

This print-out should have 12 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

MatrixProp01a
001 10.0 points

Compute $AA^T - A^T A$ for the matrix

$$A = \begin{bmatrix} 1 & -1 \\ -2 & 3 \end{bmatrix}.$$

1. $AA^T - A^T A = \begin{bmatrix} 3 & 2 \\ 2 & -3 \end{bmatrix}$
2. $AA^T - A^T A = \begin{bmatrix} 3 & -2 \\ -2 & -3 \end{bmatrix}$
3. $AA^T - A^T A = \begin{bmatrix} -3 & -2 \\ 2 & 3 \end{bmatrix}$
4. $AA^T - A^T A = \begin{bmatrix} 3 & -2 \\ 2 & -3 \end{bmatrix}$
5. $AA^T - A^T A = \begin{bmatrix} -3 & 2 \\ 2 & 3 \end{bmatrix}$ **correct**
6. $AA^T - A^T A = \begin{bmatrix} -3 & -2 \\ -2 & 3 \end{bmatrix}$

Explanation:

By matrix multiplication,

$$\begin{aligned} AA^T &= \begin{bmatrix} 1 & -1 \\ -2 & 3 \end{bmatrix} \begin{bmatrix} 1 & -2 \\ 3 & 3 \end{bmatrix} \\ &= \begin{bmatrix} 2 & -5 \\ -5 & 13 \end{bmatrix}, \end{aligned}$$

while

$$\begin{aligned} A^T A &= \begin{bmatrix} 1 & -2 \\ -1 & 3 \end{bmatrix} \begin{bmatrix} 1 & -1 \\ -2 & 3 \end{bmatrix} \\ &= \begin{bmatrix} 5 & -7 \\ -7 & 10 \end{bmatrix}, \end{aligned}$$

Consequently,

$$\begin{aligned} AA^T - A^T A &= \begin{bmatrix} 2 & -5 \\ -5 & 13 \end{bmatrix} - \begin{bmatrix} 5 & -7 \\ -7 & 10 \end{bmatrix} \\ &= \begin{bmatrix} -3 & 2 \\ 2 & 3 \end{bmatrix}. \end{aligned}$$

InverseMatrix01b
002 10.0 points

Solve for X when $A(X + B) = C$,

$$A = \begin{bmatrix} 5 & 2 \\ -3 & -1 \end{bmatrix}, \quad B = \begin{bmatrix} 2 & -2 \\ 1 & 5 \end{bmatrix},$$

and

$$C = \begin{bmatrix} 2 & 2 \\ -1 & 5 \end{bmatrix}.$$

1. $X = \begin{bmatrix} -2 & -10 \\ 0 & 26 \end{bmatrix}$ **correct**
2. $X = \begin{bmatrix} -1 & 10 \\ 1 & 26 \end{bmatrix}$
3. $X = \begin{bmatrix} 2 & 10 \\ 0 & 24 \end{bmatrix}$
4. $X = \begin{bmatrix} 2 & -10 \\ 1 & 26 \end{bmatrix}$
5. $X = \begin{bmatrix} -1 & -10 \\ 1 & 26 \end{bmatrix}$
6. $X = \begin{bmatrix} -2 & 10 \\ 0 & 24 \end{bmatrix}$

Explanation:

By the algebra of matrices,

$$X = A^{-1}C - B.$$

But the inverse of any 2×2 matrix

$$D = \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix}$$

is given by

$$D^{-1} = \begin{bmatrix} d_{22}/\Delta & -d_{12}/\Delta \\ -d_{21}/\Delta & d_{11}/\Delta \end{bmatrix}$$

with $\Delta = d_{11}d_{22} - d_{12}d_{21}$, so

$$\begin{aligned} X &= \begin{bmatrix} -1 & -2 \\ 3 & 5 \end{bmatrix} \begin{bmatrix} 2 & 2 \\ -1 & 5 \end{bmatrix} - \begin{bmatrix} 2 & -2 \\ 1 & 5 \end{bmatrix} \\ &= \begin{bmatrix} 0 & -12 \\ 1 & 31 \end{bmatrix} - \begin{bmatrix} 2 & -2 \\ 1 & -5 \end{bmatrix}. \end{aligned}$$

Thus

$$X = \begin{bmatrix} -2 & -10 \\ 0 & 26 \end{bmatrix}.$$

LUDecomp06h
003 10.0 points

Find L in an LU decomposition of

$$A = \begin{bmatrix} -1 & 5 & 3 & 4 \\ -1 & 5 & 4 & 2 \\ -5 & 25 & 18 & 15 \end{bmatrix}.$$

1. $L = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ -5 & -3 & 1 \end{bmatrix}$

2. $L = \begin{bmatrix} -1 & 0 & 0 \\ 1 & -1 & 0 \\ 5 & 3 & -1 \end{bmatrix}$

3. $L = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 5 & 3 & 1 \end{bmatrix}$ **correct**

4. $L = \begin{bmatrix} 1 & 0 & 0 \\ -1 & 1 & 0 \\ 5 & -3 & 1 \end{bmatrix}$

5. $L = \begin{bmatrix} 1 & 0 & 0 \\ -1 & 1 & 0 \\ -5 & 3 & 1 \end{bmatrix}$

6. $L = \begin{bmatrix} 2 & 0 & 0 \\ 1 & 2 & 0 \\ 5 & 3 & 2 \end{bmatrix}$

Explanation:

Recall that in a factorization $A = LU$ of an $m \times n$ matrix A , then L is an $m \times m$ lower triangular matrix with ones on the diagonal and U is an $m \times n$ echelon form of A .

We begin by computing U . Now $U = M_0A$ where j is the number of row operations on A needed to transform A into its echelon form U and M_i is a product of $j - i$ elementary matrices that represent these row operations:

$$\begin{aligned} U &= M_0A = M_1E_1A \\ &= M_1 \begin{bmatrix} 1 & 0 & 0 \\ -1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & 5 & 3 & 4 \\ -1 & 5 & 4 & 2 \\ -5 & 25 & 18 & 15 \end{bmatrix} \\ &= M_2E_2(E_1A) \\ &= M_2 \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -5 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & 5 & 3 & 4 \\ 0 & 0 & 1 & -2 \\ -5 & 25 & 18 & 15 \end{bmatrix} \\ &= E_3(E_2E_1A) \\ &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & -3 & 1 \end{bmatrix} \begin{bmatrix} -1 & 5 & 3 & 4 \\ 0 & 0 & 1 & -2 \\ 0 & 0 & 3 & -5 \end{bmatrix} \\ &= \begin{bmatrix} -1 & 5 & 3 & 4 \\ 0 & 0 & 1 & -2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{aligned}$$

Next recall that all elementary matrices are invertible, as is the product of elementary matrices. Thus we can change $U = M_0A$ to $M_0^{-1}U = A$. This shows that $L = M_0^{-1}$. Hence

$$\begin{aligned} L &= M_0^{-1} = E_1^{-1}E_2^{-1}E_3^{-1} \\ &= E_1^{-1} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 5 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 3 & 1 \end{bmatrix} \\ &= \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 5 & 3 & 1 \end{bmatrix} \\ &= \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 5 & 3 & 1 \end{bmatrix} \end{aligned}$$

Consequently,

$$L = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 5 & 3 & 1 \end{bmatrix}.$$

Subspace02a
004 10.0 points

Which of the following describes

$$H = \text{Span}\{\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3\}$$

when

$$\mathbf{v}_1 = \begin{bmatrix} 1 \\ 1 \\ -3 \end{bmatrix}, \mathbf{v}_2 = \begin{bmatrix} -2 \\ -1 \\ 7 \end{bmatrix}, \mathbf{v}_3 = \begin{bmatrix} 1 \\ 4 \\ 0 \end{bmatrix}.$$

1. H is a plane through origin **correct**
2. $H = \mathbb{R}^3$
3. H is a line
4. H is a plane not through origin

Explanation:

Since H is a subspace of \mathbb{R}^3 , H contains the origin. On the other hand, if

$$A = [\mathbf{v}_1 \ \mathbf{v}_2 \ \mathbf{v}_3] = \begin{bmatrix} 1 & -2 & 1 \\ 1 & -1 & 4 \\ -3 & 7 & 0 \end{bmatrix},$$

then $H = \text{Col}(A)$, and

$$\text{rref}(A) = \begin{bmatrix} 1 & 0 & 7 \\ 0 & 1 & 3 \\ 0 & 0 & 0 \end{bmatrix}.$$

Thus \mathbf{v}_1 and \mathbf{v}_2 are pivot columns of A , so $\{\mathbf{v}_1, \mathbf{v}_2\}$ is a basis for $\text{Col}(A)$.

Consequently,

$H \text{ is a plane through origin.}$

Invertible02
005 10.0 points

A is an $n \times n$ matrix. Which of the following statements are equivalent to A being invertible?

- (i) The columns of A form a basis of \mathbb{R}^n .
- (ii) $\dim(\text{Col } A) = n$.
- (iii) $\text{rank } A = 0$.

1. i
2. ii
3. i and ii **correct**
4. All of these
5. ii and iii
6. None of these

Explanation:

(i) Because A is invertible, the columns of A span \mathbb{R}^n and form a linearly independent set. By definition, a basis of a subspace is a linearly independent set of vectors that span that subspace. Hence the columns of A form a basis of \mathbb{R}^n .

(ii) Since A is invertible, $\text{Col } A$ is a basis for \mathbb{R}^n . If $\text{Col } A$ is a basis for \mathbb{R}^n , it must have exactly n vectors. Hence the dimension of $\text{Col } A$ is n .

(iii) Because A is invertible, $\dim \text{Col } A = n$. By the definition of rank, $\text{rank } A = \dim \text{Col } A$. Hence $\text{rank } A = n$.

Rank02e
006 10.0 points

Determine the rank of the matrix

$$A = \begin{bmatrix} 1 & 0 & 1 \\ -3 & 1 & -2 \\ 0 & 1 & 2 \end{bmatrix}.$$

1. $\text{rank}(A) = 1$
2. $\text{rank}(A) = 3$ **correct**
3. $\text{rank}(A) = 4$
4. $\text{rank}(A) = 2$
5. $\text{rank}(A) = 5$

Explanation:

Since

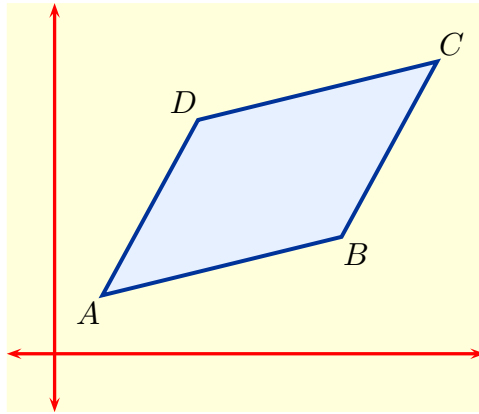
$$\text{rref}(A) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix},$$

all three rows of $\text{rref}(A)$ contain leading 1's, so

$$\boxed{\text{Rank}(A) = 3}.$$

DetArea03a
007 10.0 points

Compute the area of the parallelogram $ABCD$ shown in



having vertices at

$$A = (1, 1), \quad B = (6, 2),$$

and

$$C = (8, 5), \quad D = (3, 4).$$

1. area = 11
2. area = 12
3. area = 10
4. area = 13 **correct**
5. area = 14

Explanation:

After translating $ABCD$ so that A becomes the origin, we obtain a new parallelogram

$OB'C'D'$ of equal area with vertices at the origin and

$$B' = (5, 1), \quad C' = (7, 4), \quad D' = (2, 3).$$

Now

$$\text{area}(OB'C'D') = \left| \det \begin{bmatrix} 5 & 1 \\ 2 & 3 \end{bmatrix} \right| = 13.$$

Consequently, $ABCD$ has

$$\boxed{\text{Area} = 13}.$$

BasisNull01b
008 10.0 points

Find a basis for the Null space of the matrix

$$A = \begin{bmatrix} 3 & -6 & -3 & -3 \\ 1 & -4 & -5 & 3 \\ -3 & 4 & -1 & 9 \end{bmatrix}.$$

1. $\left\{ \begin{bmatrix} 3 \\ 1 \\ -3 \end{bmatrix}, \begin{bmatrix} -6 \\ -4 \\ 4 \end{bmatrix} \right\}$
2. $\left\{ \begin{bmatrix} -3 \\ -2 \\ 1 \\ 0 \end{bmatrix} \right\}$ **correct**
3. $\left\{ \begin{bmatrix} 3 \\ -2 \\ 1 \\ 0 \end{bmatrix} \right\}$
4. $\left\{ \begin{bmatrix} 3 \\ 2 \\ 1 \\ 0 \end{bmatrix} \right\}$
5. $\left\{ \begin{bmatrix} 3 \\ 1 \\ -3 \end{bmatrix}, \begin{bmatrix} -3 \\ -5 \\ -1 \end{bmatrix} \right\}$
6. $\left\{ \begin{bmatrix} 3 \\ 1 \\ -3 \end{bmatrix}, \begin{bmatrix} -3 \\ 3 \\ 9 \end{bmatrix} \right\}$

Explanation:

We first row reduce $[A \ 0]$:

$$\text{rref}([A \ 0]) = \begin{bmatrix} 1 & 0 & 3 & 0 & 0 \\ 0 & 1 & 2 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

to identify the free variables for \mathbf{x} in the homogeneous equation $A\mathbf{x} = \mathbf{0}$.

Thus x_1 , x_2 , and x_4 are basic variables, while x_3 is a free variable. So set $x_3 = s$. Then

$$x_1 = -3s, \quad x_2 = -2s, \quad x_3 = s, \quad x_4 = 0,$$

and

$$\text{Nul}(A) = \text{Span} \left\{ \begin{bmatrix} -3 \\ -2 \\ 1 \\ 0 \end{bmatrix} \right\}.$$

Consequently,

$$\mathcal{B} = \left\{ \begin{bmatrix} -3 \\ -2 \\ 1 \\ 0 \end{bmatrix} \right\}$$

is a basis for $\text{Nul}(A)$.

Basis03a
009 10.0 points

In the vector space V of all real-valued functions, find a basis for the subspace

$$H = \text{Span}\{\sin t, \sin 2t, \sin t \cos t\}.$$

1. $\{\cos t, \sin 2t, \sin t \cos t\}$

2. $\{\cos t, \sin 2t\}$

3. $\{\sin t, \sin 2t\}$ **correct**

4. $\{\sin t, \sin 2t, \sin t \cos t\}$

5. $\{\sin 2t, \sin t \cos t\}$

Explanation:

By double angle formula,

$$\sin 2t = 2 \sin t \cos t,$$

so the functions

$$\{\sin t, \sin 2t, \sin t \cos t\}$$

are linearly dependent, while

$$\{\sin t, \sin 2t\}$$

are linearly independent. Consequently,

$\{\sin t, \sin 2t\}$

is a basis for H .

PolyCoordVec01b
010 10.0 points

Find the coordinate vector $[\mathbf{p}]_{\mathcal{B}}$ in \mathbb{R}^3 for the polynomial

$$\mathbf{p}(t) = 2 + 3t - 6t^2$$

with respect to the basis

$$\mathcal{B} = \{1 - t^2, t - t^2, 1 - t + t^2\}$$

for \mathbb{P}_2 .

1. $[\mathbf{p}]_{\mathcal{B}} = \begin{bmatrix} 1 \\ 3 \\ 2 \end{bmatrix}$

2. $[\mathbf{p}]_{\mathcal{B}} = \begin{bmatrix} 3 \\ -2 \\ 1 \end{bmatrix}$

3. $[\mathbf{p}]_{\mathcal{B}} = \begin{bmatrix} -2 \\ -1 \\ 3 \end{bmatrix}$

4. $[\mathbf{p}]_{\mathcal{B}} = \begin{bmatrix} 2 \\ 1 \\ -3 \end{bmatrix}$

5. $[\mathbf{p}]_{\mathcal{B}} = \begin{bmatrix} 1 \\ -3 \\ -2 \end{bmatrix}$

6. $[\mathbf{p}]_{\mathcal{B}} = \begin{bmatrix} 3 \\ 2 \\ -1 \end{bmatrix}$ **correct**

Explanation:

The coordinate mapping from \mathbb{P}_2 to \mathbb{R}^3 maps

$$\mathbf{p} = a + bt + ct^2 \longrightarrow \begin{bmatrix} a \\ b \\ c \end{bmatrix}.$$

When

$$\mathbf{p}(t) = 2 + 3t - 6t^2$$

and

$$\mathcal{B} = \{1 - t^2, t - t^2, 1 - t + t^2\},$$

therefore, the entries c_1, c_2, c_3 in $[\mathbf{p}]_{\mathcal{B}}$ are the solutions of the polynomial equation

$$\begin{aligned} c_1(1 - t^2) + c_2(t - t^2) + c_3(1 - t + t^2) \\ = \mathbf{p}(t) = 2 + 3t - 6t^2. \end{aligned}$$

Equating coefficients thus shows that c_1, c_2, c_3 satisfy the matrix equation

$$\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 2 \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 4 \\ 7 \end{bmatrix},$$

which in augmented matrix form becomes

$$A = \left[\begin{bmatrix} 1 & 0 & 1 & 2 \\ 0 & 1 & -1 & 3 \\ -1 & -1 & 1 & -6 \end{bmatrix} \right].$$

But then

$$\text{rref}(A) = \left[\begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & -1 \end{bmatrix} \right].$$

Thus

$$[\mathbf{x}]_{\mathcal{B}} = \begin{bmatrix} 3 \\ 2 \\ -1 \end{bmatrix}.$$

ChangeBasis01c

011 (part 1 of 2) 10.0 points

Determine the change of coordinates matrix $P_{\mathcal{C} \leftarrow \mathcal{B}}$ from basis $\mathcal{B} = \{\mathbf{b}_1, \mathbf{b}_2\}$ to $\mathcal{C} = \{\mathbf{c}_1, \mathbf{c}_2\}$ of a vector space V when

$$\mathbf{b}_1 = -\mathbf{c}_1 + 4\mathbf{c}_2, \quad \mathbf{b}_2 = 5\mathbf{c}_1 - 3\mathbf{c}_2.$$

$$1. P_{\mathcal{C} \leftarrow \mathcal{B}} = \begin{bmatrix} 5 & 1 \\ 3 & 4 \end{bmatrix}$$

$$2. P_{\mathcal{C} \leftarrow \mathcal{B}} = \begin{bmatrix} 1 & -5 \\ -4 & -3 \end{bmatrix}$$

$$3. P_{\mathcal{C} \leftarrow \mathcal{B}} = \begin{bmatrix} 5 & -1 \\ -3 & 4 \end{bmatrix}$$

$$4. P_{\mathcal{C} \leftarrow \mathcal{B}} = \begin{bmatrix} 1 & -5 \\ 4 & -3 \end{bmatrix}$$

$$5. P_{\mathcal{C} \leftarrow \mathcal{B}} = \begin{bmatrix} -1 & 5 \\ 4 & -3 \end{bmatrix} \text{ correct}$$

$$6. P_{\mathcal{C} \leftarrow \mathcal{B}} = \begin{bmatrix} 5 & -1 \\ 3 & -4 \end{bmatrix}$$

Explanation:

The change of coordinates matrix $P_{\mathcal{C} \leftarrow \mathcal{B}}$ is the 2×2 matrix

$$P_{\mathcal{C} \leftarrow \mathcal{B}} = [[\mathbf{b}_1]_{\mathcal{C}} \quad [\mathbf{b}_2]_{\mathcal{C}}].$$

Now

$$[\mathbf{b}_1]_{\mathcal{C}} = \begin{bmatrix} -1 \\ 4 \end{bmatrix}, \quad [\mathbf{b}_2]_{\mathcal{C}} = \begin{bmatrix} 5 \\ -3 \end{bmatrix}.$$

Consequently,

$$P_{\mathcal{C} \leftarrow \mathcal{B}} = \begin{bmatrix} -1 & 5 \\ 4 & -3 \end{bmatrix}.$$

012 (part 2 of 2) 10.0 points

Determine $[\mathbf{x}]_{\mathcal{C}}$ when

$$\mathbf{x} = 5\mathbf{b}_1 + 3\mathbf{b}_2.$$

$$1. [\mathbf{x}]_{\mathcal{C}} = \begin{bmatrix} 11 \\ -10 \end{bmatrix}$$

$$2. [\mathbf{x}]_{\mathcal{C}} = \begin{bmatrix} -10 \\ 11 \end{bmatrix}$$

$$3. [\mathbf{x}]_{\mathcal{C}} = \begin{bmatrix} 10 \\ 11 \end{bmatrix} \text{ correct}$$

$$4. [\mathbf{x}]_{\mathcal{C}} = \begin{bmatrix} -11 \\ 10 \end{bmatrix}$$

$$5. [\mathbf{x}]_{\mathcal{C}} = \begin{bmatrix} 10 \\ -11 \end{bmatrix}$$

$$6. [\mathbf{x}]_{\mathcal{C}} = \begin{bmatrix} 11 \\ 10 \end{bmatrix}$$

Explanation:

When

$$\mathbf{x} = 5\mathbf{b}_1 + 3\mathbf{b}_2,$$

then

$$\mathbf{x} = 5(-\mathbf{c}_1 + 4\mathbf{c}_2) + 3(5\mathbf{c}_1 - 3\mathbf{c}_2).$$

Consequently,

$$\boxed{[\mathbf{x}]_{\mathcal{C}} = \begin{bmatrix} 10 \\ 11 \end{bmatrix}}.$$