

Calculus III
Homework # 1

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Chapter 1

Lab 2 - 13.1 Apps

1.1 Work

Question 1

Let $\vec{T}_1$ represent the tension of the leftmost cable, while $\vec{T}_2$ encodes the tension force experienced by the rightmost cable. Our coordinate system will originate at the intersection of the two cables.

$$\vec{T}_1 := \langle \|\vec{T}_1\|; 135^\circ \rangle$$

$$\vec{T}_2 := \langle \|\vec{T}_2\|; 15^\circ \rangle$$

$$500 = \|\vec{T}_1\| \sin 135^\circ + \|\vec{T}_2\| \sin 15^\circ$$

$$0 = \|\vec{T}_1\| \cos 135^\circ + \|\vec{T}_2\| \cos 15^\circ$$

$$\Rightarrow 500 = \|\vec{T}_1\| \frac{\sqrt{2}}{2} + \|\vec{T}_2\| \cdot 0.258819045103$$

$$\Rightarrow 0 = \|\vec{T}_1\| \frac{-\sqrt{2}}{2} + \|\vec{T}_2\| \cdot 0.965925826289$$

Solving the system numerically yields:

$$\|\vec{T}_1\| \Rightarrow 557.677 \text{ lb}$$

$$\|\vec{T}_2\| \Rightarrow 408.248 \text{ lb}$$

This corresponds to answer choice A

Question 2

Let $\vec{T}$ represent the tension in the cable, and $\vec{C}$ represent the compression force experienced by the boom in neutralizing the horizontal component of $\vec{T}$.

$$\vec{T} := \langle \|\vec{T}\|; 142^\circ \rangle$$

$$\|\vec{T}\| \sin 142^\circ = 450 \text{ lb}$$

$$\|\vec{T}\| = \frac{450 \text{ lb}}{\sin 142^\circ}$$

$$\|\vec{T}\| \Rightarrow 730.921 \text{ lb}$$

$$\|\vec{C}\| = (\|\vec{T}\| \cos 142^\circ) \Rightarrow 575.973 \text{ lb}$$

This corresponds to answer choice C

Question 3

Let the x' -axis of the new coordinate system be oriented along the unit vector $\hat{u} = \hat{T}_1$:

$$\vec{T}_1 := \langle 3600, 0 \rangle$$

$$\vec{T}_2 := \langle 1800; 45^\circ \rangle$$

$$\vec{T}_1 + \vec{T}_2 = \langle 3600 + 1800 \cos 45^\circ, 1800 \sin 45^\circ \rangle = \langle 3600 + 1800 \frac{\sqrt{2}}{2}, 1800 \frac{\sqrt{2}}{2} \rangle$$

$$\|\vec{T}_1 + \vec{T}_2\| \Rightarrow 5036.278 \text{ lb}$$

This corresponds with answer choice D

Question 4

Let the force vector be $\vec{F}$.

$$\vec{F} := 8 \cdot \cos 30^\circ \hat{i} + 8 \cdot \sin 30^\circ \hat{j} = 8 \cdot \frac{\sqrt{3}}{2} \hat{i} + 8 \cdot \frac{1}{2} \hat{j} = 4 \cdot \sqrt{3} \hat{i} + 4 \hat{j}$$

This corresponds with answer choice A

Question 5

Let the velocity vector be $\vec{v}_0$.

$$\vec{v}_0 := 5 \cdot \cos 56^\circ \hat{i} + 5 \cdot \sin 56^\circ \hat{j} = 2.795 \hat{i} + 4.145 \hat{j}$$

This corresponds with answer choice A

Question 6

Let the velocity vector be $\vec{v}_0$.

$$\vec{v}_0 := \langle 817; 140^\circ \rangle = \langle 817 \cos 140^\circ, 817 \sin 140^\circ \rangle \Rightarrow \langle -625.858, 525.157 \rangle$$

This corresponds with answer choice A

Question 7

Let the wind's parameters be encoded in the vector $\vec{W}$.

$$\vec{W} := \langle 5, 14 \rangle$$

$$\Rightarrow \theta = \arctan \frac{14}{5} \Rightarrow 70.346^\circ$$

This corresponds with answer choice C

Question 8

Let the boat's target velocity vector be $\vec{v}$.

$$\vec{v} := \langle 0, 31 \rangle - \langle -6, 0 \rangle$$

$$\vec{v} = \langle 6, 31 \rangle$$

$$\implies \theta = \arctan \frac{31}{6} \implies 79.04593^\circ$$

This corresponds with answer choice C, when expressed as a bearing East of North

Chapter 2

Lab 3 - 13.2

2.1 Work

Question 1

Let P be the plane in question.

$$P = \{(x, y, z) \in \mathbb{R}^3 : x = 1\}$$

Question 2

$$\text{dist}(P_1, P_2) = \sqrt{(5-1)^2 + (-6+1)^2 + (-5+2)^2} = \sqrt{4^2 + 5^2 + 3^2} = \sqrt{16 + 25 + 9} = \sqrt{50} = 5\sqrt{2}$$

Question 3

$$5^2 = (x+8)^2 + (y-10)^2 + z^2 = x^2 + 8^2 + 16x + y^2 + 100 - 20y + z^2$$

This corresponds with answer choice A

Question 4

Let C be the center point of the sphere, and r be the radius.

$$\begin{aligned} x^2 + y^2 + z^2 - 18x - 10y - 6z &= -15 \\ \implies x^2 - 18x + \left(\frac{18}{2}\right)^2 + y^2 - 10y + \left(\frac{10}{2}\right)^2 + z^2 - 6z + \left(\frac{6}{2}\right)^2 &= -15 + \left(\frac{18}{2}\right)^2 + \left(\frac{10}{2}\right)^2 + \left(\frac{6}{2}\right)^2 \\ \implies (x-9)^2 + (y-5)^2 + (z-3)^2 &= -15 + 81 + 25 + 9 = 10 + 81 + 9 = 100 = 10^2 \\ \therefore C &= (9, 5, 3) \quad r = 10 \end{aligned}$$

Question 5

The set $\{(x, y, z) \in \mathbb{R}^3 : x^2 + y^2 + z^2 > 1\}$ can be described as the set of all real points outside of a sphere with radius one centered at the origin, non-inclusive of the boundary where $x^2 + y^2 + z^2 = 1$. This corresponds with answer choice C.

Question 6

$$\vec{v} = \vec{PQ} = Q - P \quad Q = (4, 3, -3) \quad P = (-1, -3, 0)$$

$$\vec{v} = \langle 4 + 1, 3 + 3, -3 \rangle = \langle 5, 6, -3 \rangle = 5\hat{i} + 6\hat{j} - 3\hat{k}$$

This corresponds with answer choice A

Question 7

$$\vec{v} = \vec{AB} = B - A \quad B = (-2, -13, -2) \quad A = (-7, -6, -5)$$

$$\vec{v} = \langle -2 + 7, -13 + 6, -2 + 5 \rangle = \langle 5, -7, 3 \rangle = 5\hat{i} - 7\hat{j} + 3\hat{k}$$

This corresponds with answer choice B

Question 8

$$M := \text{midpoint}(A, B) = \left(\frac{3+5}{2}, \frac{5+2}{2}, \frac{5+4}{2} \right) = (4, 3.5, 4.5)$$

$$\vec{v} = M - C = \langle 4 - 1, 3.5 - 1, 4.5 - 1 \rangle = \langle 3, 2.5, 3.5 \rangle$$

This corresponds with answer choice B

Question 9

$$\vec{v} := 2\vec{u} - 6\vec{v} \quad \vec{u} = \langle 1, 1, 0 \rangle \quad \vec{v} = \langle 3, 0, 1 \rangle$$

$$\vec{v} = \langle 2, 2, 0 \rangle - \langle 18, 0, 6 \rangle = \langle -16, 2, -6 \rangle = -16\hat{i} + 2\hat{j} - 6\hat{k}$$

This corresponds with answer choice B

Question 10

The provided vector corresponds with answer choice D since:

$$\begin{aligned} 5\hat{i} + 10\hat{j} + 10\hat{k} &= 15\left(\frac{1}{3}\hat{i} + \frac{2}{3}\hat{j} + \frac{2}{3}\hat{k}\right) \\ \implies 5\hat{i} + 10\hat{j} + 10\hat{k} &= \frac{15}{3}\hat{i} + \frac{30}{3}\hat{j} + \frac{30}{3}\hat{k} \\ \implies \cancel{5\hat{i} + 10\hat{j} + 10\hat{k}} &= \cancel{5\hat{i} + 10\hat{j} + 10\hat{k}} \\ &\implies 0 = 0 \end{aligned}$$

Question 11

Let $\vec{v} = \langle -1, 6, 0 \rangle$

$$\|\vec{v}\| = \sqrt{1^2 + 6^2 + 0^2} = \sqrt{1 + 36} = \sqrt{37}$$

Chapter 3

Lab 4 - 13.3, 13.4

3.1 Work

Question 1

$$\begin{aligned}\vec{u} &:= \langle -5, 7 \rangle \quad \vec{v} := \langle 1, 6 \rangle \quad \vec{w} := \langle -11, 2 \rangle \\ \vec{u} \cdot (\vec{v} + \vec{w}) &= \vec{u} \cdot \langle 1 - 11, 6 + 2 \rangle = \vec{u} \cdot \langle -10, 8 \rangle \\ \implies \vec{u} \cdot (\vec{v} + \vec{w}) &= -5(-10) + 7(8) = 50 + 56 = 106\end{aligned}$$

Question 2

$$\begin{aligned}\vec{r} &:= \langle 7, -1, -3 \rangle \quad \vec{v} := \langle 2, 6, 6 \rangle \quad \vec{w} := \langle 7, 4, 7 \rangle \\ \vec{w} \cdot (\vec{v} + \vec{r}) &= \vec{w} \cdot \langle 9, 5, 3 \rangle = 63 + 20 + 21 = 104\end{aligned}$$

Question 3

Let o be the work done by the system.

$$\begin{aligned}o &= \langle 158; 180^\circ - 15^\circ \rangle \cdot \langle -6, 0 \rangle = \langle 158 \cos 180^\circ - 15^\circ, 158 \sin 180^\circ - 15^\circ \rangle \cdot \langle -6, 0 \rangle \\ o &= \langle -152.616280554, 40.8934091262 \rangle \cdot \langle -6, 0 \rangle = 915.697683324\end{aligned}$$

This corresponds with answer choice B

Question 4

$$\begin{aligned}\vec{u} \cdot \vec{v} &= \|\vec{u}\| \cdot \|\vec{v}\| \cos \theta \\ \implies \langle 1, -1 \rangle \cdot \langle 4, 5 \rangle &= \sqrt{2}\sqrt{4^2 + 5^2} \cos \theta = 4 - 5 = -1 = \sqrt{2}\sqrt{25 + 16} \cos \theta \\ \implies \theta &= \arccos \frac{-1}{\sqrt{2}\sqrt{41}} = 96.3401917459^\circ\end{aligned}$$

This corresponds with answer choice D

Question 5

$$\begin{aligned}\langle 4, 3 \rangle \cdot \langle 20, -8 \rangle &= 80 - 24 \neq 0 \\ \langle 15, -6 \rangle \cdot \langle 20, -8 \rangle &= 300 + 48 \neq 0 \\ \langle 20, 4 \rangle \cdot \langle 20, -8 \rangle &= 400 - 32 \neq 0 \\ \therefore \langle -10, -25 \rangle \cdot \langle 20, -8 \rangle &= -200 + 200 = 0 \\ \implies \text{Answer choice D is correct.}\end{aligned}$$

Question 6

If $\vec{v} \cdot \vec{w} = 0$:

$$\begin{aligned}\langle 1, -x \rangle \cdot \langle -4, -3 \rangle &= -4 + 3x = 0 \\ \implies 3x &= 4 \quad \therefore x = \frac{4}{3}\end{aligned}$$

Definition 3.1.1: Scalar component of a projection

$$\text{scal}_{\vec{b}}(\vec{a}) = \frac{\vec{a} \cdot \vec{b}}{\|\vec{b}\|}$$

Definition 3.1.2: Vector projection

$$\text{proj}_{\vec{b}}(\vec{a}) = \left(\frac{\vec{a} \cdot \vec{b}}{\|\vec{b}\|} \right) \frac{\vec{b}}{\|\vec{b}\|}$$

Question 7

$$\begin{aligned}\vec{v} &= \langle 2, 3 \rangle \quad \vec{w} = \langle 8, -6 \rangle \\ \text{proj}_{\vec{w}} \vec{v} &= \frac{\vec{v} \cdot \vec{w}}{\|\vec{w}\|} \frac{\vec{w}}{\|\vec{w}\|} = \frac{16 - 18}{\sqrt{8^2 + 6^2}} \frac{\langle 8, -6 \rangle}{\sqrt{6^2 + 8^2}} \\ \implies \text{proj}_{\vec{w}} \vec{v} &= \frac{-2}{10} \cdot \langle \frac{8}{10}, \frac{-6}{10} \rangle = \frac{-2}{10} \cdot \frac{2}{10} \cdot \langle 4, -3 \rangle = \frac{-4}{100} \langle 4, -3 \rangle = \frac{-1}{25} \langle 4, -3 \rangle \\ &\text{This corresponds with answer choice C}\end{aligned}$$

Question 8

$$\begin{aligned}\vec{u} &= \langle 4, 5 \rangle \quad \vec{v} = \langle 1, 1 \rangle \\ \text{scal}_{\vec{v}} \vec{u} &= \frac{\langle 4, 5 \rangle \cdot \langle 1, 1 \rangle}{\sqrt{2}} \\ \implies \text{scal}_{\vec{v}} \vec{u} &= \frac{4 + 5}{\sqrt{2}} = \frac{9}{\sqrt{2}}\end{aligned}$$

This corresponds with answer choice A

Question 9

$$\begin{aligned}\vec{u} &= \langle 0, 7, -2 \rangle \quad \vec{v} = \langle 4, -6, -7 \rangle \\ \vec{u} \cdot \vec{v} &= \|\vec{u}\| \cdot \|\vec{v}\| \cos \theta = 0 - 42 + 14 = -28 = \sqrt{7^2 + 2^2} \sqrt{4^2 + 6^2 + 7^2} \cos \theta \\ \theta &= \arccos \frac{-28}{\sqrt{53} \sqrt{101}} = 1.9635142449 \text{ rad} \\ &\text{This corresponds with answer choice B}\end{aligned}$$

Question 10

$$\begin{aligned}\vec{u} &= \langle -5, -3, 4 \rangle, \quad \vec{v} = \langle 5, -4, 2 \rangle, \quad \vec{w} = \langle 10, -5, -8 \rangle \\ \vec{u} \times \vec{v} &= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -5 & -3 & 4 \\ 5 & -4 & 2 \end{vmatrix} \\ &= \hat{i}((-3)(2) - (4)(-4)) - \hat{j}((-5)(2) - (4)(5)) + \hat{k}((-5)(-4) - (-3)(5)) \\ &= \hat{i}(-6 + 16) - \hat{j}(-10 - 20) + \hat{k}(20 + 15) \\ &= \langle 10, 30, 35 \rangle \\ \vec{w} \cdot (\vec{u} \times \vec{v}) &= \langle 10, -5, -8 \rangle \cdot \langle 10, 30, 35 \rangle \\ &= 10 \cdot 10 + (-5) \cdot 30 + (-8) \cdot 35 \\ &= 100 - 150 - 280 \\ &= -330\end{aligned}$$

This corresponds with answer choice B

Definition 3.1.3: Area of a Triangle using a Cross Product

$$\text{Area}_{\triangle ABC} = \frac{1}{2} \|\vec{B} - \vec{A} \times \vec{C} - \vec{A}\|$$

Definition 3.1.4: Area of a Parallelogram using a Cross Product

$$\text{Area}_{\text{parallelogram}} = \|\vec{u} \times \vec{v}\|$$

Question 11

In order to aptly encode the direction and magnitude of the side of the triangle let $\vec{s}_1, \vec{s}_2$ originate from P .

$$\vec{s}_1 = \langle 6 - 1, 6 - 1, -3 - 1 \rangle = \langle 5, 5, -4 \rangle \quad \vec{s}_2 = \langle 10 - 1, 4 - 1, 2 - 1 \rangle = \langle 9, 3, 1 \rangle$$

$$A = \frac{1}{2} \|\vec{s}_1 \times \vec{s}_2\| = \left| \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & 5 & -4 \\ 9 & 3 & 1 \end{vmatrix} \right|$$

$$\Rightarrow \left| \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & 5 & -4 \\ 9 & 3 & 1 \end{vmatrix} \right| = \hat{i}(5 + 12) - \hat{j}(5 + 36) + \hat{k}(15 - 45) = \langle 17, -41, -30 \rangle$$

$$\Rightarrow \frac{1}{2} \|\vec{s}_1 \times \vec{s}_2\| = \frac{1}{2} \cdot \sqrt{17^2 + 41^2 + 30^2} = \frac{1}{2} \sqrt{2870}$$

This corresponds with answer choice D

Question 12

$$\|\vec{F} \times \vec{PQ}\| = \|\vec{\tau}\| = \|\vec{PQ}\| \cdot \|\vec{F}\| \sin 45^\circ = \frac{9}{12} \cdot 5 \frac{\sqrt{2}}{2} = \frac{45\sqrt{2}}{24} = \frac{15}{8} \sqrt{2} \text{ ft} \cdot \text{lb}$$

This corresponds with answer choice D

Chapter 4

Lab 5 - 13.5

4.1 Work

Question 1

$$\vec{r} = \langle 0, 1, 0 \rangle + \langle 3, 0, -1 \rangle t$$
breaking it down into component form:
$$x = 3t, \quad y = 1, \quad z = -t$$
This corresponds with answer choice C

Question 2

$$\vec{r} = \langle -6, 5, -5 \rangle t + \langle 5, -1, -5 \rangle$$
This corresponds with answer choice C

Question 3

$$\vec{v} = P_2 - P_1 = \langle 3, 0, 4 \rangle \quad \vec{r} = \langle 3, 0, 4 \rangle t + \langle -3, 7, 3 \rangle \vee \vec{r} = \langle 3, 0, 4 \rangle t + \langle 0, 7, 7 \rangle$$
This corresponds with answer choice B

Question 4

$$\vec{u} = \langle 6, 4, 4 \rangle \quad \vec{v} = \langle -7, -6, -4 \rangle$$
$$\vec{v}_1 := \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 6 & 4 & 4 \\ -7 & -6 & -4 \end{vmatrix} = \hat{i}(-16 + 24) - \hat{j}(-24 + 28) + \hat{k}(-36 + 28) = \langle 8, -4, -8 \rangle$$
$$\vec{r} = \vec{v}_1 t + \langle -4, -7, 4 \rangle$$
This corresponds with answer choice D

Question 5

$$\vec{v}_1 = \langle 3, -3, -1 \rangle \quad \vec{v}_2 = \langle 4, -2, -5 \rangle$$

$$\nexists k | k \in \mathbb{R} \wedge k \cdot \vec{v}_1 = \vec{v}_2$$

$$\therefore l_1 \nparallel l_2$$

$$1 + 3t = 3 + 4s$$

$$3 - 3t = -1 - 2s$$

$$z = -t = 3 - 5s$$

$$s = \frac{1}{4}(3t - 2)$$

$$3 - 3t = -1 - 2 \cdot \frac{1}{4}(3t - 2)$$

$$3 - 3t = -1 - \frac{1}{2}(3t - 2)$$

$$3 - 3t = -\frac{3}{2}t$$

$$3 = \frac{3}{2}t$$

$$t = 2$$

$$s = \frac{1}{4}(3 \cdot 2 - 2) = 1$$

$$x = 1 + 3(2) = 7$$

$$y = 3 - 3(2) = -3$$

$$z = -2$$

$$x = 3 + 4(1) = 7$$

$$y = -1 - 2(1) = -3$$

$$z = 3 - 5(1) = -2$$

$$\therefore (x, y, z) = (7, -3, -2)$$

This corresponds with answer choice D

Question 6

$$\exists k | k \in \mathbb{R} \wedge k \cdot \vec{v}_1 = \vec{v}_2$$

$$\therefore l_1 \parallel l_2$$

$$3 - t = -6 + 5s$$

$$9 - t = 5s$$

$$9 - 5s = t$$

$$1 + 6(9 - 5s) = 55 - 30s = 1 + 54 - 30s$$

$$55 - 30s = 55 - 30s \forall s \in \mathbb{R}$$

$$4 - 2(9 - 5s) = -14 + 10s = 4 - 18 + 10s$$

$$-14 + 10s = -14 + 10s \forall s \in \mathbb{R}$$

$\therefore l_1$ and l_2 are identical. This corresponds to answer choice B

Question 7

$$\begin{aligned}\vec{n} \cdot (\vec{r} - \vec{r}_0) &= 0 \quad \langle 2, 7, 6 \rangle \cdot (\vec{r} - \langle 4, -3, 2 \rangle) = 0 \\ \vec{r} | \vec{r} = \langle x, y, z \rangle &\implies \langle 2, 7, 6 \rangle \cdot \langle x - 4, y + 3, z - 2 \rangle \\ 2(x - 4) + 7(y + 3) + 6(z - 2) &= 2x - 8 + 7y + 21 + 6z - 12 = 0 \\ 2x + 7y + 6z - 8 + 21 - 12 &= 0 \quad 2x + 7y + 6z = -1 \\ \text{This corresponds with answer choice C}\end{aligned}$$

Question 8

Considering answer choice A:

$$\begin{aligned}5(-1) - 7(8) + 58 &= -5 - 56 + 58 = -3 \neq 3 \therefore \mathcal{A} \\ 5(-1) + 7(8) - 58 &= -5 + 56 - 58 = -7 \neq 3 \therefore \mathcal{B} \\ 5(-1) + y(8) - 58 &\neq -3 \therefore \mathcal{C} \\ 5(-1) - 7(8) + 58 &= -5 - 56 + 58 = -3 \therefore \text{The answer is D}\end{aligned}$$

Question 9

$$\begin{aligned}-2x + 2 &= -2y \\ -2x &= 2 + 5z = 2 \\ z_0 := 0 \quad -2y + 5(0) &= 2 \implies y = -2 \\ -2x + 2(-2) &= -2 = -2x - 4 \\ -2x &= 2 \\ \implies x &= -1 \\ r_0 &= (-1, -2, 0)\end{aligned}$$

By parameterizing r_0 , only answer choice D has the necessary constant terms.

Question 10

$$\begin{aligned}x + y &= 7 - z \\ 7 - z &= 12 \\ z &= -5 \\ x &= t \\ t + y &= 12 \\ y &= 12 - t \\ \therefore x = t \quad y = 12 - t \quad z &= -5\end{aligned}$$

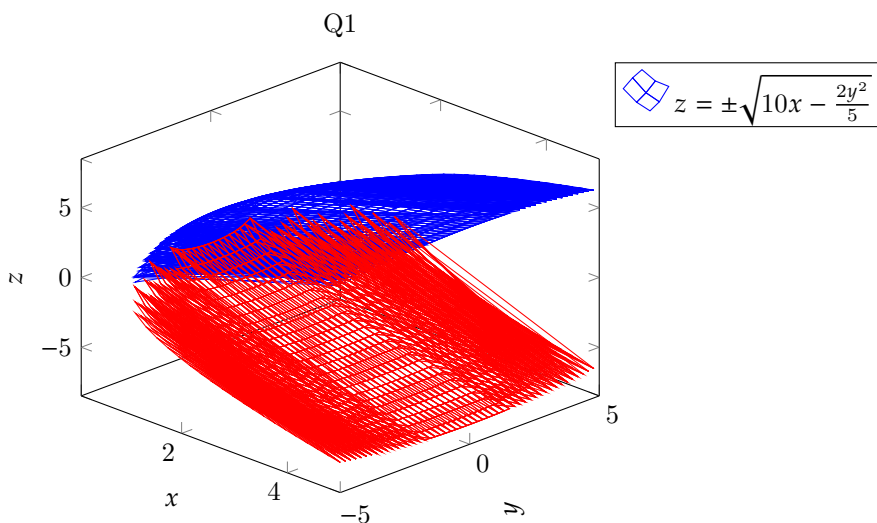
This corresponds with answer choice B. Answer Choice A is the same line with different parametrization to $x = -t$ instead of $x = t$

Chapter 5

Lab 6 - 13.6

5.1 Work

Question 1



This image corresponds to that of an elliptical paraboloid, corresponding with answer choice A.

Question 2

Since all terms are raised to the second degree, all behave linearly with respect to each other. Therefore, this is not a curved surface. Furthermore, the coefficient of the term containing x is negative. Therefore, the equation represents an elliptical cone along the x -axis. This corresponds with answer choice D.

Question 3

This surface is linear along the y -axis, and has a negative coefficient on the x term. Therefore, the surface is a Hyperbolic paraboloid, corresponding with answer choice A.

Question 4

The surface is linear along the z -axis, guaranteeing it to be a paraboloid. The xz -trace occurs when $y = 0$. The yz -trace occurs when $x = 0$.

$$\begin{aligned}xz\text{-trace: } 16x^2 - 16(0)^2 &= z = 16x^2 \\yz\text{-trace: } 16(0)^2 - 16y^2 - z &= 0 = 16y^2 + z\end{aligned}$$

This corresponds with answer choice D.

Question 5

Since two terms have a negative coefficient, and all terms are quadratic, the surface must be a hyperboloid of two sheets, leaving only answer choices B and D. A hyperboloid of two sheets only has hyperbolic cross-sections, so B must be the answer.

Question 6

Since the equation only yields circular cross sections, and varies quadratically over $\hat{i}, \hat{j}, \hat{k}$, The answer is Figure 1, A.

Question 7

The equation yield a circular cross section for any plane parallel to the yz -plane, and only discontinuous sets for the xy -plane and the xz -plane, the surface must be elliptical $\forall(y, z)$. Only Figure 3 satisfies the conditions, validating answer choice C.