

MATB42: Assignment #7

1. (a) Find an equation of the tangent plane to the surface S defined parametrically by $\Phi(u, v) = (u^2 + v, v, u + v^2)$ at the point $(9, 0, 3)$.

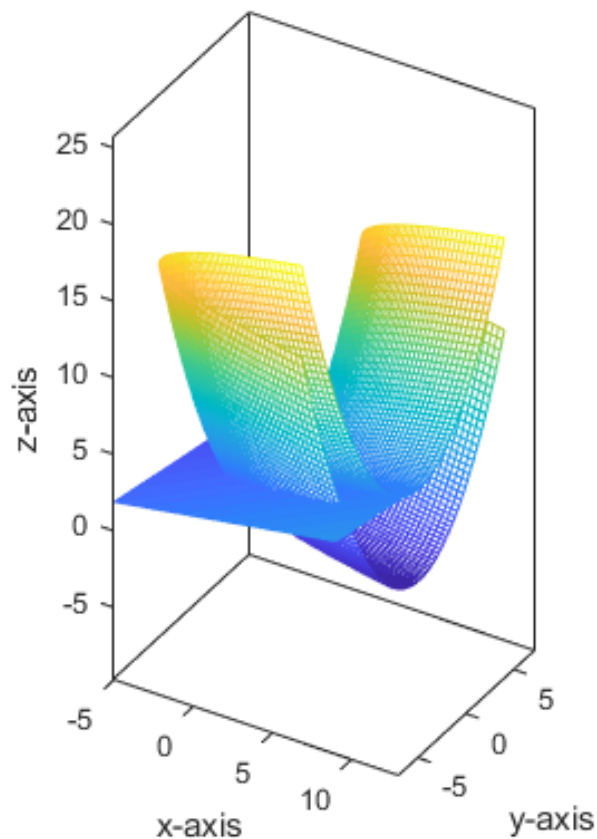
$$v = 0 \qquad u + v^2 = 3 \implies u = 3$$

$$\begin{aligned}\phi_u &= (2(3), 0, 1) \\ \phi_v &= (1, 1, 2(0)) \\ \phi_u \times \phi_v &= (-1, 1, 6)\end{aligned}$$

So the tangent plane can be given by

$$\begin{aligned}0 &= ((x - 9, y, z - 3) \cdot (-1, 1, 6)) \\ 0 &= (9 - x + y + 6z - 18) \\ 9 &= -x + y + 6z\end{aligned}$$

- (b) Use symbolic algebra software to sketch the surface S and its tangent plane from part (a).



2. Use a surface integral to find the area of the triangle in \mathbb{R}^3 with vertices $(1, 1, 0)$, $(1, 2, 1)$ and $(3, 3, 2)$.
3. Calculate the surface area of the piece of the cone $x^2 + y^2 - z^2 = 0$ which lies outside the cylinder $x^2 + y^2 = 4$.

4. (a) Find the area of the portion of the unit sphere that is cut out by the cone $z = \sqrt{x^2 + y^2}$.
(cf. page 391, #10)
- (b) Find the area of the portion of the cone $z = \sqrt{x^2 + y^2}$ that is cut out by the unit sphere.
5. Let $\Phi : D \subset \mathbb{R}^2 \rightarrow \mathbb{R}^3$ be a parametrization of a 2-dim surface S in \mathbb{R}^3 .

(a) Set

$$E = \|\phi_u\|^2, \quad F = \phi_u \cdot \phi_v, \quad G = \|\phi_v\|^2,$$

Show that the surface area of S is

$$A(S) = \iint_D \sqrt{EG - F^2} dA$$

$$\begin{aligned} \iint_D \sqrt{EG - F^2} dA &= \iint_D \sqrt{\|\phi_u\|^2 \|\phi_v\|^2 - (\phi_u \cdot \phi_v)^2} dA \\ &= \iint_D \sqrt{(\|\phi_u\| \|\phi_v\|)^2 - (\|\phi_u\| \|\phi_v\| \cos \theta)^2} dA \quad \text{Where } \theta \text{ is the angle between } \phi_u \text{ and } \phi_v. \\ &= \iint_D \sqrt{(\|\phi_u\| \|\phi_v\|)^2 (1 - \cos^2 \theta)} dA \\ &= \iint_D \sqrt{(\|\phi_u\| \|\phi_v\|)^2 (\sin^2 \theta)} dA \\ &= \iint_D \sqrt{\|\phi_u \times \phi_v\|^2} dA \\ &= \iint_D \|\phi_u \times \phi_v\| dA \\ &= \int_{\Phi} 1 dS \end{aligned}$$

- (b) What does the formula for $A(S)$ become if the vectors ϕ_u and ϕ_v are orthogonal?
If the vectors are orthogonal, then the dot product is 0, so the equation reduces to

$$A(S) = \iint_D \|\phi_u\| \|\phi_v\| dA$$

- (c) Use parts (a) and (b) to compute the surface area of a sphere of radius a .
(cf. Marsden & Tromba, page 399, # 23.)

$$\begin{aligned} \Phi(\theta, \varphi) &= a(\cos \theta \sin \varphi, \sin \theta \sin \varphi, \cos \varphi) \\ \phi_\theta &= a(-\sin \theta \sin \varphi, \cos \theta \sin \varphi, 0) \\ \phi_\varphi &= a(\cos \theta \cos \varphi, \sin \theta \cos \varphi, -\sin \varphi) \\ \|\phi_\theta\| &= a \sin \varphi, \quad \|\phi_\varphi\| = a \\ \implies A(S) &= a^2 \int_0^{2\pi} \int_0^\pi \sin \varphi d\varphi d\theta \\ &= a^2 \int_0^{2\pi} \left[-\cos \varphi \right]_0^\pi d\theta \\ &= a^2 \int_0^{2\pi} -(-1 - 1) d\theta \\ &= a^2 2 \int_0^{2\pi} 1 d\theta \\ &= 4\pi a^2 \end{aligned}$$

6. For each of the following surfaces S , sketch S (using symbolic software) and evaluate the surface integral $\int_S f \, dS$, where $f(x, y, z) = x$.

- (a) S is that part of the surface $y = 4 - x^2$ between $z = 0$ and $z = 1$, with $y \geq 0$.

$$y \geq 0 \implies 4 - x^2 \geq 0 \implies x^2 \leq 4 \implies |x| < 2$$

$$\Phi(x, z) = (x, 4 - x^2, z)$$

$$\phi_x = (1, -2x, 0), \phi_z = (0, 0, 1)$$

$$\phi_x \times \phi_z = (-2x, -1, 0) \implies \|\phi_x \times \phi_z\| = \sqrt{4x^2 + 1}$$

$$\int_S f \, dS = \int_0^1 \int_{-2}^2 x \sqrt{4x^2 + 1} \, dx \, dz$$

The integrand is odd since x odd and $\sqrt{4x^2 + 1}$ even, so the integral over x is 0, making the entire integral 0.

- (b) S is the upper half of the unit sphere centered at the origin.

$$\Phi(\theta, \varphi) = (\cos \theta \sin \varphi, \sin \theta \sin \varphi, \cos \varphi)$$

$$\phi_\theta = (-\sin \theta \sin \varphi, \cos \theta \sin \varphi, 0)$$

$$\phi_\varphi = (\cos \theta \cos \varphi, \sin \theta \cos \varphi, -\sin \varphi)$$

$$\phi_\theta \times \phi_\varphi = (-\cos \theta \sin^2 \varphi, -\sin \theta \sin^2 \varphi, -\sin^2 \theta \sin \varphi \cos \varphi - \cos^2 \theta \sin \varphi \cos \varphi)$$

$$= (-\cos \theta \sin^2 \varphi, -\sin \theta \sin^2 \varphi, -\sin \varphi \cos \varphi)$$

$$\|\phi_\theta \times \phi_\varphi\| = \sqrt{\cos^2 \theta \sin^4 \varphi + \sin^2 \theta \sin^4 \varphi + \sin^2 \varphi \cos^2 \varphi}$$

$$= \sqrt{\sin^4 \varphi + \sin^4 \varphi + \sin^2 \varphi \cos^2 \varphi}$$

- (c) S is that part of the surface $x = \sin y$ with $0 \leq y \leq \pi$ and $0 \leq z \leq 2$.

7. Find the mass of the metallic surface S given by $z = 1 - \frac{x^2 + y^2}{2}$ with $0 \leq x \leq 1$, $0 \leq y \leq 1$, if the mass density at $(x, y, z) \in S$ is given by $m(x, y, z) = xy$.