1. *(24 pts)* The function $f : \mathbb{R}^2 \to \mathbb{R}^3$ is defined by $f(x,y) = (xy^3, ye^x, x+y) = (f_1, f_2, f_3)$. (A) Show that f is differentiable. (B) Compute $D_{\vec{v}} f(\vec{a})$ with $\vec{a} = (0,2)$ and $\vec{v} = (1,3)$. (C) Considering the surface with equation $z = f_2(x,y)$ at the point where $x = 0$ and $y = 2$, in what direction is z increasing the fastest, and how steep is the surface in that direction?

2. *(20 pts)* The functions $f : \mathbb{R}^2 \to \mathbb{R}^2$ and $g : \mathbb{R}^2 \to \mathbb{R}^3$ are defined by $f(x,y) = (xy, x+y)$ and $g(x,y) = (2xy, x^2 - xy, x^3)$. (A) *Without composing these functions directly*, find the Jacobian matrix for the composition $h(x,y) = (g \circ f)(x,y) = (h_1, h_2, h_3)$ at the point $(1,2)$. (B) Does the curve with equation $h_2(x,y) = h_2(1,2)$ allow for viewing y as a function of x near $(1,2)$?

3. *(16 pts)* The region R is the tetrahedron with vertices at $(0,0,1)$, $(0,0,2)$, $(1,1,0)$, and $(-1,1,0)$. Mass is distributed through R with density $\delta(x,y,z) = 1 + \sin(xyz)$. Write (but do not evaluate) a triple nested (iterated) integral representing the mass in the region R.

4. *(24 pts)* In uvw-space, the line segment S goes from $(0,0,0)$ to $(1,2,3)$. The solid M has horizontal ($w = c$) cross sections that are disks of radius 2 with their centers all on S. The image of M by the linear transformation $L(u,v,w) = (u - \frac{1}{3}w, v - \frac{2}{3}w, w) = (x,y,z)$ is a right cylinder R in xyz-space whose axis is the z-axis. (A) Compute the Jacobian determinant of L. (B) Compute $\iiint_M u\,du\,dv\,dw$.

5. *(16 pts)* The hyperbolic paraboloid H has equation $z = 6 + 2y^2 - x^2$. The solid ellipse E in the xy-plane is described by $x^2 + 4y^2 \leq 4$. A potato chip is in the shape P that is the part of H sitting above E. (A) Write (but do not yet evaluate) a double nested (iterated) integral representing the area of P.
(Bonus *(10 pts)*:) Compute the area of P.