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- Start by printing your name in the above box and check your section in the box to the left.
- Do not detach pages from this exam packet or unstaple the packet.
- Please write neatly. Answers which are illegible for the grader can not be given credit.
- **Show your work.** Except for problems 1-2, we need to see details of your computation.
- No notes, books, calculators, computers, or other electronic aids can be allowed.
- You have 90 minutes time to complete your work.

1		20
2		10
3		10
4		10
5		10
6		10
7		10
8		10
9		10
Total:		100

Problem 1) TF questions (20 points)

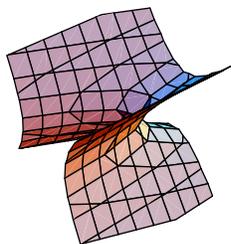
Mark for each of the 20 questions the correct letter. No justifications are needed.

- 1) T F For a moving frame $(\vec{T}, \vec{N}, \vec{B})$, (remember that \vec{T} is the unit tangent vector, \vec{N} is the normal vector and \vec{B} is the binormal vector), one always has $\vec{B} \cdot (\vec{T} \times \vec{N}) = 1$.
- 2) T F For any three points P, Q, R in space, $\vec{PQ} \times \vec{PR} = \vec{QP} \times \vec{RP}$
- 3) T F The triangle defined by the three points $(-1, 0, 2), (-4, 2, 1), (1, -1, 2)$ has a right angle.
- 4) T F Any two distinct non-parallel planes intersect in a line.
- 5) T F $\vec{u} \times \vec{u} = 0$ implies $\vec{u} = \vec{0}$.
- 6) T F The level curves $f(x, y) = 1$ and $f(x, y) = 2$ of a smooth function f never intersect.
- 7) T F For any vector \vec{v} we have $P_i(P_j(\vec{v})) = \vec{0}$.
- 8) T F $(\vec{j} \times \vec{i}) \times \vec{i} = \vec{k} \times (\vec{i} \times \vec{k})$
- 9) T F If a parametrized curve $\vec{r}(t)$ lies in a plane and the velocity $\vec{r}'(t)$ is never zero, then the normal vector $\vec{N}(t)$ also lies in that plane.
- 10) T F The angle between $\vec{r}'(t)$ and $\vec{r}''(t)$ is always 90 degrees.
- 11) T F If \vec{v}, \vec{w} are two nonzero vectors, then the projection vector $P_{\vec{w}}(\vec{v})$ can be longer than \vec{v} .
- 12) T F A line intersects an ellipsoid in at most 2 distinct points.
- 13) T F For any vectors \vec{v} and \vec{w} , the formula $(\vec{v} - \vec{w}) \cdot P_{\vec{w}}(\vec{v}) = 0$ holds.
- 14) T F Let S be a plane normal to the vector \vec{n} , and let P and Q be points not on S . If $\vec{n} \cdot \vec{PQ} = 0$, then P and Q lie on the same side of S .
- 15) T F The vectors $\langle 2, 2, 1 \rangle$ and $\langle 1, 1, -4 \rangle$ are perpendicular.
- 16) T F $\|\vec{v} \times \vec{w}\| = \|\vec{v}\| \|\vec{w}\| \cos(\alpha)$, where α is the angle between \vec{v} and \vec{w} .
- 17) T F The vector $\vec{i} \times (\vec{j} \times \vec{k})$ has length 1.
- 18) T F The distance between the z -axis and the line $x - 1 = y = 0$ is 1.

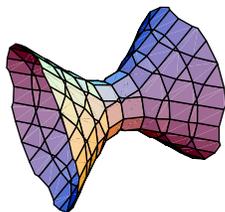
- 19) T F There is a quadric surface which both hyperbola and parabola appear as traces. Traces are intersections of the surface with the coordinate planes $x = 0$, $y = 0$, or $z = 0$.
- 20) T F The equation $x^2 + y^2 - z^2 = -1$ defines a one-sheeted hyperboloid.

Problem 2) (10 points)

Match the equation with the pictures. No justifications are necessary in this problem.



I



II

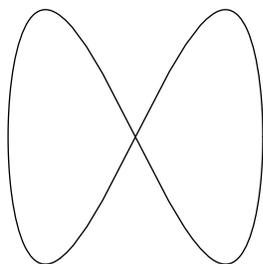


III

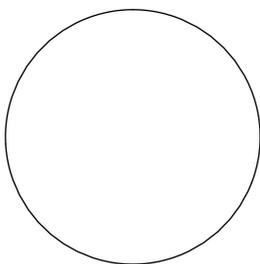


IV

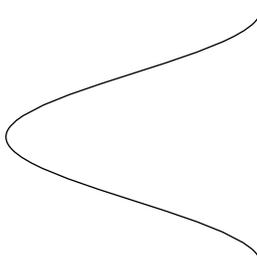
Enter I,II,III,IV here	Equation
	$x + y^2 - z^2 - 1 = 0$
	$-x^2 + y^2 + z^2 - 1 = 0$
	$-x^2 + y^2 + z^2 + 1 = 0$
	$-x + y^2 + z^2 + 1 = 0$



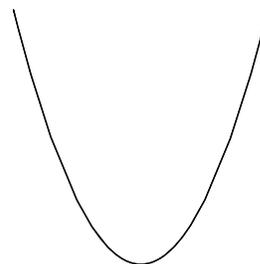
1



2

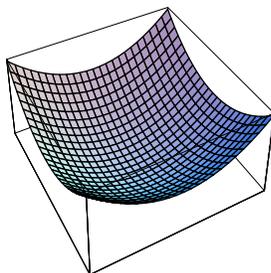


3

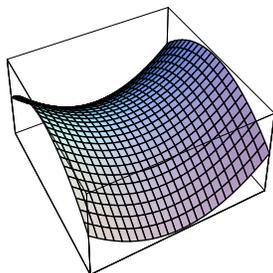


4

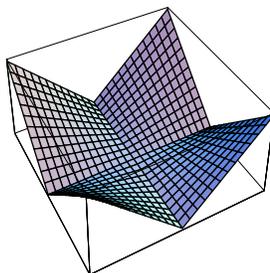
Enter 1,2,3,4 here	Equation
	$\langle \cos(t), \sin(t) \rangle$
	$\langle \cos(t), t \rangle$
	$\langle \cos(t), \cos^2(t) \rangle$
	$\langle \cos(t), \sin(2t) \rangle$



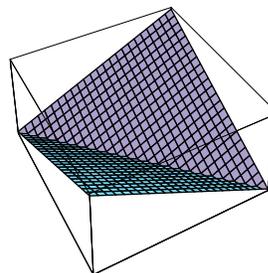
A



B



C



D

Enter A,B,C,D here	Equation
	$f(x, y) = x^2 - y^2$
	$f(x, y) = x + y $
	$f(x, y) = x^2 + y^2$
	$f(x, y) = xy $

Problem 3) (10 points)

Imagine the planet Earth as the unit sphere in 3D space centered at the origin. An asteroid is approaching from the point $P = (0, 4, 3)$ along the path

$$\vec{r}(t) = \langle (4 - t) \sin(t), (4 - t) \cos(t), 3 - t \rangle .$$

- a) When and where will it first hit the Earth?
 b) What velocity will it have at the impact?



Problem 4) (10 points)

Find the distance between the z -axis and the line

$$L : \frac{x + 2}{4} = \frac{y - 1}{3} = \frac{z}{2} .$$

Problem 5) (10 points)

- a) Find a parametrization $\vec{r}(t)$ of the line which is the intersection of the two planes

$$4x + 6y - z = 1$$

and

$$4x + z = 0 .$$

- b) Find the point on the line which is closest to the origin.

Hint. What relation between $\vec{r}(t)$ and \vec{v} (a vector in the line) assures that \vec{r} is closest to the origin?

Problem 6) (10 points)

Consider the parameterized curve

$$\vec{r}(t) = \langle e^t + e^{-t}, 2 \cos(t), 2 \sin(t) \rangle .$$

Find the arc length of this curve from $t = 0$ to $t = 4$.

Problem 7) (10 points)

The set of points P for which the distance from P to $A = (1, 2, 3)$ is equal to the distance from P to $B = (5, 8, 5)$ forms a plane S .

a) Find the equation $ax + by + cz = d$ of the plane S .

b) Find the distance from A to S .

Problem 8) (10 points)

The Swiss tennis player Roger Federer hits the ball at the point $\vec{r}(0) = (0, 0, 3)$. The initial velocity is $\vec{r}'(0) = \langle 100, 10, 13 \rangle$. The tennis ball experiences a constant acceleration $\vec{r}''(t) = \langle 2, 0, -32 \rangle$ which is due to the combined force of gravity and a constant wind in the x direction.



a) Where does the tennis ball hit the ground $z = 0$?

b) What is the z -component = (projection onto z vector) $P_{\vec{k}}(\vec{r}'(t))$ of the ball velocity at the impact?

Problem 9) (10 points)

a) (6 points) Parameterize the intersection of the ellipsoid

$$\frac{x^2}{4} + \frac{y^2}{4} + \frac{z^2}{9} = 2$$

with the plane $z = 3$.

b) (4 points) What is the curvature of the curve at the point $(2, 0, 3)$?

Hint. While you can use the curvature formula $\kappa(t) = \frac{|\vec{r}'(t) \times \vec{r}''(t)|}{|\vec{r}'(t)|^3}$ you are also allowed to cite a fact which you know about the curvature.