

Name :

MAT 140

Final

Fall 2016

Part I: Calculators NOT allowed

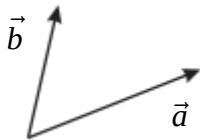
1. $\vec{a} \cdot \vec{b} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} \cdot \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} =$ (5pts)

2. If $\vec{a} \perp \vec{b}$ then (5pts)

3. $\begin{bmatrix} 3 \\ 4 \\ -2 \end{bmatrix} \times \begin{bmatrix} -5 \\ -2 \\ -1 \end{bmatrix} =$ (5pts)

4. Draw $\vec{a} + \vec{b}$ (5pts)

5. Draw $\vec{a} - \vec{b}$ (5pts)



6. If $\vec{a} = \begin{bmatrix} 1 \\ -2 \\ 1 \end{bmatrix}$ and $\vec{b} = \begin{bmatrix} -7 \\ 8 \\ 5 \end{bmatrix}$ compute $\text{proj}_{\vec{a}}(\vec{b}) =$ (5pts)

7. Find a **vector equation** of the line through $P = (2, -3, 1)$ and $Q = (-2, 2, -5)$

$(x, y, z) = (\quad , \quad , \quad) + t \begin{bmatrix} \quad \\ \quad \\ \quad \end{bmatrix}$ (5pts)

8. Find a **vector equation** of the plane: $3x - 4y + 6z = 12$

$(x, y, z) = (\quad , \quad , \quad) + t \begin{bmatrix} \quad \\ \quad \\ \quad \end{bmatrix} + s \begin{bmatrix} \quad \\ \quad \\ \quad \end{bmatrix}$ (5pts)

9. Find a **normal equation** of the plane: $(x, y, z) = (2, -3, 4) + t \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix} + s \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$

(5pts)

10. Complete $\|\vec{v} \times \vec{w}\| = \|\vec{v}\| \cdot$

(5pts)

11. The 2D lines $(x, y) = (1, 2) + t \begin{bmatrix} 3 \\ -4 \end{bmatrix}$ and $4x + 3y = 5$ are

(5pts)

(a) **Parallel** (b) **Perpendicular** (c) **Neither** [Circle correct answer]

12. Compute the **intersection** of $(x, y, z) = (5, 1, 2) + t \begin{bmatrix} 2 \\ -1 \\ 3 \end{bmatrix}$ and $x - 3y - z = 4$

(5pts)

13. Compute the distance between the point $P = (1, 2, -4)$

and the plane $2x + 2y - z = 1$

(5pts)

14. Compute $\begin{bmatrix} 2 & -4 \\ 3 & 1 \end{bmatrix} \cdot \begin{bmatrix} 3 & 5 & 2 \\ 2 & 1 & -1 \end{bmatrix} =$

(5pts)

15. Compute $\begin{bmatrix} 2 \\ 5 \\ -1 \end{bmatrix} \cdot \begin{bmatrix} 3 & -1 & 2 \end{bmatrix} =$

(5pts)

16. $\det \begin{bmatrix} 3 & 4 & 5 \\ 0 & 0 & 3 \\ -1 & 2 & 7 \end{bmatrix} = \quad -30 \quad -10 \quad -6 \quad -2 \quad 0 \quad 2 \quad 6 \quad 10 \quad 30 \quad \text{other} \quad (5\text{pts})$

17. In the line $\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 3 \\ 2 \\ 0 \end{bmatrix} + t \begin{bmatrix} -2 \\ 5 \\ 1 \end{bmatrix}$ the $\begin{bmatrix} 3 \\ 2 \\ 0 \end{bmatrix}$ refers to a **point / vector / other** (5pts)

18. In the line $\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 3 \\ 2 \\ 0 \end{bmatrix} + t \begin{bmatrix} -2 \\ 5 \\ 1 \end{bmatrix}$ the $\begin{bmatrix} -2 \\ 5 \\ 1 \end{bmatrix}$ refers to a **point / vector / other** (5pts)

19. The equation $\vec{n} \cdot \vec{x} = 5$ in **3D** represents a **point / vector / line / plane / other** (5pts)

20. If a linear transformation T is defined by $T \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 2 & -1 \\ 1 & 1 \\ -1 & 3 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$ then

(a) T maps **from** a **3D** space **to** a **2D** space **True / False** (5pts)

(b) The image of $\begin{bmatrix} 3 \\ 1 \end{bmatrix}$ is (5pts)

21. The matrix of a 3D rotation is $M = (1 - \cos \theta) \frac{\vec{v} \vec{v}^T}{\|\vec{v}\|^2} + \cos \theta \cdot I + \frac{\sin \theta}{\|\vec{v}\|} C_{\vec{v}}$

(a) If $\vec{v} = \begin{bmatrix} a \\ b \\ c \end{bmatrix}$ then $C_{\vec{v}} = \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix}$ (5pts)

(b) $\text{Trace}(M) =$ (5pts)

22. Write as matrix multiplications: $(\vec{a} \cdot \vec{b}) \vec{c} =$ (5pts)

23. Let $\begin{cases} T \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 1 & -2 \\ 3 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \\ S \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \end{cases} \Rightarrow$ the matrix for $S \circ T$ is (5pts)

24. Let $T(\vec{x}) = A\vec{x} + \vec{b}$. Suppose $T(\vec{x}_0) = \vec{x}_0$. We discussed two ways to find $\vec{b}$:

(a) $\vec{b} =$ (5pts) (b) $\vec{b} =$ (5pts)

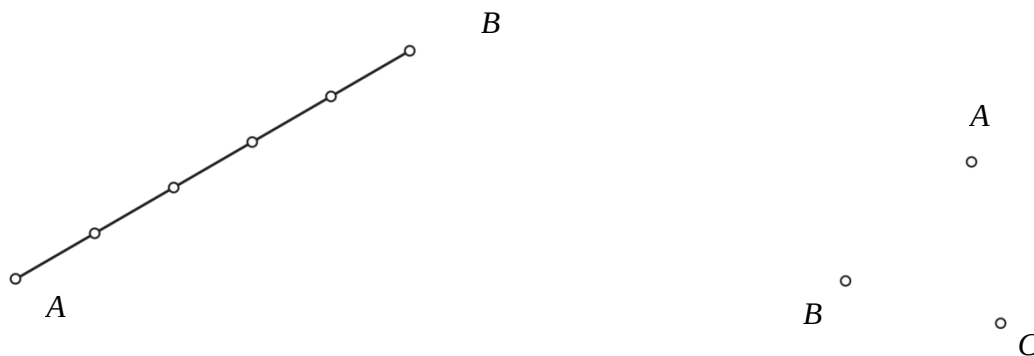
25. Let $T(\vec{x}) = A\vec{x} + \vec{b}$, then $T^{-1}(\vec{x}) =$ (5pts)

26. A point X has Barycentric coordinates: $a = \frac{1}{3}$, $b = \frac{1}{6}$, $c = \frac{1}{2}$ with respect to the

points $A = (6, 2)$, $B = (3, 2)$ and $C = (3, -4)$. Find $X =$ (5pts)

27. Locate the point: $X = \frac{3}{5}A + \frac{2}{5}B$ (5pts)

28. Locate the point: $X = -A + 3B - C$ (5pts)



29. Which of the following matrices is the homogeneous matrix of a **perspective projection**:

[Circle correct answer]

(5pts)

$\tilde{N} \tilde{q} - (\tilde{N} \cdot \tilde{q}) I$	$\tilde{q} \tilde{N}^T + (\tilde{q} \cdot \tilde{N}) I$	$\tilde{N} \tilde{q}^T - (\tilde{N} \cdot \tilde{q}) I$	$\tilde{q} \cdot \tilde{N}^T - (\tilde{q} \tilde{N}) I$
$\tilde{q} \tilde{N} - (\tilde{q} \cdot \tilde{N}) I$	$\tilde{N} \tilde{q}^T + (\tilde{N} \cdot \tilde{q}) I$	$\tilde{q} \tilde{N}^T - (\tilde{q} \cdot \tilde{N}) I$	$\tilde{N} \cdot \tilde{q}^T - (\tilde{N} \tilde{q}) I$

30. Suppose a 3×3 matrix M is NOT a scaling, and that $\det(M) = 1$ and $\text{Trace}(M) = -1$. Then M as a transformation matrix of 3D space, could be a

(a) Shear (b) Skew projection (c) Projection onto a line (d) Reflection in a plane

(e) Other (e.g.) [Circle all that apply] (5pts)

31. If the matrix of the skew projection onto the line $5x + 2y = 0$ is $\begin{bmatrix} -4 & -2 \\ 10 & 5 \end{bmatrix}$,

then $\begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -4 & -2 & 0 \\ 10 & 5 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix}$ gives us the affine matrix for

the skew projection onto the line: (5pts)

(a) $5x + 2y = 7$ (b) $5x + 2y = -7$ (c) $5x + 2y = 3$ (d) $5x + 2y = -3$

32. Let $\vec{x} = t \begin{bmatrix} 2 \\ 3 \\ -1 \end{bmatrix}$ be a line in $\mathbb{R}^3$. We can compute the matrix of the **reflection** in this

line using $\vec{v} = \begin{bmatrix} 2 \\ 3 \\ -1 \end{bmatrix}$ in $\frac{2}{\|\vec{v}\|^2} \vec{v} \vec{v}^T - I$ **or** using a normal $\vec{n} = \begin{bmatrix} 1 \\ 0 \\ 2 \end{bmatrix}$ in $I - \frac{2}{\|\vec{n}\|^2} \vec{n} \vec{n}^T$.

(a) **Yes** (both formulas will give the same matrix)

(b) Only the **first** formula is correct, using $\vec{v}$

(c) Only the **second** formula is correct, using $\vec{n}$

(d) **Neither** method is correct (5pts)

33. Which of the following matrices are in **reduced row echelon** form?

$$\text{I} \begin{bmatrix} 0 & 1 & 2 & 0 & 3 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad \text{II} \begin{bmatrix} 0 & 1 & 2 & 0 & 3 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad \text{III} \begin{bmatrix} 0 & 1 & 2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

(a) I (b) I and II (c) II (d) II and III (e) III (f) none (g) all

[Circle the most complete answer amongst (a) through (g)] (5pts)

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34. Use **row reduction** to compute the intersection of the two planes $2x + 3y - 6z = 1$ and $4x + y + 8z = 7$:

$$\text{rref} \begin{bmatrix} 2 & 3 & -6 & 1 \\ 4 & 1 & 8 & 7 \end{bmatrix} = \boxed{\phantom{\begin{bmatrix} & & & \end{bmatrix}}} \quad (5\text{pts})$$

hence the **intersection** is:

(5 pts)

35. Find the **distance** from $P = (3, 1, 3)$ to the line $(x, y, z) = (1, -1, 2) + t \begin{bmatrix} 1 \\ -2 \\ 2 \end{bmatrix}$
-
- (5pts)

36. Find the **angle** (in **degrees**) between the plane $2x - 9y + z = 5$ and the line

$$(x, y, z) = (2, 0, 1) + t \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$$

(5 pts)

37. $T(\vec{x}) = \begin{bmatrix} 1 & 3 & 2 \\ 0 & 2 & 1 \\ -1 & 4 & 1 \end{bmatrix} \vec{x} + \begin{bmatrix} 5 \\ 3 \\ 2 \end{bmatrix}$. $T^{-1}(\vec{x}) = \left[\begin{array}{c|c|c} & & \end{array} \right] \vec{x} + \left[\begin{array}{c} \\ \\ \end{array} \right]$ (5pts)

38. A **skew reflection** is given by $P(\vec{x}) = \begin{bmatrix} 9 & -12 & 16 \\ 12 & -17 & 24 \\ 4 & -6 & 9 \end{bmatrix} \vec{x} + \begin{bmatrix} 4 \\ 6 \\ 2 \end{bmatrix}$.

(a) Find the **images** of the points $(-1, -2, -1)$, $(0, 1, 1)$ and $(1, -1, -1)$?

$\left(\quad, \quad, \quad \right)$ $\left(\quad, \quad, \quad \right)$ $\left(\quad, \quad, \quad \right)$ (5pts)

(b) Determine the **plane** of the skew reflection P (in **normal form**).

$\left[\begin{array}{c} \end{array} \right]$ (5pts)

(c) Determine the skew **vector** of the skew reflection P : $\vec{v} =$

$\left[\begin{array}{c} \end{array} \right]$ (5 pts)

39. A **rotation** $R: \mathbb{R}^3 \rightarrow \mathbb{R}^3$ has matrix $\frac{1}{9} \begin{bmatrix} -4 & -4 & 7 \\ 8 & -1 & 4 \\ -1 & 8 & 4 \end{bmatrix}$.

(a) Compute the **angle** of rotation (in **degrees**): $\theta =$

$\left[\begin{array}{c} \end{array} \right]$ (5 pts)

(b) Find the **vector** around which is being rotated: $\vec{v} =$

$\left[\begin{array}{c} \end{array} \right]$ (5 pts)

40. Let $S(\vec{x}) = \begin{bmatrix} 3 & 1 & 2 \\ 2 & 1 & 0 \\ -1 & 2 & 4 \end{bmatrix} \vec{x} + \begin{bmatrix} -1 \\ 3 \\ 1 \end{bmatrix}$ and $T(\vec{x}) = \begin{bmatrix} 1 & 2 & 1 \\ -1 & 0 & 3 \\ 2 & 1 & -1 \end{bmatrix} \vec{x} + \begin{bmatrix} 1 \\ 1 \\ 4 \end{bmatrix}$.

Find $T \circ S$

$(T \circ S)(\vec{x}) = \left[\begin{array}{c} \end{array} \right] \vec{x} + \left[\begin{array}{c} \end{array} \right]$ (5 pts)

41. Let $A = (1, 2, 1)$, $B = (-1, 3, 2)$, $C = (4, -1, 5)$, and $D = (2, -3, 4)$.

(a) Find the **barycentric** coordinates of $P = (17, -3, 8)$ with respect to A, B, C and D .

$$P = \left[\begin{array}{ccc} & , & , & , \end{array} \right] \quad (5 \text{ pts})$$

(b) Find the **rectangular** x, y and z coordinates of the point Q with barycentric coordinates $[2, -1, 3, -3]$ with respect to A, B, C and D . (5 pts)

$$Q = \left(\begin{array}{cc} & , & , \end{array} \right)$$

(c) The Barycentric equation " $c = 0$ " refers to a **point / line / plane** (5 pts)

(d) What point / line / plane?
[coordinates or equation]

42. Let $S: \mathbb{R}^3 \rightarrow \mathbb{R}^3$ be defined by $S(\vec{x}) = \begin{bmatrix} 5 & 8 & -8 \\ 2 & 5 & -4 \\ 4 & 8 & -7 \end{bmatrix} \vec{x} + \begin{bmatrix} 4 \\ 2 \\ 4 \end{bmatrix}$ and let l be the line

$$l: \vec{x} = \begin{bmatrix} -3 \\ 4 \\ 2 \end{bmatrix} + t \begin{bmatrix} -1 \\ 2 \\ 1 \end{bmatrix}.$$

(a) The **image** of the line l is a **plane / line / point** (5 pts)

(b) Find the image:

(c) What kind of transformation is S ? [Determine things like $\vec{n}, \vec{v}, \theta$ etc.] (5 pts)

43. Let $T : \mathbb{R}^3 \rightarrow \mathbb{R}^3$ be defined using the affine matrix $\tilde{M} = \begin{bmatrix} 1 & -2 & 1 & -2 \\ 4 & 1 & -3 & 5 \\ -2 & 3 & 2 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

and $\vec{v} = \begin{bmatrix} -2 \\ -1 \\ 1 \end{bmatrix}$, $P = (3, 2, 1)$ and $Q = (4, 2, 1)$. Compute the following

[Write your answer **either** as a **point** (a, b, c) or as a **vector** $\begin{bmatrix} a \\ b \\ c \end{bmatrix}$ as appropriate.]

(a) $T(\vec{v}) =$ (3 pts) (b) $T(P - \vec{v}) =$ (3 pts)

(c) $T(P - Q) =$ (3 pts) (d) $T(3P - 2Q) =$ (3 pts)

44. Let $T : \mathbb{R}^3 \rightarrow \mathbb{R}^3$ be the **skew projection** with $2x - 3y + z = -3$ and $\vec{v} = \begin{bmatrix} 3 \\ 1 \\ -4 \end{bmatrix}$

Compute the affine matrix of T .

(5 pts)

$$\begin{bmatrix} 1 & 0 & 0 & \boxed{} \\ 0 & 1 & 0 & \boxed{} \\ 0 & 0 & 1 & \boxed{} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & \boxed{} \\ 0 & 1 & 0 & \boxed{} \\ 0 & 0 & 1 & \boxed{} \\ 0 & 0 & 0 & 1 \end{bmatrix} =$$

$$= \begin{bmatrix} \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

45. Let $P: \mathbb{R}^3 \rightarrow \mathbb{R}^3$ be a perspective projection from $Q = (1, 2, 6)$ onto the plane $3x - 2y + z = 1$.

(a) Find $\tilde{M}$ such that $\tilde{P}\left(\begin{bmatrix} \vec{x} \\ 1 \end{bmatrix}\right) \cong \tilde{M}\begin{bmatrix} \vec{x} \\ 1 \end{bmatrix}$. $\tilde{M} = \begin{bmatrix} & & & \\ & & & \\ & & & \end{bmatrix}$ (5 pts)

(b) Find the **image** P' of $P = (-2, 1, 17)$: $P' = \begin{pmatrix} & , & , & \end{pmatrix}$ (5 pts)

(c) Find the **image** R' of $R = (2, 1, 1)$: (Explain) (5 pts)

46. (a) Find the 3D **affine transformation** $T(\vec{x}) = A\vec{x} + \vec{b}$ with

$$P = (2, 1, -1) \xrightarrow{T} P' = (18, -4, -8)$$

$$Q = (2, 0, -1) \xrightarrow{T} Q' = (13, -1, -10)$$

$$R = (1, 1, 0) \xrightarrow{T} R' = (9, 1, 5)$$

$$S = (1, 0, 1) \xrightarrow{T} S' = (-4, 13, 9)$$

$T(\vec{x}) = A\vec{x} + \vec{b} = \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix} \vec{x} + \begin{bmatrix} \\ \\ \end{bmatrix}$ (5 pts)

(b) $X = P + Q - 2R + S$. Find the **coordinates** of $T(X) = \begin{pmatrix} & , & , & \end{pmatrix}$ (5 pts)

47. In $\mathbb{R}^3$ let R be the **rotation** around $\vec{v} = \begin{bmatrix} -1 \\ 1 \\ -1 \end{bmatrix}$ over 60° and F the **projection** onto

the plane $2x + y - 2z = 0$ and S the **scaling** by $\begin{bmatrix} 81 & 0 & 0 \\ 0 & 27 & 0 \\ 0 & 0 & -54 \end{bmatrix}$

Compute the 3×3 matrix of $S \circ F \circ R$:

(5 pts)

48. Let $S: \mathbb{R}^3 \rightarrow \mathbb{R}^3$ be defined by the **affine** matrix $\begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & -1 \\ 0 & 0 & -1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

(a) Find the **fixed points** of this transformation

(5pts)

(b) This transformation is a

Rotation / Reflection / Projection / Shear / Scaling / other (5pts)

(c) Find the image of the plane $x - y = 1$

(5pts)

(d) Describe the transformations in terms of things like $\vec{n}, \vec{v}, \theta$ etc.

(5pts)

49. (a) Write the **reflection** S in the line $\vec{x} = \begin{bmatrix} 1 \\ -1 \\ 2 \end{bmatrix} + t \begin{bmatrix} 1 \\ 0 \\ -3 \end{bmatrix}$. (5 pts)

$$\text{as } S \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & \boxed{} \\ 0 & 1 & 0 & \boxed{} \\ 0 & 0 & 1 & \boxed{} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -0.8 & \boxed{} & \boxed{} & 0 \\ \boxed{} & \boxed{} & \boxed{} & 0 \\ \boxed{} & \boxed{} & \boxed{} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & \boxed{} \\ 0 & 1 & 0 & \boxed{} \\ 0 & 0 & 1 & \boxed{} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

- (b) i.e. the matrix of this reflection is:

$$\begin{bmatrix} \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ \boxed{} & \boxed{} & \boxed{} & \boxed{} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

50. The following matrix is for a **perspective projection**:

$$\begin{bmatrix} 15 & -1 & 5 & -2 \\ 9 & 9 & 15 & -6 \\ -6 & 2 & 2 & 4 \\ 3 & -1 & 5 & 10 \end{bmatrix}$$

- (a) Find the plane onto which is being projected (in normal form) (5 pts)

- (b) Find the point Q from which is being projected. (5 pts)

$$Q = \left(, , \right)$$

51. BONUS. Identify the following matrices. (They are matrices for **3D** transformations like rotations, reflections, perspective projections, skew projections, shears etc.)

For credit you need to identify planes, lines, normals, direction vectors and angles etc.

$$(a) \begin{bmatrix} -3 & 16 & -12 & 8 \\ -2 & 9 & -6 & 4 \\ -2 & 8 & -5 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$(b) \frac{1}{3} \begin{bmatrix} 1 & -1 & 1 & 3 \\ -1 & 1 & -1 & -12 \\ 1 & -1 & 1 & -15 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

$$(c) \begin{bmatrix} -11 & 16 & -48 & -4 \\ 9 & -11 & 36 & 3 \\ 6 & -8 & 25 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$(d) \begin{bmatrix} 7 & -6 & 2 & 6 \\ 6 & -6 & 3 & 9 \\ -2 & 3 & 2 & -3 \\ 2 & -3 & 1 & 6 \end{bmatrix}$$

$$(e) \frac{1}{3} \begin{bmatrix} 2 & -2 & 1 & 6 \\ -2 & -1 & 2 & 12 \\ 1 & 2 & 2 & -6 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

$$(f) \frac{1}{3} \begin{bmatrix} -2 & 1 & -2 & 9 \\ 1 & -2 & -2 & -9 \\ -2 & -2 & 1 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

$$(g) \frac{1}{3} \begin{bmatrix} 2 & -2 & -1 & 12 \\ 1 & 2 & -2 & -6 \\ 2 & 1 & 2 & 6 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

$$(h) \begin{bmatrix} -5 & 3 & -9 & 18 \\ -4 & 3 & -6 & 12 \\ 2 & -1 & 4 & -6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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