(b) converse not true
OR
Theorem gives one case of when there will be HC; it is not exhaustive  (2)
QUESTION 6

6.1 (a) \( m + n \)  
\hspace{2cm} (2)

(b) \( m \cdot n \)  
\hspace{2cm} (2)

6.2 \( 1 \times 10 = 11 \) or \( 2 \times 5 = 7 \)  
\hspace{2cm} (4)

6.3 \hspace{2cm} \begin{array}{c}
\text{vertices} \\
\text{edges}
\end{array}  
\hspace{2cm} (4)

\[12\]

Total for Module 4: 100 marks

Total: 300 marks