1. Find the volume of the parallelepiped with edges \((3, 2, 0), (-1, 1, 2)\) and \((0, 4, 1)\).

   a. -23
   b. -19
   c. 19
   d. 21
   e. 23

2. Find the unit tangent vector \(\hat{T}\) to the curve \(\vec{r}(t) = (3t, 2t^2, 4t^3)\) at the point \(\vec{r}(1) = (3, 2, 4)\).

   a. \(\left( \frac{3}{13}, \frac{4}{13}, \frac{12}{13} \right)\)
   b. \(\left( \frac{3}{\sqrt{29}}, \frac{4}{\sqrt{29}}, \frac{12}{\sqrt{29}} \right)\)
   c. \(\left( \frac{3}{169}, \frac{4}{169}, \frac{12}{169} \right)\)
   d. \(\left( \frac{3}{29}, \frac{4}{29}, \frac{12}{29} \right)\)
   e. \(\left( \frac{3}{169}, -\frac{4}{169}, \frac{12}{169} \right)\)
3. If a jet flies around the world from East to West, directly above the equator, in what direction does the unit binormal $\hat{B}$ point?
   a. North
   b. South
   c. East
   d. West
   e. Down (toward the center of the earth)

4. At the point $(x,y,z)$ where the line $\vec{r}(t) = (2 + t, 3 - t, t)$ intersects the plane $2x - y + z = 5$, we have $x + y + z =$
   a. 2
   b. 3
   c. 4
   d. 5
   e. 6

5. The temperature in an ideal gas is given by $T = \kappa \frac{P}{\rho}$ where $\kappa$ is a constant, $P$ is the pressure and $\rho$ is the density. At a certain point $Q = (1,2,3)$, we have
   $P(Q) = 4 \quad \vec{\nabla}P(Q) = (-3,2,1)$
   $\rho(Q) = 2 \quad \vec{\nabla}\rho(Q) = (3,-1,2)$
   So at the point $Q$, the temperature is $T(Q) = 2\kappa$ and its gradient is $\vec{\nabla}T(Q) =$
   a. $\kappa(-4.5,0,2.5)$
   b. $\kappa(1.5,0,2.5)$
   c. $\kappa(1.5,2,-4.5)$
   d. $\kappa(-4.5,2,-1.5)$
   e. $\kappa(-1.5,2,2.5)$
6. The saddle surface \( z = xy \) may be parametrized as \( R(u, v) = (u, v, uv) \). Find the plane tangent to the surface at the point \( (1, 2, 2) \).

- a. \( 3x + y - z = 3 \)
- b. \( 2x + y - z = 2 \)
- c. \( 3x + 2y - z = 5 \)
- d. \( 2x - y + z = 2 \)
- e. \( 3x - y + z = 3 \)

7. Find the minimum value of the function \( f = x^2 + y^2 + z^2 \) on the plane \( x + 2y + 3z = 14 \).

- a. 0
- b. \( \frac{7}{4} \)
- c. \( \frac{7}{2} \)
- d. 14
- e. 28
8. Compute \( \int_0^3 \int_y^9 y \cos(x^2) \, dx \, dy \)

a. \( \frac{1}{4} \sin 81 \)

b. \( \frac{1}{2} \cos 9 - \frac{1}{2} \)

c. \( \frac{9}{2} \sin 81 + \cos 9 - 1 \)

d. \( -\frac{9}{2} \sin 81 + \frac{9}{2} \sin y^4 \)

e. \( \frac{9}{2} \sin 81 - \cos 9 + 1 \)

9. Compute \( \iiint z^2 \, dV \) over the solid sphere \( x^2 + y^2 + z^2 \leq 4 \).

a. \( \frac{64\pi}{5} \)

b. \( \frac{256\pi}{3} \)

c. \( \frac{48\pi}{5} \)

d. \( \frac{64\pi}{15} \)

e. \( \frac{128\pi}{15} \)

10. Compute \( \iint \vec{F} \cdot d\vec{S} \) for \( \vec{F} = (x, y^3, z) \) over the surface of the cube \( 0 \leq x \leq 1, \quad 0 \leq y \leq 1, \quad 0 \leq z \leq 1 \) with outward normal.

a. 1

b. 2

c. 3

d. 4

e. 6
11. (15 points) Find the area of the diamond shaped region between the curves 
\[ y = e^x, \quad y = \frac{1}{4} e^x, \quad y = e^{-x} \quad \text{and} \quad y = 4e^{-x}. \]
You must use the curvilinear coordinates \( u = ye^{-x} \) and \( v = ye^x \).
12. (10 points) Find the mass of a wire in the shape of the curve \( y = \ln(\cos x) \) for \( 0 \leq x \leq \frac{\pi}{4} \) if the density is \( \rho = \frac{\sin x}{e^y} \).

Note: The wire may be parametrized as \( \vec{r}(t) = (t, \ln(\cos t)) \).
13. (10 points) Compute \( \int x \, dx + z \, dy - y \, dz \) around the boundary of the triangle with vertices \((0,0,0), (0,1,0), (0,0,1)\), traversed in this order of the vertices. Hint: The \(yz\)-plane may be parametrized as \( \vec{R}(u,v) = (0,u,v) \).
14. (15 points) Compute \[ \iiint_{S} \nabla \times \vec{F} \cdot d\vec{S} \]

for \( \vec{F} = (x^2y, y^2z, z^2) \) over the piece of the sphere \( x^2 + y^2 + z^2 = 25 \) for \( 0 \leq z \leq 4 \) with normal pointing away from the \( z \)-axis.

Hint: Parametrize the upper and lower edges.