#### 1. Who invented linear algebra?

Linear algebra was invented by the Greek mathematician Euclid around 300 BC.

#### 2. What are the main areas of application for linear algebra?

Linear algebra is used in a variety of fields, including physics, engineering, and mathematics. It is also used in computer science, particularly for solving problems in graphics and vision. Additionally, linear algebra is used in machine learning and artificial intelligence.

#### 3. Can you explain what a vector is in linear algebra?

A vector is a mathematical object that has both a magnitude and a direction. Vectors can be used to represent physical quantities that have both a magnitude and a direction, such as velocity or force. In linear algebra, vectors are often used to represent points in space.

#### 4. What’s the difference between a matrix and a vector?

A matrix is a two-dimensional array of numbers, while a vector is a one-dimensional array. Vectors can be thought of as points in space, and matrices can be thought of as transformations of those points.

IMG_256

#### 5. What does it mean to add or subtract vectors from one another?

Adding or subtracting vectors from one another simply means to combine them together to create a new vector. The process is the same regardless of whether you are adding or subtracting, you simply combine the vectors together component-wise. So, if you have two vectors, A and B, and you want to add them together to create a new vector C, you would do so like this:

C = A + B

This would give you a new vector whose first component would be the sum of the first components of A and B, whose second component would be the sum of the second components of A and B, and so on.

#### 6. How do you calculate the dot product of two vectors?

The dot product of two vectors is the product of the magnitude of each vector multiplied by the cosine of the angle between them.

#### 7. What is an eigenvector?

In linear algebra, an eigenvector is a vector that changes by only a scalar factor when that vector is multiplied by a matrix. In other words, if Av = λv, then v is an eigenvector of A with eigenvalue λ.

#### 8. What is an eigenvalue?

In linear algebra, an eigenvalue is a scalar value associated with an eigenvector of a linear transformation. The eigenvectors are the vectors that do not change direction when that linear transformation is applied to them.

#### 9. What’s the best way to solve problems involving large matrices?

There is no one-size-fits-all answer to this question, as the best way to solve problems involving large matrices will vary depending on the specific problem at hand. However, some general tips that may be helpful include breaking the problem down into smaller pieces, using numerical methods to approximate solutions, and using matrix decomposition techniques to simplify the matrix.

#### 10. What’s the best way to find the inverse of a matrix in Python?

There are a few different ways to find the inverse of a matrix in Python. One way is to use the numpy.linalg.inv() function. Another way is to use the scipy.linalg.inv() function. Finally, you can also use the sympy.Matrix.inv() function.

#### 11. What is the rank of a matrix?

The rank of a matrix is the number of non-zero rows in the matrix.

#### 12. What is the difference between a system of equations and a set of linear equations?

A system of equations is a set of two or more equations that are related to each other. A set of linear equations is a subset of the system of equations in which all the equations are linear.

#### 13. What is a null space?

The null space of a matrix is the set of all vectors that are mapped to the zero vector by the matrix. In other words, it is the set of all vectors that are mapped to zero by the matrix.

#### 14. What is the transpose of a matrix?

The transpose of a matrix is a new matrix that is formed by flipping the rows and columns of the original matrix. So, if the original matrix is m x n, then the transpose will be n x m.

#### 15. Is it possible to multiply two scalars together? If yes, then how?

Yes, it is possible to multiply two scalars together. This is done by simply multiplying the two numbers together. For example, if you wanted to multiply the scalars 2 and 3 together, you would simply multiply 2 times 3 to get 6.

#### 16. When solving systems of linear equations, why is it important to understand the dimensions of the underlying matrices?

The dimensions of the underlying matrices are important because they determine the number of solutions that the system of linear equations will have. If the matrices are of different sizes, then the system will not have any solutions. If the matrices are the same size, then the system will have either one solution, no solutions, or infinitely many solutions.

#### 17. What is the importance of understanding the dimensionality of a matrix when performing vector operations on it?

The dimensionality of a matrix is important when performing vector operations on it because it determines the number of rows and columns in the matrix. This information is necessary in order to correctly perform the operation. For example, if you are trying to multiply two matrices together, the number of columns in the first matrix must match the number of rows in the second matrix. If the dimensions are not correct, then the operation will not be able to be performed.

#### 18. What are some common applications of linear algebra in computer science?

Linear algebra is used in computer science for a variety of tasks, including solving systems of linear equations, manipulating matrices, and transforming vectors. It is also used in machine learning and artificial intelligence for tasks such as training neural networks and performing matrix operations.

#### 19. What is the best way to visualize linear transformations?

The best way to visualize linear transformations is to think of them as a change in basis. So, if you have a vector v and you apply a linear transformation T to it, the result is T(v). You can think of this as v being transformed from the original basis to the new basis defined by T. This is why linear transformations are often represented by matrices – because they define a new basis.

#### 20. Why is it important to learn about linear algebra before studying machine learning algorithms like Random Forest?

Linear algebra is the mathematics of vectors and matrices, which are used to represent data in machine learning algorithms. Without a strong understanding of linear algebra, it would be difficult to understand how these algorithms work and how to optimize them.

## *Q1*:

**At what conditions does the inverse of a diagonal matrix exist?**

**Junior**

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**Answer**

The invert of a square ****diagonal matrix**** exists if all entries of the diagonal are non-zero. If it is the case, the invert is obtained by replacing each element in the diagonal with its reciprocal.

D = \begin{pmatrix} \begin{array}{cccc}d\_{1} & 0 & \cdots & 0\\0 & d\_{2} & \cdots & 0\\ \vdots & \vdots & \ddots & \vdots \\0 & 0 & \cdots & d\_{i}\end{array} \end{pmatrix} \qquad \Rightarrow D^{-1} = \begin{pmatrix} \begin{array}{cccc} 1/d\_{1} & 0 & \cdots & 0\\0 & 1/d\_{2} & \cdots & 0\\ \vdots & \vdots & \ddots & \vdots \\0 & 0 & \cdots & 1/d\_{i}\end{array} \end{pmatrix}*D*=⎝⎜⎜⎛​*d*1​0⋮0​0*d*2​⋮0​⋯⋯⋱⋯​00⋮*di*​​​⎠⎟⎟⎞​⇒*D*−1=⎝⎜⎜⎛​1/*d*1​0⋮0​01/*d*2​⋮0​⋯⋯⋱⋯​00⋮1/*di*​​​⎠⎟⎟⎞​

## *Q2*:

**How do you find eigenvalues of a matrix? Could you provide an example?**

**Junior**

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**Answer**

Given a matrix ****A****, we find its eigenvalues λ by solving the equation:

\det \left( \lambda I -A \right) = 0det(*λI*−*A*)=0

For example, given the following matrix,

A = \left ( \begin{array}{rr} -5 & 2 \\ -7 & 4 \end{array} \right )*A*=(−5−7​24​)

we determine its eigenvalues in the following way:

\begin{aligned} \det ( \lambda I - A ) &= \left| \lambda \left ( \begin{array}{rr} 1 & 0 \\ 0 & 1 \end{array} \right ) - \left ( \begin{array}{rr} -5 & 2 \\ -7 & 4 \end{array} \right ) \right| \\ \\ &= \left| \left ( \begin{array}{cc} \lambda +5 & -2 \\ 7 & \lambda -4 \end{array} \right ) \right| \end{aligned}det(*λI*−*A*)​=∣∣∣∣​*λ*(10​01​)−(−5−7​24​)∣∣∣∣​=∣∣∣∣​(*λ*+57​−2*λ*−4​)∣∣∣∣​​

Now the characteristic polynomial is:

\lambda ^2 + \lambda - 6 = 0*λ*2+*λ*−6=0

The solutions of this equation and therefore the eigenvalues are then,

\lambda\_1 = 2, \lambda\_2 = -3*λ*1​=2,*λ*2​=−3

## *Q3*:

**What is Ax = b*Ax*=*b*? When does Ax = b*Ax*=*b* has a unique solution?**

**Junior**

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**Answer**

****Ax = b**** is a system of linear equations expressed in matrix notation, in which:

* ****A**** is the coefficient matrix of order m x n.
* ****x**** is the incognite variables vector of order n x 1.
* ****b**** is the vector formed by the constants and its order is m x 1.

The system ****Ax = b**** has a unique solution if and only if

rank [A] = rank[A|b] = n*rank*[*A*]=*rank*[*A*∣*b*]=*n*

where the matrix A|b is matrix ****A**** with ****b**** appended as an extra column.

## *Q4*:

**What's the difference between Cross Product and Dot Product?**

**Junior**

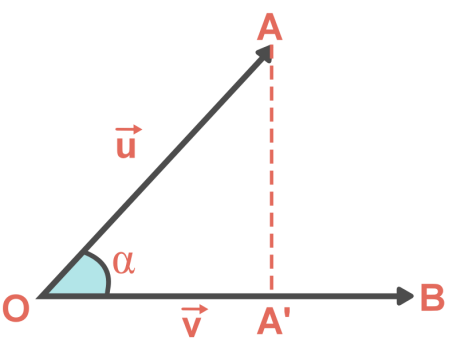
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**Answer**

* A ****dot product**** is a fundamental way we can combine two vectors. Intuitively, it tells us something about how much two vectors point in the same direction or what is the projection of a vector on another vector and it ****returns a single number****. It's defined as:

\vec{u} \cdot \vec{v} = \| \vec{u} \|\| \vec{v} \| \cos (\alpha)*u*⋅*v*=∥*u*∥∥*v*∥cos(*α*)

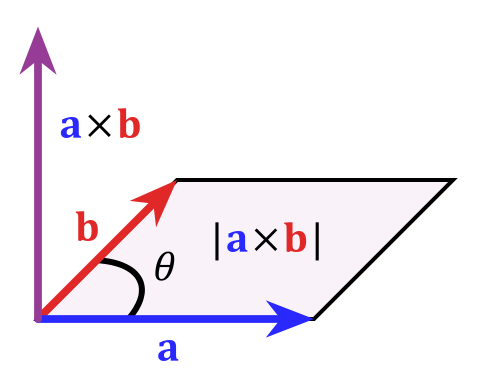
* where α is the angle between the vectors.



* In the picture, ****OA'**** is the projection of the vector of u on v.
* A ****cross product**** is another way to combine two vectors. The difference here is that the ****result is another vector**** that is perpendicular to the initial ones. The cross prodct it's defined as:

\vec{a} \times \vec{b} = \| \vec{a} \|\| \vec{b} \| \sin (\theta)*a*×*b*=∥*a*∥∥*b*∥sin(*θ*)

* where θ is the angle between the vectors.



## *Q5*:

**When are two vectors x and y orthogonal?**

**Junior**

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**Answer**

Two vectors are said to be orthogonal if the dot product of them is equal to zero,

\vec{x} \cdot \vec{y} = 0*x*⋅*y*​=0

This is because the definition of the dot product:

\vec{x} \cdot \vec{y} = |x||y| \cos(\theta)*x*⋅*y*​=∣*x*∣∣*y*∣cos(*θ*)

where θ is the angle between the two vectors, therefore if x and y are orthogonal, the angle between them is 90 and cos(90) = 0.

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## *Q6*:

**Determine which of the following matrices is normal**

**Mid**

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**Problem**

A = \begin{pmatrix} 1 & i \\ 0 & 1 \end{pmatrix},*A*=(10​*i*1​),

B = \begin{pmatrix} 1 & i \\ 1 & 2 + i \end{pmatrix}*B*=(11​*i*2+*i*​)

**Answer**

We say that a matrix A is ****normal**** if AA^\* = A^\* A,*AA*∗=*A*∗*A*, where A\* is the conjugate transpose of matrix A.

Prove equality for A:

AA^\* = \begin{pmatrix} 1 & i \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ -i & 1 \end{pmatrix} = \begin{pmatrix} 2 & i \\ -i & 1 \end{pmatrix}*AA*∗=(10​*i*1​)(1−*i*​01​)=(2−*i*​*i*1​)

A^\*A = \begin{pmatrix} 1 & 0 \\ -i & 1 \end{pmatrix} \begin{pmatrix} 1 & i \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} 1 & i \\ -i & 2 \end{pmatrix}*A*∗*A*=(1−*i*​01​)(10​*i*1​)=(1−*i*​*i*2​)

\therefore AA^\* \not = A^\* A \Rightarrow A \text{ is not normal.}∴*AA*∗̸=*A*∗*A*⇒*A* is not normal.

Prove equality for B:

BB^\* = \begin{pmatrix} 1 & i \\ 1 & 2+1 \end{pmatrix} \begin{pmatrix} 1 & 1 \\ -i & 2-i \end{pmatrix} = \begin{pmatrix} 2 & 2+2i \\ 2-2i & 6 \end{pmatrix}*BB*∗=(11​*i*2+1​)(1−*i*​12−*i*​)=(22−2*i*​2+2*i*6​)

B^\*B = \begin{pmatrix} 1 & 1 \\ -i & 2-i \end{pmatrix} \begin{pmatrix} 1 & i \\ 1 & 2+i \end{pmatrix} = \begin{pmatrix} 2 & 2+2i \\ 2-2i & 6 \end{pmatrix}*B*∗*B*=(1−*i*​12−*i*​)(11​*i*2+*i*​)=(22−2*i*​2+2*i*6​)

\therefore BB^\* = B^\* B \Rightarrow B \text{ is normal.}∴*BB*∗=*B*∗*B*⇒*B* is normal.

## *Q7*:

**Find the inverse of the following matrix**

**Mid**

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**Problem**

Consider the matrix:

A = \left[\begin{array}{ccc}4 & -2 & 1\\5 & 0 & 3\\-1 & 2 & 6\end{array}\right]*A*=⎣⎡​45−1​−202​136​⎦⎤​

**Answer**

We will compute inverse using the following equation: A^{-1} = \frac{1}{det(A)} adj(A)*A*−1=*det*(*A*)1​*adj*(*A*) where adj(A) is the adjugate of matrix A. Now we follow the next steps:

****Calculate the determinant of**A**:****

\begin{aligned} det(A) =& 4\left|\begin{matrix}0&3\\2 & 6\end{matrix}\right| -(-2)\left|\begin{matrix}5&3\\-1 & 6\end{matrix}\right|+1\left|\begin{matrix}5&0\\-1& 2\end{matrix}\right| \\ \ \\ = \, & 4(0 - 6) + 2(30 + 3) + 1(10 - 0) \\ \ \\ =& \, 52 \not = 0 \therefore \text{the matrix is invertible} \end{aligned}*det*(*A*)= = =​4∣∣∣∣​02​36​∣∣∣∣​−(−2)∣∣∣∣​5−1​36​∣∣∣∣​+1∣∣∣∣​5−1​02​∣∣∣∣​4(0−6)+2(30+3)+1(10−0)52̸=0∴the matrix is invertible​

****Calculate the cofactor**** of each element:

\begin{aligned} C\_{11} &= \left(-1\right)^{1 + 1} \left|\begin{array}{cc}0 & 3\\2 & 6\end{array}\right| = -6, \qquad C\_{12} = \left(-1\right)^{1 + 2} \left|\begin{array}{cc}5 & 3\\-1 & 6\end{array}\right| = -33 , \\ \ \\ C\_{13} &= \left(-1\right)^{1 + 3} \left|\begin{array}{cc}5 & 0\\-1 & 2\end{array}\right| = 10, \qquad C\_{21} = \left(-1\right)^{2 + 1} \left|\begin{array}{cc}-2 & 1\\2 & 6\end{array}\right| = 14, \\ \ \\ C\_{22} &= \left(-1\right)^{2 + 2} \left|\begin{array}{cc}4 & 1\\-1 & 6\end{array}\right| = 25, \qquad C\_{23} = \left(-1\right)^{2 + 3} \left|\begin{array}{cc}4 & -2\\-1 & 2\end{array}\right| = -6, \\ \ \\ C\_{31} &= \left(-1\right)^{3 + 1} \left|\begin{array}{cc}-2 & 1\\0 & 3\end{array}\right| = -6, \qquad C\_{32} = \left(-1\right)^{3 + 2} \left|\begin{array}{cc}4 & 1\\5 & 3\end{array}\right| = -7, \\ \ \\ C\_{33} &= \left(-1\right)^{3 + 3} \left|\begin{array}{cc}4 & -2\\5 & 0\end{array}\right| = 10. \end{aligned}*C*11​ *C*13​ *C*22​ *C*31​ *C*33​​=(−1)1+1∣∣∣∣​02​36​∣∣∣∣​=−6,*C*12​=(−1)1+2∣∣∣∣​5−1​36​∣∣∣∣​=−33,=(−1)1+3∣∣∣∣​5−1​02​∣∣∣∣​=10,*C*21​=(−1)2+1∣∣∣∣​−22​16​∣∣∣∣​=14,=(−1)2+2∣∣∣∣​4−1​16​∣∣∣∣​=25,*C*23​=(−1)2+3∣∣∣∣​4−1​−22​∣∣∣∣​=−6,=(−1)3+1∣∣∣∣​−20​13​∣∣∣∣​=−6,*C*32​=(−1)3+2∣∣∣∣​45​13​∣∣∣∣​=−7,=(−1)3+3∣∣∣∣​45​−20​∣∣∣∣​=10.​

Thus, the cofactor matrix is: C = \left[\begin{array}{ccc}-6 & -33 & 10\\14 & 25 & -6\\-6 & -7 & 10\end{array}\right]*C*=⎣⎡​−614−6​−3325−7​10−610​⎦⎤​

1. ****Obtain the adjugate matrix**** by transposing cofactor matrix

adj(A) = \left[\begin{array}{ccc}-6 & 14 & -6\\-33 & 25 & -7\\10 & -6 & 10\end{array}\right]*adj*(*A*)=⎣⎡​−6−3310​1425−6​−6−710​⎦⎤​

1. Finally, the inverse matrix is the ****adjugate matrix divided by the determinant****:

\begin{aligned} A^{-1} &= \dfrac{1}{52} \cdot \left[\begin{matrix}-6 & 14 & -6\\-33&25&-7\\10&-6 & 10\end{matrix}\right] \\ \ \\ A^{-1} &= \left[\begin{matrix}-3/26 & 7/26 & -3/26\\-33/52&25/52&-7/52\\5/26&-3/26 & 5/26\end{matrix}\right] \end{aligned}*A*−1 *A*−1​=521​⋅⎣⎡​−6−3310​1425−6​−6−710​⎦⎤​=⎣⎡​−3/26−33/525/26​7/2625/52−3/26​−3/26−7/525/26​⎦⎤​​

## *Q8*:

**How do you diagonalize a matrix?**

**Mid**

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**Answer**

Given an nxn matrix ****A****, to find its diagonal matrix ****D**** we must follow the next steps:

1. Find the characteristic polynomial of ****A****.
2. Find the roots of the characteristic polynomial to obtain the eigenvalues λ of ****A****.
3. For each eigenvalue λ of ****A****, find their correspondent eigenvectors.
4. If the total number of eigenvectors m found in step 3 is not equal to n (the numbers of rows and columns of ****A****), then the matrix is not diagonalizable, but if m = n then the diagonal matrix ****D**** is given by:

\bf D = P^{-1} A P,**D**=**P**−**1AP**,

1. where ****P**** is a matrix which columns are the eigenvectors of the matrix ****A****.

## *Q9*:

**How do you find the inverse of a 2x2 matrix?**

**Mid**

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**Answer**

For an arbitrary A matrix, we can derive it's inverse by following the next steps:

A = \begin{pmatrix} a & b \\ c & d \end{pmatrix}*A*=(*ac*​*bd*​)

1. Check if the matrix if invertible by finding its determinant :

|A| = ad -bc.∣*A*∣=*ad*−*bc*.

1. If |A| ≠ 0 then the matrix is invertible.
2. Interchange the two elements on the diagonal.
3. Take the negatives of the other two elements out of the diagonal.
4. Divide each element of the matrix by |A|. The result of the inverse of the matrix A is then:

A^{-1} = \frac{1}{|A|} \begin{pmatrix} d & -b \\ c & a \end{pmatrix}*A*−1=∣*A*∣1​(*dc*​−*ba*​)

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## *Q10*:

**How many ways of measure a vector do you know?**

**Mid**

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**Answer**

There are different ways to measure the magnitude of vectors, the most common are:

****L0 norm****: Although ****it's not formally speaking a norm****, it's often used as if was one. It corresponds to the total number of nonzero elements in a vector. For example, the L0 norm of the vector [0,2] is 1 because there is only one nonzero element.

****L1 norm****: Also known as Manhattan Distance, is the sum of absolute values of the components of the vector. For example, for some vector:

X = [x\_1, x\_2]*X*=[*x*1​,*x*2​]

The L1 norm is calculated by:

\| x\|\_1 = |x\_1| + |x\_2|∥*x*∥1​=∣*x*1​∣+∣*x*2​∣

****L2 norm****: Also known as the Euclidean norm, it is the shortest distance to go from one point to another. Using the same example as before, the L2 norm for the vector defined above is:

\| x\|\_2 = \sqrt{ x\_1^2 + x\_2^2 }∥*x*∥2​=*x*12​+*x*22​​

****L-infinity norm****: Gives the largest magnitude among each element of a vector. For example, having the vector X= [-6, 4, 2], the L-infinity norm is 6.

## *Q11*:

**What are positive definite, negative definite, positive semi definite and negative semi definite matrices?**

**Mid**

**Answer**

* A ****Positive definite**** matrix is a symmetric matrix ****M**** such that the number ****zᵗMz**** is positive for every nonzero column vector ****z****.
* A ****Positive semi-definite**** matrix is a symmetric matrix ****M**** such that the number ****zᵗMz**** is positive or zero for every nonzero column vector ****z****.
* ****Negative-definite**** and ****negative semi-definite**** matrices are defined analogously.

Given that we can associate each matrix with the quadratic equation ****zᵗMz****, these kinds of matrix helps us to solve optimization problems. For example, a positive definite matrix ****M**** will imply a convex function, which guarantees the existence of the global minimum. This allows us to use the Hessian matrix to solve the optimization problem. Similar arguments also hold for negative definite matrices.

## *Q12*:

**What is broadcasting in connection to Linear Algebra?**

**Mid**

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**Answer**

****Broadcasting**** is a mechanism for relaxing elementwise operations according to the dimension requirements. We say that two matrices are compatible for broadcasting if the corresponding dimensions in each matrix (rows vs rows, columns vs columns) meet the following criteria:

* The dimensions are equal, or
* One dimension is of size 1.

The way that broadcasting works are by duplicating the smaller array so that it is the dimensionality and size as the larger array.

Initially, this method was developed for NumPy, but it has also been adopted more broadly in other numerical computational libraries, such as Theano, TensorFlow, and Octave.

## *Q13*:

**What is an Orthogonal Matrix? Why is computationally preferred?**

**Mid**

**Answer**

An ****orthogonal matrix**** is a type of square matrix whose columns and rows are orthonormal unit vectors, e.g. perpendicular, and have a length or magnitude of 1. Formally, it's defined as follows:

Q^t Q = Q Q^t = I*QtQ*=*QQt*=*I*

Where Q is the orthogonal matrix, Qᵗ indicates the transpose of Q, and I is the identity matrix. From the above definition, we can see that

Q^{-1} = Q^t*Q*−1=*Qt*

Therefore, the orthogonal matrix is preferred because they are computationally cheap and stable to calculate their inverse as simply their transpose.

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## *Q14*:

**What is the determinant of a square matrix? How is it calculated?**

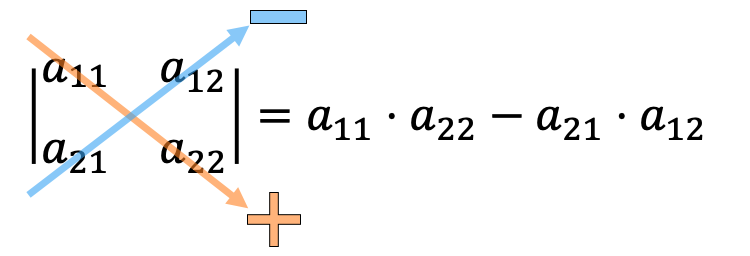
**Mid**

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**Answer**

The ****determinant**** is a scalar value that is a function of the entries of a square matrix. The determinant of a matrix ****A**** is denoted ****det(A)****, ****det A****, or ****|A|****. Geometrically, it can be viewed as the volume scaling factor of the linear transformation described by the matrix.

In the case of a 2 × 2 matrix the determinant is calculated following the next diagram:



That is, the determinant is equal to the product of the elements along the plus-labeled arrow minus the product of the elements along the minus-labeled arrow.

Similarly, for a 3 × 3 matrix ****A****, its determinant is

Each determinant of a 2 × 2 matrix in the equation above is called a minor of the matrix ****A****.

For an n × n matrix, the previous procedure is extended and provides a recursive definition for the determinant, known as a Laplace expansion.

## *Q15*:

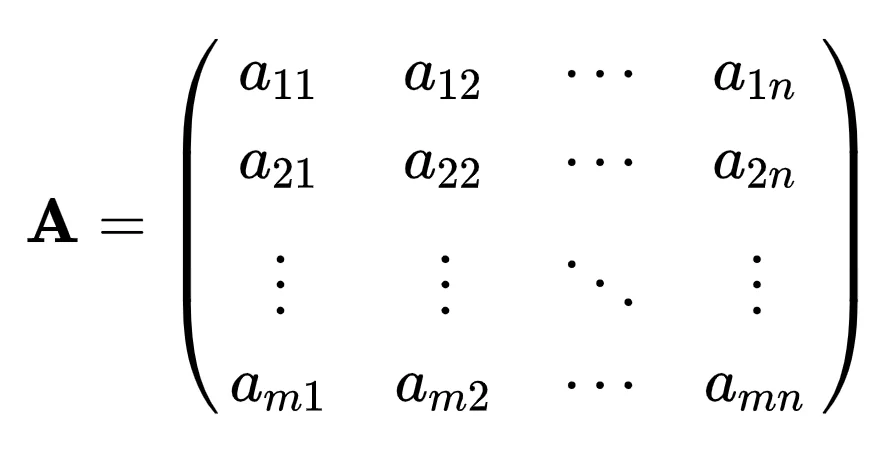
**What’s the difference between a Matrix and a Tensor?**

**Mid**

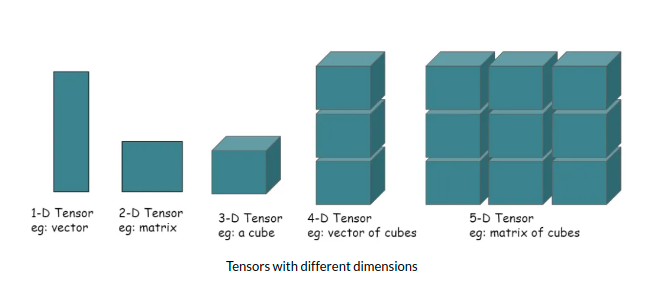
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**Answer**

In simple terms, a ****matrix**** is a grid of n × m (say, 3 × 3) numbers surrounded by brackets. We can add and subtract matrices of the same size, multiply one matrix with another as long as the sizes are compatible, and multiply an entire matrix by a constant.



A tensor is a generalization of matrices to N-dimensional space. That is, it could be a 1-D matrix (a vector), a 3-D matrix (something like a cube of numbers), or even a 0-D matrix (a single number), etc. The dimension of the tensor is called rank.



A ****tensor**** can be also seen as a mathematical entity that lives in a structure and interacts with other mathematical entities. If one transforms the other entities in the structure in a regular way, then the tensor obeys a related transformation rule. This dynamical property of a tensor is also a key to distinguish it from a mere matrix. For example, any rank-2 tensor can be represented as a matrix, but not every matrix is really a rank-2 tensor. The difference depends on the transformation rules that have been applied to the entire system.