* ATTENDANCE *

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Section: ________ **E-Mail address:** ________________________

MATH 251 (04,06,07), Dr. Z. , Final Exam ,Tue., Dec. 19, 2017, SEC 118, 12:00-3:00pm

WRITE YOUR FINAL ANSWER TO EACH PROBLEM IN THE INDICATED PLACE (right under the question)
Do not write below this line

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1. (out of 12)
2. (out of 12)
3. (out of 12)
4. (out of 12)
5. (out of 12)
6. (out of 12)
7. (out of 12)
8. (out of 12)
9. (out of 12)
10. (out of 12)
11. (out of 12)
12. (out of 12)
13. (out of 12)
14. (out of 12)
15. (out of 12)
16. (out of 12)
17. (out of 8)

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tot. (out of 200)

Important note: Unlike Exams 1 and 2, you are not required to state the type of the answer, and there is no credit for stating the type. But if the given answer is the **wrong type**, you would get 0 points.

Example: Find $f'(2)$ if $f(x) = x^3$. If you give the answer $3x^2$ instead of 12, you would get **zero** points!

Formula that you may (or may not) need

If the surface S is given in **explicit** notation $z = g(x, y)$, above the region of the xy-plane , D, then

$$\int\int_S \mathbf{F} \cdot d\mathbf{S} =$$

$$\int\int_D \left(-P\frac{\partial g}{\partial x} - Q\frac{\partial g}{\partial y} + R \right) dA \quad .$$

1. (12 points) Compute the line-integral

$\int f(r(t)) \cdot \|r'(t)\|$

$$\int_C 7y\,dx + 3x\,dy \quad ,$$

where C is the circle $x^2 + y^2 = 100$ traveled in the clockwise direction.

Ans.: 4π

$0 < r < 10$

$0 < \theta < 2\pi$

$F = \langle 7y, 3x \rangle$

$F(r(t)) = \langle 70\sin\theta, 30\sin\theta \rangle$

$x = 10\cos\theta$

$y = 10\sin\theta$

$r'(t) = \langle -10\sin\theta, 10\cos\theta \rangle$

$f(r(t)) \cdot r'(t) = -700\sin^2\theta + 300\cos^2\theta$

$$-\int_0^{2\pi} 3\cos^2\theta - 7\sin^2\theta \, d\theta$$

$$-\int_0^{2\pi} 3\left(\frac{1+\cos(2\theta)}{2}\right) - 7\left(\frac{1-\cos(2\theta)}{2}\right) d\theta$$

$$-\left(\frac{3}{2}\int_0^{2\pi} 1+\cos(2\theta)\, d\theta - \frac{7}{2}\int_0^{2\pi} 1-\cos(2\theta)\, d\theta\right)$$

$$-\left(\frac{3}{2}\left(\theta + \frac{\sin(2\theta)}{2}\right)\Big|_0^{2\pi} - \frac{7}{2}\left(\theta - \frac{\sin(2\theta)}{2}\right)\Big|_0^{2\pi}\right)$$

$$-\left(\frac{3}{2}\left((2\pi + 0) - (0+0)\right) - \frac{7}{2}\left((2\pi - 0) - (0-0)\right)\right)$$

$$-\left(\frac{6\pi}{2} - \frac{14\pi}{2}\right) = \boxed{4\pi}$$

2. (12 points) Find an equation of the tangent plane to the surface

$$z = x^2 + 3xy + y^2 \quad ,$$

at the point $(1, 1, 5)$.

Ans.: $5x + 5y + y = 15$

$f(x,y) = x^2 + 3xy + y^2$

$\frac{\partial f}{\partial x} = 2x + 3y$

$\frac{\partial f}{\partial y} = 3x + 2y$

$\frac{\partial f}{\partial x}(1,1,5) = 2+3 = 5$

$\frac{\partial f}{\partial y}(1,1,5) = 3+2 = 5$

$5(x-1) + 5(y-1) + y-5) = 0$

$5x - 5 + 5y - 5 + y - 5 = 0$

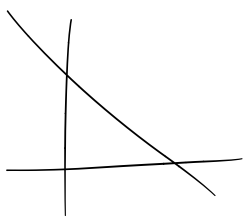
$5x + 5y + y = 15$

3. (12 points) Find the absolute maximum value and the absolute minimum value of the function $f(x, y) = x^2\, y$ in the region

$$\{(x, y) \,|\, 0 \le x \le 1\,,\, 0 \le y \le 1 - x\,\}.$$

Absolute minimum value:

Absolute maximum value:



$\frac{\partial f}{\partial x} = 2xy$

$2xy = 0$

$\frac{\partial f}{\partial y} = x^2$

$x^2 = 0$

$x = 0$

$y = 0$

$(0, 0)$

$g = x^2(1-x)$

$g = x^2 - x^3$

$g' = 2x - 3x^2 = 0$

4. (12 points) Compute $f_{xxyz}(0,0,0)$ (in other words $\frac{\partial^4}{\partial x^2 \partial y \partial z} f(x,y,z)|_{x=0,y=0,z=0}$) if

$$f(x,y,z) = \sin(\, x^2 \; + \; y \; + \; z \,) \quad .$$

Ans.: $f_{xxyz} = 2x\sin(x^2+y+z) + 2\sin(x^2+y+z)$

$f_x = \cos(x^2+y+z) \cdot 2x$

$f_{xx} = -\sin(x^2+y+z) \cdot 2x * 2x + \cos(x^2+y+z) * 2$

$= -2x\sin(x^2+y+z) + 2\cos(x^2+y+z)$

$f_{xxy} = -2x\cos(x^2+y+z) - 2\cos(x^2+y+z)$

$f_{xxyz} = 2x\sin(x^2+y+z) + 2\sin(x^2+y+z)$

5. (12 points) Find $\frac{\partial z}{\partial y}$ at the point $(1, 1, 1)$ if (x, y, z) are related by:

$$xy + xz + yz + x^2y^2z^2 = 4 \quad .$$

Ans.: -3

$$\frac{\partial z}{\partial y} = \quad x + xz' + z + yz' + x^2(2yz^2 + y^2 2zz') = 0$$

$$1 + z' + 1 + z' + 2 + 2 = 0$$

$$2z' + 6 = 0$$

$$2z' = -6$$

$$z' = -3$$

6. (12 points) Find an equation for the plane that contains both the line

$$x = 1 + t\,,\ y = 2 + t\,,\ z = 3 + t \quad (-\infty < t < \infty) \quad ,$$

and the line

$$x = -t\,,\ y = 1 + t\,,\ z = 2 + t \quad (-\infty < t < \infty) \quad .$$

Ans.: $2z - 2y = 2$

$U = (1,1,1) \qquad V = (-1,1,1)$

$$U \times V = \begin{vmatrix} i & j & k \\ 1 & 1 & 1 \\ -1 & 1 & 1 \end{vmatrix} = (1-1)i - (1+1)j + (1+1)k = \langle 0, -2, 2 \rangle$$

$t = 0$

$P_1 = (1, 2, 3)$

$$0(x-1) - 2(y-2) + 2(z-3) = 0$$

$$-2y + 4 + 2z - 6 = 0$$

$$2z - 2y = 2$$

7. (12 points) A certain particle has acceleration given by

$$\mathbf{a}(t) = \langle -4\sin 2t\,,\, -4\cos 2t\,,\, 9e^{3t} \rangle \quad .$$

If its velocity at $t = 0$ is $\langle 2, 0, 3 \rangle$ and its position at $t = 0$ is $\langle 0, 1, 1 \rangle$, finds its position at the time $t = \frac{\pi}{4}$.

Ans.: $\langle 1, 0, e^{3\pi/4} \rangle$

$a(t) = \langle -4\sin(2t), -4\cos(2t), 9e^{3t} \rangle$

$v(t) = \langle 2\cos(2t) + C, -2\sin(2t) + C, 3e^{3t} + C \rangle$

$v(0) = \langle 2 + C, 0 + C, 3 + C \rangle \quad C = 0$

$v(t) = \langle 2\cos(2t), -2\sin(2t), 3e^{3t} \rangle$

$r(t) = \langle \sin(2t) + C, \cos(2t) + C, e^{3t} + C \rangle$

$r(0) = \langle 0 + C, 1 + C, 1 + C \rangle \quad C = 0$

$r(\pi/4) = \langle \sin(\pi/2), \cos(\pi/2), e^{3\pi/4} \rangle$

$= \langle 1, 0, e^{3\pi/4} \rangle$

8. (12 points) Compute the (scalar-function) line-integral

$$\int_C (x + y + 2z)\, ds$$

$\int_a^b f(x(t), y(t), z(t)) \cdot \|r'(t)\| \, dt$

where the curve C is given by the parametric equation:

$$\mathbf{r}(t) = \langle t, 2t, 2t \rangle \quad , \quad 0 \le t \le 1 \quad .$$

Ans.: $\frac{21}{2}$

$r'(t) = \langle 1, 2, 2 \rangle$

$\|r'(t)\| = \sqrt{1+4+4} = \sqrt{9} = 3$

$3\int_0^1 (t + 2t + 4t)\, dt$

$3\left(\frac{t^2}{2} + t^2 + 2t^2 \Big|_0^1\right) = \frac{1}{2} + 1 + 2 = 3\left(\frac{7}{2}\right)$

$= \frac{21}{2}$

9. (12 points)

If

$$\lim_{(x,y,z)\to(1,1,1)} f(x,y,z) = 1 \quad , \quad \lim_{(x,y,z)\to(1,1,1)} g(x,y,z) = 2$$

compute

$$\lim_{(x,y,z)\to(1,1,1)} \sin\left(\frac{\pi}{3} f(x,y,z)\right) \cos\left(\frac{\pi}{4} g(x,y,z)\right)$$

Ans.: 0

$$\lim_{x,y,z \to (1,1,1)} \sin\left(\frac{\pi}{3}\right) \cos\left(\frac{\pi}{4} \cdot 2\right)$$

$$= \frac{\sqrt{3}}{2} \cdot 0 = 0$$

10. (12 points) Compute

$$\iint_S \mathbf{F} \cdot d\mathbf{S}\ , \quad = \iint \left(-P\frac{\partial g}{\partial x} - Q\frac{\partial g}{\partial y} + R\right) dA$$

where

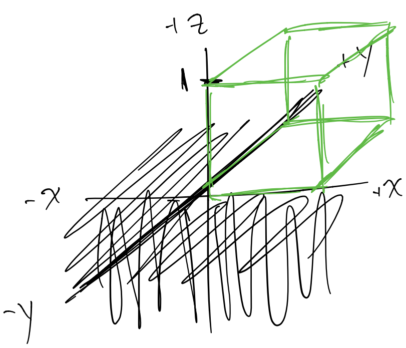
$$\mathbf{F} = \langle x^2 + \sin(y+z)\,,\, y^2 + xz^3\,,\, z^2 + e^{xy}\,\rangle$$

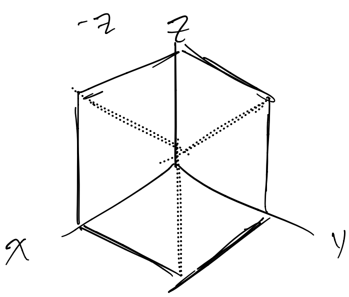
and where S is the boundary (consisting of all six faces) of the cube

$$\{(x,y,z)\,|\,0 \le x, y, z \le 1\}$$

with the normal pointing **outward**.

Ans.:





$$\int_0^1\int_0^1 -(x^2+\sin(y+z)(2x)) - (y^2+xz^3)(2y) + z^2+e^{xy}$$

$$\int_0^1\int_0^1 -(x^2+2x\sin(y+z)) - (2y^3+2xyz^3) + z^2+e^{xy}$$

$$\int_0^1\int_0^1 -x^2-2x\sin(y+z)-2y^3-2xyz^3+z^2+e^{xy}\,dx\,dy$$

$$= \int_0^1 \left(-\frac{x^3}{3} - x^2\sin(y+z) - 2xy^3 - x^2yz^3 + xz^2 + e^{xy}\Big|_0^1\right)$$

$$= \int_0^1 -\frac{1}{3} - \sin(y+z)$$

11. (12 points) By finding a function f such that $\mathbf{F} = \nabla f$, evaluate $\int_C \mathbf{F} \cdot d\mathbf{r}$ along the given curve C.

$$\mathbf{F}(x, y, z) = \langle 2e^{2x+3y+4z}, 3e^{2x+3y+4z}, 4e^{2x+3y+4z} \rangle \quad ,$$

$$C : x = t \quad , \quad y = 2t \quad , \quad z = t^2 \quad , \quad 0 \le t \le 1 \quad .$$

$r(t) = \langle t, 2t, t^2 \rangle$

Ans: $2e^{12} - 2e$

$f(x,y,z) = \int 2e^{2x+3y+4z}\, dx = e^{2x+3y+4z} + g(y,z)$

$\frac{\partial}{\partial y}\left(e^{2x+3y+4z} + g(y,z)\right) = e^{2x+3y+4z} \cdot 3 + g_y(y,z)$

$3e^{2x+3y+4z} + g_y(y,z) = 3e^{2x+3y+4z} \quad \therefore \; g_y(y,z) = 0$

$g(y,z) = c + h(z)$

$\frac{\partial}{\partial z}\left(c + h(z)\right) = h'(z) = 4e^{2x+3y+4z}$

$\therefore \; h(z) = e^{2x+3y+4z}$

potential function: $f(x,y,z) = 2e^{2x+3y+4z}$

$r(0) = (0,0,0) \quad r(1) = (1,2,1)$

$f(1,2,1) - f(0,0,0) = 2e^{2+6+4} - 2e$

$= 2e^{12} - 2e$

12. (12 points) Evaluate the line integral

$$\int_C 5y\,dx + 5x\,dy + 6z\,dz \quad ,$$

where $C : x = t^2\,,\; y = t\,,\; z = t^2\,,\; 0 \le t \le 1.$

Ans.: 8

$$\int_0^1 5(t)\cdot 2t\,dt + 5(t^2)\,dt + 6(t^2)\cdot 2t\,dt$$

$$= \int_0^1 10t^2 + 5t^2 + 12t^3\,dt = 10\frac{t^3}{3} + 5\frac{t^3}{3} + 3t^4 \Big|_0^1$$

$$= \left(\frac{10}{3} + \frac{5}{3} + \frac{9}{3}\right) - (0)$$

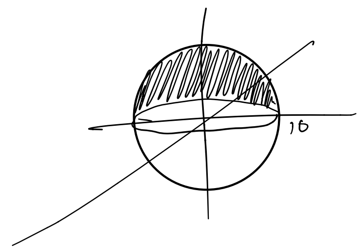
$$= 8$$

13. (12 points) Evaluate

$$\iiint_E \frac{1}{\sqrt{x^2+y^2+z^2}}\, dV \quad ,$$

where E is the hemisphere

$$\{(x,y,z)\,|\,x^2+y^2+z^2 \leq 100, z < 0\} \quad .$$



Ans.: 100π

$0 < \rho < 10$

$0 < \theta < 2\pi$

$\pi/2 < \phi < \pi$

$$\int_{\pi/2}^{\pi}\int_0^{2\pi}\int_0^{10} \frac{1}{\sqrt{\rho^2}} \quad \rho^2 \sin\phi \, d\rho \, d\theta \, d\phi$$

$$\int_{\pi/2}^{\pi}\int_0^{2\pi}\int_0^{10} \rho \sin\phi \, d\rho \, d\theta \, d\phi$$

$$\int_0^{10} \rho \sin\phi \, d\rho = \frac{\rho^2}{2} \sin\phi \Big|_0^{10} = 50 \sin\phi$$

$$\int_0^{2\pi} 50 \sin\phi \, d\theta = 50\theta \sin\phi \Big|_0^{2\pi} = 100\pi \sin\phi$$

$$\int_{\pi/2}^{\pi} 100\pi \sin\phi \, d\phi = -100\pi \cos\phi \Big|_{\pi/2}^{\pi} = -100\pi(-1-0)$$

$$= 100\pi$$

14. (12 points) Evaluate the quadruple integral

$$\int\int\int\int_E 360\, x\, dV \quad ,$$

where

$$E = \{(x, y, z, w) \,|\, 0 \le w \le 1\,,\; 0 \le z \le w\,,\; 0 \le y \le z\,,\; 0 \le x \le y\} \quad .$$

Ans.: 3

$$\int_0^1 \int_0^w \int_0^z \int_0^y 360x \; dx\, dy\, dz\, dw$$

$$\int_0^y 360x\,dx = 180x^2 \Big|_0^y = 180y^2$$

$$\int_0^z 180y^2\,dy = 60y^3 \Big|_0^z = 60z^3$$

$$\int_0^w 60z^3\,dz = 15z^4 \Big|_0^w$$

$$\int_0^1 15w^4 = 3w^5 \Big|_0^1 = 3-0 = \boxed{3}$$

15. (12 points) Find the Jacobian of the transformation from (u, v)-space to (x, y)-space.

$$x = 3\sin(2u+v) \quad , \quad y = u+v+\cos(u+v) \quad ,$$

at the point $(u, v) = (0, 0)$.

Ans.: -3

$$\begin{vmatrix} \frac{\partial x}{\partial u} & \frac{\partial x}{\partial v} \\ \frac{\partial y}{\partial u} & \frac{\partial y}{\partial v} \end{vmatrix} =$$

$$(3\cos(2u+v)\cdot 2\cdot(1-\sin(u+v)))-(3\cos(2u+v)\cdot(1-\sin(u+v)))$$

$$(6\cos(0)\cdot(1-\sin(0)))-(3\cos(0)\cdot 1-\sin(0))$$

$$(6\cdot 0)-(3\cdot(1-0))$$

$$0 - 3$$

$$\text{Jac} = -3$$

16. (12 points) Find the local maximum and minimum **points** and saddle point(s) of the function $f(x, y) = x^3 + y^2 - 6xy$

Local maximum points(s):

Local minimum points(s):

saddle point(s):

$f_x = 3x^2 - 6y$

$f_y = 2y - 6x$

$f_{xx} = 6x$

$f_{yy} = 2$

$f_{xy} = -6$

$3x^2 - 6y = 0$

$3x^2 = 6y$

$x^2 = 2y$

$y = \frac{x^2}{2}$

$y = \frac{36}{2} = 18$

$2y - 6x = 0$

$2\left(\frac{x^2}{2}\right) = 6x$

$x^2 = 6x$

$x = 6$

$(6, 18)$

$f_{xx}(6,18) = 36$

$f_{yy}(6,18) = 2$

$f_{xy}(6,18) = -6$

$D = 72 - 36 = 36 > 0$

$(6,18)$ LOCAL MAX

17. (8 points) Use the Divergence Theorem to calculate the surface integral $\int\int_S \mathbf{F} \cdot d\,\mathbf{S}$, where

$$\mathbf{F}(x, y, z) = \langle\, x + y, y + z \,,\, x + z \,\rangle \quad ,$$

where S is the sphere (center $(1, -2, 4)$ and radius 10), in other words the region in 3D space:

$$\{(x, y, z) \,|\, (x-1)^2 \,+\, (y+2)^2 \,+\, (z-4)^2 = 100\} \quad .$$

$\operatorname{div} F = 1 + 1 + 1 = 3$

$$3 \int_0^{\pi} \int_0^{2\pi} \int_0^{10} \rho^2 \sin\phi \, d\rho \, d\theta \, d\phi$$

$$3 \int_0^{\pi} \sin\phi \, d\phi \int_0^{2\pi} d\phi \int_0^{10} \rho^2 \, d\rho$$

$$3 \left(-\cos\phi \Big|_0^{\pi} \right) \left(\theta \Big|_0^{2\pi} \right) \left(\frac{\rho^3}{3} \Big|_0^{10} \right)$$

$$\cancel{3} \left(1 + 1 \right) \left(2\pi \right) \left(\frac{1000}{\cancel{3}} \right)$$

4000π