

Subject: A Course of Mathematics
Paper: A
Note: Attempt Six questions in all by selecting Three questions from each section.

SECTION-I

(a) Define continuous function in term of $(\delta - \varepsilon)$ form and discuss the continuity of $f(x) = x - [x]$, $x \in \mathbb{R}$, for integral values of $\mathbb{R}$. 3+6/3

Define least upper bound and prove that the set $S = \{x : x^2 < 2\}$ has least upper bound $= \sqrt{2}$. 2+6/1

2(a) If u is a derivable function of v and v is a derivable function of x , then prove that $\frac{du}{dx} = \frac{du}{dv} \cdot \frac{dv}{dx}$. 9

3(a) If $y(x) = e^{ax} x^2$, find a formula for $y^{(n)}(x)$. 8/8

Q.3(a) If f is differentiable on $[a, b]$ and f' decreases strictly on $[a, b]$, prove that $f'(b) < \frac{f(b) - f(a)}{b - a} < f'(a)$. How is this result modified if f' increases strictly on $[a, b]$? Hence show that if $f(x) = \sin x$, $a = \frac{\pi}{3}$, $b = \frac{61\pi}{180}$ then $\sin 61^\circ - \sin 60^\circ < 0.0088$. 9

(b) Evaluate the following limit: $\lim_{x \rightarrow 1} \frac{(1-x^{n+1})(1-x^{n+2})(1-x^{n+3}) \dots (1-x^{n+k})}{(1-x)(1-x^2)(1-x^3) \dots (1-x^k)}$. 8

Q.4(a) Describe the geometrical significance of the derivative of the radius vector with respect to the polar angle. 9

(b) Show that Pedal equation of the ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ is $\frac{1}{p^2} = \frac{1}{a^2} + \frac{1}{b^2} - \frac{r^2}{a^2 b^2}$. 8

Q.5(a) Show that the maximum value of $(\frac{1}{x})^x$ is $(e)^{1/e}$. 8

(b) If $y(x) = (x + \sqrt{1+x^2})^n$, prove that $(1+x^2)y''(x) + xy'(x) - n^2 y(x) = 0$ and $(1-x^2)y^{(n+2)}(x) + (2n+1)xy^{(n+1)}(x) + (n^2 - n^2)y^{(n)}(x) = 0$. 2/10

Q.6(a) Find the centre of curvature of the astroid $x^{2/3} + y^{2/3} = a^{2/3}$. 9

(b) The normal to a given curve is a tangent to its evolute. 8

SECTION-II

Q.7(a) State and prove the fundamental theorem of the integral calculus. 9

(b) Prove that $\int_0^{\pi} \frac{\ln(1+x^2)}{1+x^2} dx = \pi \ln 2$. 8

Q.8(a) Define improper integral and determine the convergence or divergence of the following improper integral and evaluate. The convergent integral $\int_0^{\infty} e^{-x} x^5 dx$. 2+7/9

(b) Evaluate $\int \frac{x^2}{(1+x^2)^3} dx$. 8/8

Q.9(a) Evaluate $\int \frac{x + \sin x}{1 + \cos x} dx$. 8/2

(b) (i) If $f(x)$ and $g(x)$ are two antiderivatives of $\phi(x)$ then $f(x)$ and $g(x)$ must differ by a constant. 4/1

(ii) Evaluate $\int \frac{\sqrt{9x^2-1}}{x} dx$. 4/4

Q.10(a) Show that the intrinsic equation of the semicubical parabola $ay^2 = x^3$, taking the cusp as the fixed point is $27S = 8a(\sec^2 \psi - 1)$. 8

(b) Find the area of the region included between the cardioid $r = 2a(1 + \cos \theta)$ and the circle $r = 6a \cos \theta$. 8

Q.11(a) Assuming that the area of an ellipse with semi axes a and b is πab , compute the volume of the ellipsoid $\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$. 8

(b) Find the Fourier series representing the function $f(x) = |x|$, $-\pi \leq x \leq \pi$. 8

Q.12(a) Determine whether the series $\sum_{n=1}^{\infty} \frac{\arctan n}{1+n^2}$ converges or diverges. 8

(b) Apply any appropriate test to determine the convergence or divergence of the series $\sum_{n=1}^{\infty} \frac{(2n+1)!}{n^2(n+1)!}$. 8

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