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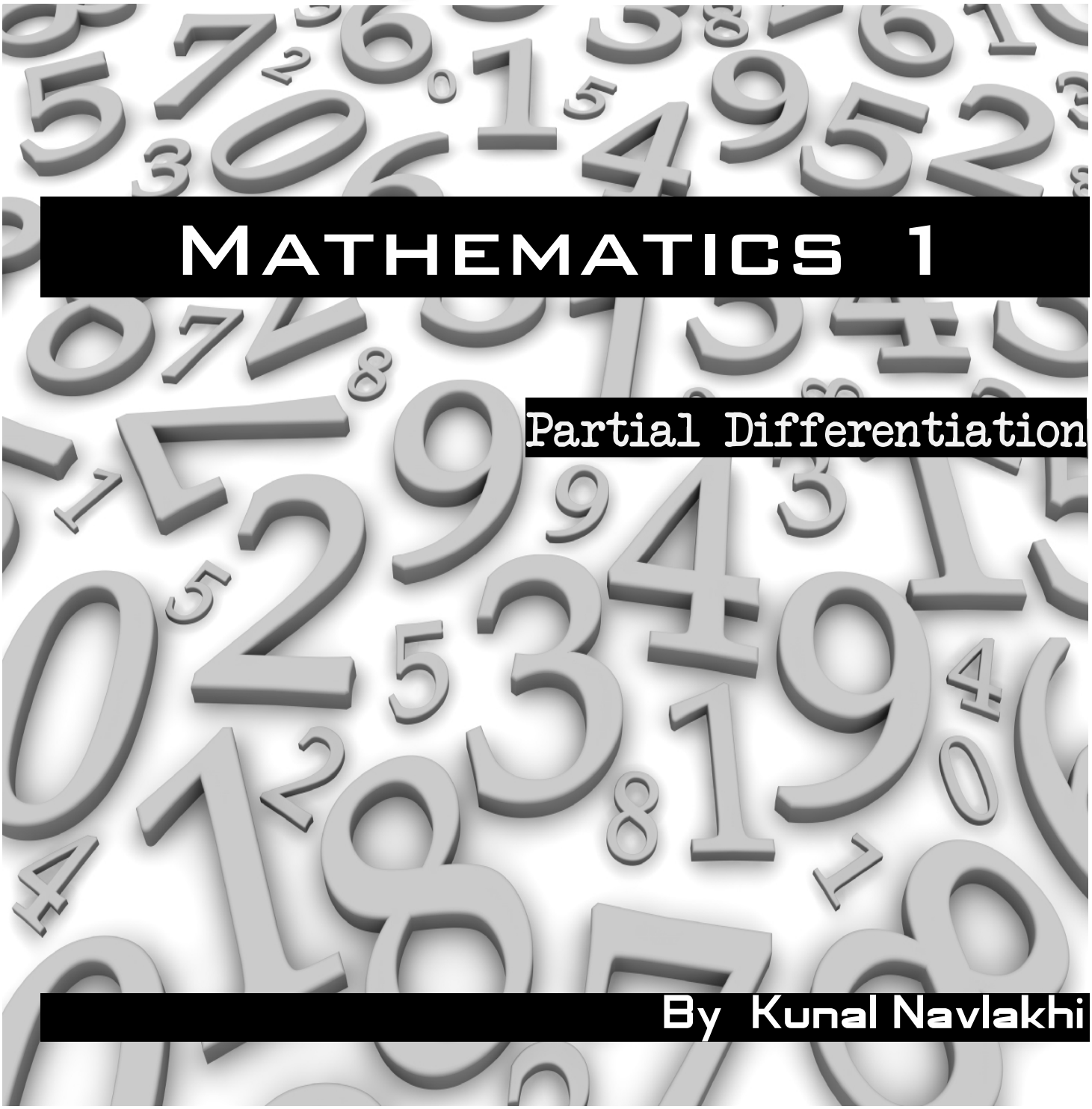

MATHEMATICS 1

Partial Differentiation

By Kunal Navlakhi

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NAME:	KUNAL NAVLAKHI
QUALIFICATION:	➢ B.E. Electronics, ➢ Entrepreneurship Management, Wellingkar, ➢ International Executive Management, UBS,Belgium
EXPERIENCE:	➢ 2 yrs in Educational Technology Unit at NCST ➢ More than 17 yrs of coaching experience
SOME ACADEMIC ACHIEVEMENTS:	➢ Distinction in MBA from Wellingkar ➢ First class each year in engineering ➢ Second Rank in Engineering Degree College ➢ 90/100 in maths in ICSE ➢ 97/100 in maths in HSC

NAME:	ABHISHEK NAVLAKHI
QUALIFICATION:	➢ B.E. Computers
EXPERIENCE:	➢ 2 years as programmer at CMC Ltd. ➢ More than 17 yrs of coaching experience
SOME ACADEMIC ACHIEVEMENTS:	➢ First class each year in engineering ➢ 92 percentile in Data Structures at the all India NCST G level exam ➢ 100/100 in physics at hsc (1st in maharashtra) ➢ 89.5% aggregate In hsc ➢ 1 92/200 in electronics at hsc ➢ 96/100 in maths @ ICSE ➢ 94/100 in Science @ ICSE

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PART 1

Partial Differentiation - Classwork Questions

By Kunal Navlakhi

Q1) If $z = x^y + y^x$ prove $\frac{\partial^2 z}{\partial x \partial y} = \frac{\partial^2 z}{\partial y \partial x}$

Q2) If $z^3 - zx - y = 0$ prove $\frac{\partial^2 z}{\partial x \partial y} = -\frac{(3z^2 + x)}{(3z^2 - x)^3}$

Q3) If $u = \log(x^3 + y^3 + z^3 - 3xyz)$ prove that $\left(\frac{\partial}{\partial x} + \frac{\partial}{\partial y} + \frac{\partial}{\partial z}\right)^2 u = \frac{-9}{(x+y+z)^2}$

Q4) If $v = (1 - 2xy + y^2)^{-1/2}$ prove (i) $x\frac{\partial v}{\partial x} - y\frac{\partial v}{\partial y} = y^2 v^3$

(ii) $\frac{\partial}{\partial x}\left[(1-x^2)\frac{\partial v}{\partial x}\right] + \frac{\partial}{\partial y}\left[y^2 \frac{\partial v}{\partial y}\right] = 0$

Q5) If $u(x+y) = x^2 + y^2$ prove $\left[\frac{\partial u}{\partial x} - \frac{\partial u}{\partial y}\right]^2 = 4\left[1 - \frac{\partial u}{\partial x} - \frac{\partial u}{\partial y}\right]$

Q6) If $u = \log(\tan x + \tan y + \tan z)$ prove $\sin 2x \frac{\partial u}{\partial x} + \sin 2y \frac{\partial u}{\partial y} + \sin 2z \frac{\partial u}{\partial z} = 2$

Q7) If $\theta = t^n e^{-r^2/4t}$ prove $n = -\frac{3}{2}$ if $\frac{1}{r^2}\frac{\partial}{\partial r}\left[r^2 \frac{\partial \theta}{\partial r}\right] = \frac{\partial \theta}{\partial t}$

Q8) If $u(x,t) = Ae^{-qx}\sin(nt - qx)$ prove $q = \sqrt{\frac{n}{2u}}$ if $\frac{\partial u}{\partial t} = u\frac{\partial^2 u}{\partial x^2}$

Q9) If $\frac{x^2}{a^2+u} + \frac{y^2}{b^2+u} + \frac{z^2}{c^2+u} = 1$ prove $u_x^2 + u_y^2 + u_z^2 = 2(xu_x + yu_y + zu_z)$

Q10) If $v = e^{\frac{r-x}{t}}$ where $r^2 = x^2 + y^2$ prove $\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{2}{t}\frac{\partial v}{\partial x} = \frac{v}{tr}$

Q11) If $u = x^y$ prove $\frac{\partial^3 u}{\partial x^2 \partial y} = \frac{\partial^2 u}{\partial x \partial y \partial x}$

Q12) If $u = f(x-y, y-z, z-x)$ prove $\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y} + \frac{\partial u}{\partial z} = 0$

Q13) If $f(xy^2, z-2x) = 0$ prove $x\frac{\partial z}{\partial x} - \frac{y}{2}\frac{\partial z}{\partial y} = 2x$

Q14) If $u = f\left(\frac{x^2}{y}\right)$ prove (i) $x\frac{\partial u}{\partial x} + 2y\frac{\partial u}{\partial y} = 0$

(ii) $x^2\frac{\partial^2 u}{\partial x^2} + 3xy\frac{\partial^2 u}{\partial x \partial y} + 2y^2\frac{\partial^2 u}{\partial y^2} = 0$

Q15) If $f(lx+my+nz, x^2+y^2+z^2) = 0$ prove $(ly-mx)+(ny-mz)\frac{\partial z}{\partial x} + (lz-nx)\frac{\partial z}{\partial y} = 0$

Q16) If $z = f(x+cy) + \phi(x-cy)$ prove $\frac{\partial^2 z}{\partial y^2} = c^2\frac{\partial^2 z}{\partial x^2}$

Q17) If $f(x,y) = 0$ & $\phi(x,z) = 0$ prove $\frac{\partial \phi}{\partial x}\cdot\frac{\partial f}{\partial y}\cdot\frac{dy}{dz} = \frac{\partial f}{\partial x}\cdot\frac{\partial \phi}{\partial z}$

Q18) If $u = xe^{y}z$ where $y = \sqrt{a^2-x^2}$ and $z = \sin^3 x$ find $\frac{du}{dx}$

Q19) If $v = f(r)$ where $r^2 = x^2+y^2+z^2$ prove $\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2} = \frac{d^2v}{dr^2} + \frac{2}{r}\frac{dv}{dr}$

Q20) If $v = (x^2-y^2)f(xy)$ prove (i) $\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} = (x^4-y^4)f''(xy)$

(ii) $\frac{\partial^2 v}{\partial x \partial y} = (x^2-y^2)[3f'(xy) + xy f''(xy)]$

Q21) Prove that for $x^x y^y z^z = c$, $\frac{\partial^2 z}{\partial x \partial y} = -(x \log ex)^{-1}$ for $x = y = z$

Q22) If $z = u(x,y).e^{ax+by}$ where $\frac{\partial^2 u}{\partial x \partial y} = 0$ find a, b if $\frac{\partial^2 z}{\partial x \partial y} - \frac{\partial z}{\partial x} - \frac{\partial z}{\partial y} + z = 0$

Q23) If $u = \sin\frac{x}{y}$ and $x = e^t$ and $y = t^2$ verify

$$\frac{du}{dt} = \frac{\partial u}{\partial x}\cdot\frac{dx}{dt} + \frac{\partial u}{\partial y}\cdot\frac{dy}{dt}$$

Q24) If $u = x\log(xy)$ where $x^3+y^3+3xy=1$ find $\frac{du}{dx}$ at $(1,1)$

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Part 2

Partial Differentiation - Important Practice Questions

By Kunal Navlakhi

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PARTIAL DIFFERENTIATION

Q1) Find n such that $V=r^n(3\cos^2\theta-1)$ satisfies $\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right)+\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial V}{\partial\theta}\right)=0$

Q2) If $\frac{1}{u^2}=x^2+y^2+z^2$ show that $\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}=0$

Q3) If $u=f\left(\frac{y-x}{xy},\frac{z-x}{xz}\right)$ show that $x^2\frac{\partial^2 u}{\partial x^2}+y^2\frac{\partial^2 u}{\partial y^2}+z^2\frac{\partial^2 u}{\partial z^2}=0$

Q4) If $a^2x^2+b^2y^2-c^2z^2=0$ show that $\frac{1}{a^2}\frac{\partial^2 z}{\partial x^2}+\frac{1}{b^2}\frac{\partial^2 z}{\partial y^2}=\frac{1}{c^2 z}$

Q5) If $z=(3xy-y^3)-(y^2-2x)^{3/2}$ prove $\frac{\partial^2 z}{\partial x\partial y}=\frac{\partial^2 z}{\partial y\partial z}$

Q6) If $z=\tan^{-1}\left(\frac{x}{y}\right)$ where $x=2t$, $y=1-t^2$ prove $\frac{dz}{dt}=\frac{2}{1+t^2}$

Q7) If $x^x y^y z^z=c$ prove at $x=y=z$

$$\frac{\partial^2 z}{\partial x^2}-2xy\frac{\partial^2 z}{\partial x\partial y}+\frac{\partial^2 z}{\partial y^2}=\frac{2(x^2-2)}{x(1+\log x)}$$

Q8) If $u=(x^2+y^2+z^2)^{-1/2}$ prove $\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}=0$

Q9) If $u=r^m$ and $r^2=x^2+y^2+z^2$ prove that

$$\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}=m(m+1)r^{m-2}$$

~~Q10)~~

Q10) If $u=f(x^2+y^2+z^2)$, $x=r\cos\alpha\cos\beta$, $y=r\cos\alpha\sin\beta$, $z=r\sin\alpha$ prove $\frac{\partial u}{\partial \alpha}=\frac{\partial u}{\partial \beta}=0$

Q11) If $u=e^{xyz}f\left(\frac{xy}{z}\right)$ Prove $x\frac{\partial u}{\partial x}+z\frac{\partial u}{\partial z}=2xyzu$; $y\frac{\partial u}{\partial y}+z\frac{\partial u}{\partial z}=2xyzu$. Hence prove $x\frac{\partial^2 u}{\partial z\partial x}=y\frac{\partial^2 u}{\partial z\partial y}$

Q12) If $z=x\log(x+r)-r$ where $r^2=x^2+y^2$ prove that $\frac{\partial^2 z}{\partial x^2}+\frac{\partial^2 z}{\partial y^2}=\frac{1}{x+r}$

Q13) If $u=\log(x^2+y^2+z^2)$ prove $x\frac{\partial^2 u}{\partial y\partial z}=y\frac{\partial^2 u}{\partial z\partial x}=z\frac{\partial^2 u}{\partial x\partial y}$

Q14) If $z=ct^{-1/2}e^{-x^2/4a^2t}$ prove $\frac{\partial z}{\partial t}=a^2\frac{\partial^2 z}{\partial x^2}$

Q15) If $z=xf(x+y)+yg(x+y)$ prove $\frac{\partial^2 z}{\partial x^2}-2\frac{\partial^2 z}{\partial x\partial y}+\frac{\partial^2 z}{\partial y^2}=0$

Q16) If $u=\log(x^3+y^3-x^2y-xy^2)$ prove $\frac{\partial^2 u}{\partial x^2}+2\frac{\partial^2 u}{\partial x\partial y}+\frac{\partial^2 u}{\partial y^2}=\frac{-4}{(x+y)^2}$

Q17) If $x=r\cos\theta$, $y=r\sin\theta$ prove $\frac{\partial^2\theta}{\partial x^2}+\frac{\partial^2\theta}{\partial y^2}=0$

Q18) If $u=x^3e^{-x/y}$ prove $x^2\frac{\partial^2 u}{\partial x^2}+2xy\frac{\partial^2 u}{\partial x\partial y}+y^2\frac{\partial^2 u}{\partial y^2}=6u$

Q19) Find n if $V=r^n(3\cos^2\theta-1)$ satisfies $\frac{\partial}{\partial r}\left(r^2\frac{\partial v}{\partial r}\right)+\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial v}{\partial\theta}\right)=0$ [Ans n=2, n=-3]

Q20) If $z=f(x,y)$, $x=e^u+e^{-v}$, $y=e^u-e^v$ prove $\frac{\partial z}{\partial u}-\frac{\partial z}{\partial v}=x\frac{\partial z}{\partial x}-y\frac{\partial z}{\partial y}$

Q21) If $z=f(x,y)$, $x=\log u$, $y=\log v$ prove $\frac{\partial^2 z}{\partial x \partial y} = uv\frac{\partial^2 z}{\partial u \partial v}$

Q22) If $z=f(x,y)$, $x=e^u\cos v$, $y=e^u\sin v$ prove

(i) $x\frac{\partial z}{\partial v}+y\frac{\partial z}{\partial u} = e^{2u}\frac{\partial z}{\partial y}$ (ii) $\left(\frac{\partial z}{\partial x}\right)^2+\left(\frac{\partial z}{\partial y}\right)^2 = e^{-2u}\left[\left(\frac{\partial z}{\partial u}\right)^2+\left(\frac{\partial z}{\partial v}\right)^2\right]$

Q23) If $x=\sqrt{vw}$, $y=\sqrt{wu}$, $z=\sqrt{uv}$ prove

$x\frac{\partial \phi}{\partial x}+y\frac{\partial \phi}{\partial y}+z\frac{\partial \phi}{\partial z} = u\frac{\partial \phi}{\partial u}+v\frac{\partial \phi}{\partial v}+w\frac{\partial \phi}{\partial w}$

Q24) If $x=p\cos\theta - q\sin\theta$, $y=p\sin\theta+q\cos\theta$ prove

prove $\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2} = \frac{\partial^2 u}{\partial p^2}+\frac{\partial^2 u}{\partial q^2}$

Q25) If $x=r\cos\theta$, $y=r\sin\theta$ show that $\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}=0$ transforms to $\frac{\partial^2 u}{\partial r^2}+\frac{1}{r}\cdot\frac{\partial u}{\partial r}+\frac{1}{r^2}\cdot\frac{\partial^2 u}{\partial \theta^2}=0$

Q26) If $z=f(u,v)$, $u=lx+my$, $v=ly-mx$ prove

$\frac{\partial^2 z}{\partial x^2}+\frac{\partial^2 z}{\partial y^2} = (l^2+m^2)\left(\frac{\partial^2 z}{\partial u^2}+\frac{\partial^2 z}{\partial v^2}\right)$

Q27) If $u=\log(x^2+y^2)$, $v=y/x$ prove $x\frac{\partial z}{\partial y}-y\frac{\partial z}{\partial x}=(1+v^2)\partial z/\partial v$

Q28) If $u=f(x^2-y^2, y^2-z^2, z^2-x^2)$ prove that

$\frac{1}{x}\frac{\partial u}{\partial x}+\frac{1}{y}\frac{\partial u}{\partial y}+\frac{1}{z}\frac{\partial z}{\partial y}=0$

Q29) If $u=x^2-y^2$, $v=2xy$ and $z=f(u,v)$ prove

$\left(\frac{\partial z}{\partial x}\right)^2+\left(\frac{\partial z}{\partial y}\right)^2 = 4(u^2+v^2)^{1/2}\left[\left(\frac{\partial z}{\partial u}\right)^2+\left(\frac{\partial z}{\partial v}\right)^2\right]$

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Part 3

Homogeneous - Classwork Questions

By Kunal Navlakhi

Q1) If u is homogeneous of x,y,z of degree n and if $\frac{x^2}{a^2+u}+\frac{y^2}{b^2+u}+\frac{z^2}{c^2+u}=1$ show that $u_x^2+u_y^2+u_z^2=2nu$

Q2) If $u=\frac{x^2y^2z^2}{x^2+y^2+z^2}+\cos\left(\frac{xy+yz}{x^2+y^2+z^2}\right)$ find $x\frac{\partial u}{\partial x}+y\frac{\partial u}{\partial y}+z\frac{\partial u}{\partial z}$ [Ans: $\frac{4x^2y^2z^2}{x^2+y^2+z^2}$]

Q3) If $z=x^n f_1\left(\frac{y}{x}\right)+y^{-n}f_2\left(\frac{x}{y}\right)$ prove that

$x^2\frac{\partial^2 z}{\partial x^2}+2xy\frac{\partial^2 z}{\partial x\partial y}+y^2\frac{\partial^2 z}{\partial y^2}+x\frac{\partial z}{\partial x}+y\frac{\partial z}{\partial y}=n^2z$

Q4) If $z=f(x,y)$ and u,v are homogeneous functions of degree n in x,y prove $x\frac{\partial z}{\partial x}+y\frac{\partial z}{\partial y}=n\left(u\frac{\partial z}{\partial u}+v\frac{\partial z}{\partial v}\right)$

Q5) If $u=\tan^{-1}\left(\frac{x^3+y^3}{x-y}\right)$ prove $x\frac{\partial u}{\partial x}+y\frac{\partial u}{\partial y}=\sin 2u$

Q6) If $u=\operatorname{cosec}^{-1}\sqrt{\frac{x^{1/2}+y^{1/2}}{x^{1/3}+y^{1/3}}}$ prove $x^2\frac{\partial^2 u}{\partial x^2}+2xy\frac{\partial^2 u}{\partial x\partial y}+y^2\frac{\partial^2 u}{\partial y^2}=\frac{\tan u}{144}(13+\tan^2 u)$

Q7) If $u=\sin^{-1}\sqrt{x^2+y^2}$ prove $x^2\frac{\partial^2 u}{\partial x^2}+2xy\frac{\partial^2 u}{\partial x\partial y}+y^2\frac{\partial^2 u}{\partial y^2}=\tan^3 u$

Q8) If $u=f(v)$ where v is homogeneous in x,y in degree n prove $x\frac{\partial u}{\partial x}+y\frac{\partial u}{\partial y}=nvf'(v)$. If $u=\log v$ prove $x\frac{\partial u}{\partial x}+y\frac{\partial u}{\partial y}=n$

Q9) If u is homogeneous in x,y,z of degree n where $u=f(X,Y,Z)$ where $X=\partial u/\partial x$, $Y=\partial u/\partial y$, $Z=\partial u/\partial z$ Prove $X\partial u/\partial X+Y\partial u/\partial Y+Z\partial u/\partial Z=nu/(n-1)$

Q10) Verify Euler's theorem for $u = \frac{x^2+y^2+z^2}{x+y+z}$

Q11) If $f(x,y,z)=0$ where f is homogeneous of degree n then prove $x^2\frac{\partial^2 z}{\partial x^2} = -xy\frac{\partial^2 z}{\partial x \partial y} = y^2\frac{\partial^2 z}{\partial y^2}$

Q12) If $f(x,y)$ and $\phi(x,y)$ are homogeneous of x,y in degree p,q resp. and $u=f+\phi$ prove that
$f(x,y) = \frac{1}{p(p-q)}\left[x^2\frac{\partial^2 u}{\partial x^2} + 2xy\frac{\partial^2 u}{\partial x \partial y} + y^2\frac{\partial^2 u}{\partial y^2}\right] - \frac{q-1}{p(p-q)}\left[x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y}\right]$

Q13) If $x = e^u \tan v$ & $y = e^u \sec v$ find $\left(x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y}\right)\left(x\frac{\partial v}{\partial x} + y\frac{\partial v}{\partial y}\right)$

Q14) If $u = \sin^{-1}\left(\frac{x+y}{\sqrt{x}+\sqrt{y}}\right)$ prove $x^2\frac{\partial^2 u}{\partial x^2} + 2xy\frac{\partial^2 u}{\partial x \partial y} + y^2\frac{\partial^2 u}{\partial y^2} = -\frac{\sin u \cos 2u}{4\cos^3 u}$

Q15) If $u = \frac{x^3+y^3}{y\sqrt{x}} + \frac{1}{x^7}\sin^{-1}\left(\frac{x^2+y^2}{x^2+2xy}\right)$
find $x^2\frac{\partial^2 u}{\partial x^2} + 2xy\frac{\partial^2 u}{\partial x \partial y} + y^2\frac{\partial^2 u}{\partial y^2} + x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y}$ at $(1,2)$
[Ans: $\frac{81+196\pi}{8}$]

Q16) If $u = \frac{f(\theta)}{r}$, $x = r\cos\theta$, $y = r\sin\theta$ prove that
$x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = -u$

Q17) If $u = \sin(\sqrt{x}+\sqrt{y})$ prove $x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} = \frac{\sqrt{x}+\sqrt{y}}{2}\cos(\sqrt{x}+\sqrt{y})$

Q18) Verify Euler's theorem for $f(x,y,z) = 3x^2yz + 5xy^2z + 4z^4$

Q19) Verify Euler's theorem for $f(x,y) = \tan^{-1}\left(\frac{\sqrt{x^2+y^2}}{y}\right)$

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Part 4

Homogeneous - Important Practice Questions

By Kunal Navlakhi

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HOMOGENEOUS FUNCTIONS.

Q1) Do ALL 5 PROOF'S OF EULER'S THEOREM

Q2) If $u = \sin^{-1}(xyz)$ prove $x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} + z\frac{\partial u}{\partial z} = 3\tan u$

Q3) If $z = \log(x^2+y^2) + \frac{x^2+y^2}{x+y} - 2\log(x+y)$ find $x\frac{\partial z}{\partial x} + y\frac{\partial z}{\partial y}$ [Ans: $\frac{x^2+y^2}{x+y}$]

Q4) If $u = \tan^{-1}\left(\frac{x^3+y^3}{x-y}\right)$ prove $x^2\frac{\partial^2 z}{\partial x^2} + 2xy\frac{\partial^2 z}{\partial x \partial y} + y^2\frac{\partial^2 y}{\partial y^2} = 2\sin u\cos 3u$

Q5) If $u = \tan^{-1}\left(\frac{x^3+y^3}{2x+3y}\right)$ prove that :-

$x^2\frac{\partial^2 u}{\partial x^2} + 2xy\frac{\partial^2 u}{\partial x \partial y} + y^2\frac{\partial^2 u}{\partial y^2} = \sin 4u - \sin 2u$

Q6) If $u = \sin^{-1}(x^2+y^2)^{1/5}$ prove $x^2\frac{\partial^2 u}{\partial x^2} + 2xy\frac{\partial^2 u}{\partial x \partial y} + y^2\frac{\partial^2 u}{\partial y^2} = \frac{2}{25}\tan u(2\tan^2 u - 3)$

Q7) If $u = \tan^{-1}\left(\frac{x^2+y^2}{x-y}\right)$ prove $x^2\frac{\partial^2 u}{\partial x^2} + 2xy\frac{\partial^2 u}{\partial x \partial y} + y^2\frac{\partial^2 u}{\partial y^2} = -2\sin^3 u\cos u$

Q8) If $u = \sinh^{-1}\left(\frac{x^3+y^3}{x^2+y^2}\right)$ prove that

$x^2\frac{\partial^2 u}{\partial x^2} + 2xy\frac{\partial^2 u}{\partial x \partial y} + y^2\frac{\partial^2 u}{\partial y^2} = \tanh^3 u$

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