Lecture-12-Vectors-and-Matrics

Warm-up exercises

1. $\dfrac{0.002}{50}$ =

2. $\dfrac{1.5 \times 10^8}{500}$ =

3. $\dfrac{[2 \times 10^{-15}]^3}{4 \times 3 \times [9 \times 10^{-12}]^2 \times 10^{-10}}$ =

4. $\ln(A-3) - \ln A$ =

5. $\log \sqrt{N} + \log N^3$ =

6. $\displaystyle\int_{-\infty}^{\infty} x^3 dx$ =

7. $\displaystyle\int_{0}^{1} \dfrac{1}{e^{-2x}} dx$ =

8. If $\dfrac{dy}{dx} = \sqrt{x}$ find $y =$

Challenge

> **For you:**
>
> Answer to Week 7 Challenge: I have 8 identical balls, and a ninth that looks identical but which is either lighter or heavier than the others. I have a pair of weighing scales which are the old fashioned balance ones with a plate on each side of the balance point. I am allowed three uses of these scales to identify the odd ball. How can I do it?

Divide the balls into 3 groups of 3, and for the 3 allowed uses of the scales, you could do the following:

1. Take one group of 3 and put it on 1 side, and another group on the other side. If they are equal, the odd ball is in the third group (in which case see point (4)).
2. If one group goes down relative to the other, I don't know if I have a light ball or a heavy ball with respect to the norm, so I would test one group against the resting group. Then I would know which group the odd ball was in, and I would also know whether it was lighter or heavier than the others.

3. Now I take the group of three in which the odd ball is lurking, and put one of them on each side of the scales. If they are equal, the odd ball is the unweighed one. If not, I know which is the odd one, since I already know if it is lighter or heavier than the others. Thus in this case I found the odd one in 2 weighings.
4. In point (1) if the 2 groups of 3 are equal, the odd ball is in the unweighed trio, and I don't know yet if it is heavier or lighter. So I weigh the trio against one of the other trios, and then I am at (2) above and can do (3), so I have found the odd ball in 3 weighings.

> **For you:**
>
> Week 8 Challenge: I put a piece of string of length Q metres all the way around the equator next to the earth. I cut another piece of string, π metres longer than the first, and put it around the equator too, held an equal distance from the centre of the earth all the way round. How far from the earth is the second piece of string?

Basic Scalar and Vector Algebra

A **scalar** quantity is one that is fully defined by magnitude alone.

e.g. Length is a scalar quantity as the length of a piece of string does not depend on its direction when it is measured. Temperature, density and volume and are also scalars.

A **vector** is a quantity which has both **magnitude** and a specific **direction** in space.

Vector nomenclature

It is represented as a straight line the length of which is its magnitude and with an arrow indicating its direction. It is usually written bold type. e.g. **a** or when handwritten, it is underlined $\underline{a}$. If it is between point A and B it can be written $\vec{AB}$ with an arrow above it.

Velocity, acceleration, and force are all examples of vectors. Electric fields (and magnetic ones) are 'vector fields'.

The magnitude of the vector is its *modulus* ($|\underline{a}|$).

Below are drawn two vectors, $\vec{AB}$ and $\vec{BA}$.
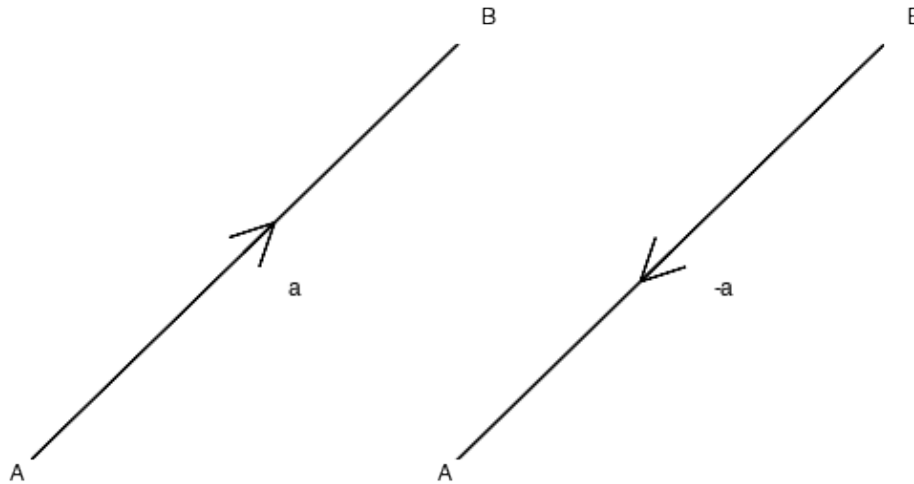
Vector manipulation

We can *multiply* a vector by a scalar, λ to get $\lambda\underline{a}$ which is in the same direction as $\underline{a}$ but has a magnitude λ times the modulus of $\underline{a}$ i.e. $\lambda|a|$.

The vector $-\underline{a}$ has the same magnitude as $\underline{a}$ but has the *opposite* direction.

We can *add* 2 vectors $\underline{p}$ and $\underline{q}$ by placing the tail of $\underline{q}$ at the head of $\underline{p}$, and drawing a line between the tail of $\underline{p}$ and the head of $\underline{q}$ to get a so called *resultant*.
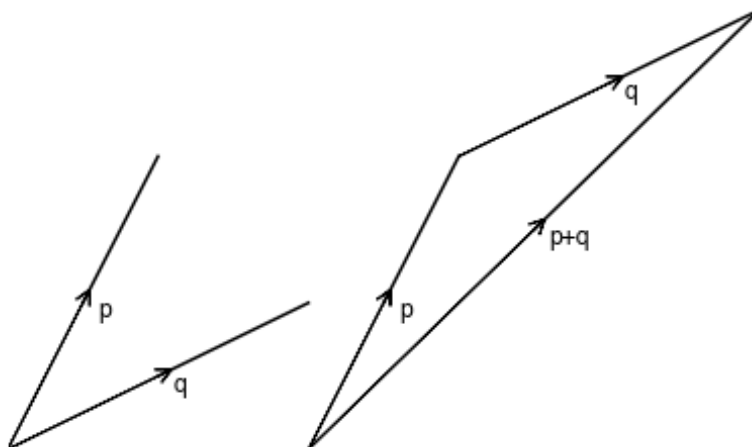
We can also *subtract* 2 vectors $\underline{p} - \underline{q}$ by replacing $\underline{q}$ by $-\underline{q}$ (same magnitude, opposite direction) and adding it to $\underline{p}$, as above to get $\underline{p} - \underline{q}$
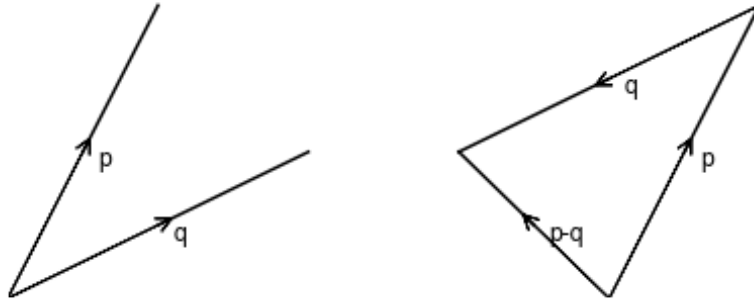
Three-dimensional vectors in Cartesian space

In Cartesian space, a vector can be represented by 3 orthogonal directional components of unit magnitude $\underline{i}, \underline{j}, \underline{k}$ multiplied by scalar.

For example,

$$\underline{v_1} = 2\underline{i} + 3\underline{j} - 4\underline{k}$$

and

$$\underline{v_2} = 4\underline{i} - 2\underline{j} + 6\underline{k}$$

These directional components are sometimes written with a 'hat'; this signifies that they have length one.

e.g.

$$\underline{v_1} = 2\hat{\underline{i}} + 3\hat{\underline{j}} - 4\hat{\underline{k}}$$

Vectors can also be represented as *column vectors* where, starting from the top and working down, they given you the magnitudes of $\underline{i}, \underline{j}$ and $\underline{k}$, respectively.

$$\underline{v_1} = \begin{pmatrix} 2 \\ 3 \\ -4 \end{pmatrix}$$

$$\underline{v_2} = \begin{pmatrix} 4 \\ -2 \\ 6 \end{pmatrix}$$

Adding and subtracting is simply a case of collecting similar components ($\underline{i}$ etc) together

e.g.

$$\underline{v_1} + \underline{v_2} = (2\underline{i} + 3\underline{j} - 4\underline{k}) + (4\underline{i} - 2\underline{j} + 6\underline{k})$$
$$= (2+4)\underline{i} + (3-2)\underline{j} + (-4+6)\underline{k}$$
$$= 6\underline{i} + \underline{j} + 2\underline{k}$$

$$\underline{v_1} - \underline{v_2} = (2\underline{i} + 3\underline{j} - 4\underline{k}) - (4\underline{i} - 2\underline{j} + 6\underline{k})$$
$$= (2-4)\underline{i} + (3-(-2))\underline{j} + (-4-6)\underline{k}$$
$$= -2\underline{i} + 5\underline{j} - 10\underline{k}$$

or, using column vectors

$$\underline{v_1} + \underline{v_2} = \begin{pmatrix} 2 \\ 3 \\ -4 \end{pmatrix} + \begin{pmatrix} 4 \\ -2 \\ 6 \end{pmatrix}$$
$$= \begin{pmatrix} 6 \\ 1 \\ 2 \end{pmatrix}$$

$$\underline{v_1} - \underline{v_2} = \begin{pmatrix} 2 \\ 3 \\ -4 \end{pmatrix} - \begin{pmatrix} 4 \\ -2 \\ 6 \end{pmatrix}$$
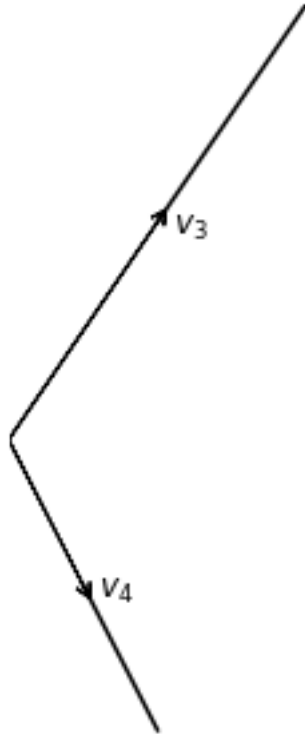$$= \begin{pmatrix} -2 \\ 5 \\ 10 \end{pmatrix}$$

Example

Show
$$\underline{v_3} = 2\underline{i} + 3\underline{j}$$
and
$$\underline{v_4} = 4\underline{i} - 2\underline{j}$$
on an $x - y$ plane. It does not matter where on the $x - y$ plane you place them.

v_3

v_4

From the sketch, the magnitude of $\underline{v_3}$ (i.e. $|v_3|$) is given by Pythagoras' theorem:

$$|v_3| = \sqrt{2^2 + 3^2} = \sqrt{13}$$

The scalar (or dot) product

The scalar product of two vectors $\underline{a}$ and $\underline{b}$ can be constructed by taking the component of one vector in the direction of the other (i.e. the magnitude of first $\times \cos\theta$) and multiplying it by the magnitude of the other vector. i.e.

$$\underline{a}.\underline{b} = |a||b|\cos\theta$$

Note that since $|a||b|\cos\theta = |b||a|\cos\theta$, then $\underline{a}.\underline{b} = \underline{b}.\underline{a}$

Example

Find $\underline{v_3}.\underline{v_4}$

$$\underline{v_3}.\underline{v_4} = (2\underline{i} + 3\underline{j}).(\underline{i} - 2\underline{j})$$
$$= 2\underline{i}.\underline{i} - 4\underline{i}.\underline{j} + 3\underline{j}.\underline{i} - 6\underline{j}.\underline{j}$$
$$= 2 - 0 - 0 - 6$$
$$= -4$$

Since $\underline{i}.\underline{i} = |\underline{i}||\underline{i}|\cos 0 = i^2 = 1$ (and likewise for $\underline{j}.\underline{j}$) and $\underline{i}.\underline{j} = |\underline{i}||\underline{j}|\cos 90 = 0$ (since $\underline{i}$ and $\underline{j}$ are orthogonal) (and likewise for $\underline{j}.\underline{i}$).

We can also use column vectors, which is simpler but doesn't show you how the orthongality simplifies the expression

$$\underline{v_3}.\underline{v_4} = \begin{pmatrix} 2 \\ 3 \end{pmatrix} . \begin{pmatrix} 1 \\ -2 \end{pmatrix}$$
$$= 2 - 6$$
$$= -4$$

We can rearrange the dot product to make θ the subject

$$\cos\theta = \frac{\underline{a}.\underline{b}}{|\underline{a}||\underline{b}|}$$

and hence this gives us a way of calculating the angle, θ, between two vectors.

since $|v_3| = \sqrt{13}$ and $|v_4| = \sqrt{5}$,

$$\cos\theta = \frac{-4}{\sqrt{13} \times \sqrt{5}}$$
$$= -\frac{4}{\sqrt{65}}$$
$$\theta = 119°$$
$$= 2.1 \text{ radians}$$

Thought:

Notice how the dot product has correctly given us an obtuse angle.

The vector (or cross) product

Given two linearly independent vectors $\underline{a}$ and $\underline{b}$, the *cross product*, $\underline{a} \wedge \underline{b}$, is a *vector* that is perpendicular to both $\underline{a}$ and $\underline{b}$ and therefore *normal* to the plane containing them.

The magnitude of the vector product of two vectors can be constructed by taking the product of the magnitudes of the vectors multiplied by the sine of the angle ($< 180°$) between them. The magnitude of the vector product can be expressed in the form:

$$|\underline{a} \wedge \underline{b}| = |a||b| \sin \theta$$

Note that sometimes the cross ($\wedge$) between 2 vectors is replaced by a bold cross ($\times$): either is used to denote the so called 'cross product'. For two vectors $\underline{a}$ and $\underline{b}$, θ can be determined from the dot product.

> **Thought:**
>
> Unlike the dot product, the vector product yields a vector. Since the result is orthogonal to the original two vectors and any two vectors, whether 2- or 3-dimensional, always describe a 2-d plane, you always end up with a 3-d arrangement.

> **For you:**
>
> Draw two vectors and their resultant cross product vector here:

We are not going to show how to perform the cross product since it is more complex.

Applications in Biochemistry

We will use vector algebra in conjuction with a so-called 'Argand diagram' in Year 3 when we prepare for understanding the diffraction patterns made by X-rays incident on protein crystals. These patters enable us to determine the 3-dimensional structure of proteins, RNA and DNA using crystallographic methods. In crystallography we will sum the X-ray scattering contributions of all the atoms in the protein by adding them *vectorially*.

> **Thought:**
>
> We have chosen to introduce this mathematics here so when you reach Y3 you will have seen it once before.

Matrics

What is a matrix?

A matrix is an array of numbers such as:

$$\begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix}$$

The *order* of the matrix is the (number of rows × number of columns) hence the order of the above matrix is: 3×3.

Basic Matrix Algebra

I can add or subtract 2 matrices as long as they have the *same* order:

$$\begin{pmatrix} 2 & 1 \\ 3 & -4 \end{pmatrix} + \begin{pmatrix} 6 & -5 \\ 1 & -7 \end{pmatrix} = \begin{pmatrix} 8 & -4 \\ 4 & -11 \end{pmatrix}$$

I can also multiply a matrix by a scalar:

$$5. \begin{pmatrix} 2 & 1 \\ 3 & -4 \end{pmatrix} = \begin{pmatrix} 10 & 5 \\ 15 & -20 \end{pmatrix}$$

What use are matrices?

Consider the pair of *simultaneous equations*.

$$a_1 x + b_1 y = c_1$$
$$a_2 x + b_2 y = c_2$$

where a_1, b_1, a_2, b_2, c_1 and c_2 are given constants.

We know that x and y can be found (i.e. expressed in terms of the constants $a_1, a_2 \ldots$ etc) by substitution or adding or subtracting the equations.

For example, if we multiply the first equation by b_2 and the second by b_1 we get

$$b_2 a_1 x + b_2 b_1 y = b_2 c_1$$
$$b_1 a_2 x + b_1 b_2 y = b_1 c_2$$

Now subtracting the second equation from the first:

$$b_2 a_1 x - b_1 a_2 x = b_2 c_1 - b_1 c_2$$

Thus:

$$x = \frac{b_2 c_1 - b_1 c_2}{b_2 a_1 - b_1 a_2}$$
$$y = \frac{a_1 c_2 - a_2 c_1}{a_1 b_2 - a_2 b_1}$$

provided $a_1 b_2 - a_2 b_1 \neq 0$

To simplify our notation, let's define a *determinant, D*

$$D = \begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}$$
$$= a_1 \times b_2 - a_2 \times b_1$$

(multiply the NW-SE diagonal elements and subtract the SW-NE diagonal elements multiplied together)

This lets us write the general solution to this pair of simultaneous equations as

$$\frac{x}{\begin{vmatrix} c_1 & b_1 \\ c_2 & b_2 \end{vmatrix}} = \frac{y}{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}} = \frac{1}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}}$$

Now that is fine, but it is a lot of algebra. We can instead write our pair of simultaneous equations in *matrix form*.

$$\begin{pmatrix} a_1 & b_1 \\ a_2 & b_2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix}$$

This is identical to

$$a_1 x + b_1 y = c_1$$
$$a_2 x + b_2 y = c_2$$

Multiplying matrices

The principle is rows $\times$ columns

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} \begin{pmatrix} 1 & -1 \\ 0 & 2 \end{pmatrix} = \begin{pmatrix} 1 & 3 \\ 3 & 5 \end{pmatrix}$$

$$\begin{pmatrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \end{pmatrix} \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \\ 10 & 11 & 12 \end{pmatrix} = \begin{pmatrix} 70 & 80 & 90 \\ 158 & 84 & 210 \end{pmatrix}$$

Hence the

number of rows of LH matrix = number of columns of RH matrix

from which we can infer that matrix multiplication is *not commutative.*

Multiply these 2 matrices together.

$$\begin{pmatrix} 4 & 0 & 2 & 3 \\ 1 & 0 & 5 & 2 \end{pmatrix} \begin{pmatrix} 6 & 0 \\ 2 & 1 \\ 3 & 0 \\ 3 & 10 \end{pmatrix} =$$

Notation

Sometimes it is helpful to be able to refer to an element in a matrix; here we use the convention of 'rows then columns' (which is a bit like x then y). In a matrix A, the element at the $i$the row and jth column would then be described as a_{ij}.

This notation lets us describe matrix multiplication:

$$c_{jk} = \sum_{l=1}^{n} a_{jl} b_{lk}$$

but usually it is easier to remember how you multiply matrices visually!

The identity matrix, I

Just as we know that there is a number (1) such that when other numbers are multiplied by it leads to no change, there is a matrix that when other matrices are multipled by it do not change the matrix.

This is called the *identity matrix, I*, and it has zeros everywhere, except on the *leading diagonal*.

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 2 & -1 \\ 3 & 1 & -4 \\ -4 & 1 & 2 \end{pmatrix} = \begin{pmatrix} 1 & 2 & -1 \\ 3 & 1 & -4 \\ -4 & 1 & 2 \end{pmatrix}$$

Multiplication by the identity matrix *is* communtative i.e.

$$AI = IA = A$$

Determinant of a matrix

If

$$A = \begin{pmatrix} p & q \\ r & s \end{pmatrix}$$

then the *determinant* of A is

$$|A| = ps - qr$$

11

If $|A| = 0$ the matrix is said to be *singular*

Finding the inverse of a matrix

All non-singular matrices, A, have an inverse, A^{-1}, such that $A^{-1}A = I$.

$$A = \begin{pmatrix} p & q \\ r & s \end{pmatrix}$$

$$A^{-1} = \frac{1}{ps - qr} \begin{pmatrix} s & -q \\ -r & p \end{pmatrix}$$

$$= \frac{1}{|A|} \begin{pmatrix} s & -q \\ -r & p \end{pmatrix}$$

(you can see how if $|A| = 0$ the prefactor will be undefined, hence the requirement it isn't zero i.e. A is not singular)

To find the inverse of a 2×2 matrix: 1. Swap the top left and bottom right elements. 2. Change the sign of the top right and bottom left elements. 3. Divide through by the *determinant* of the matrix.

If $|A|$ is zero, the matrix is SINGULAR and has NO INVERSE.

We've just stated it, so let's check it is true.

$$A^{-1}A = \frac{1}{ps - qr} \begin{pmatrix} s & -q \\ -r & p \end{pmatrix} \begin{pmatrix} p & q \\ r & s \end{pmatrix}$$

$$= \frac{1}{ps - qr} \begin{pmatrix} sp - qr & sq - qs \\ -rp + rp & -rq + ps \end{pmatrix}$$

$$= \frac{1}{ps - qr} \begin{pmatrix} ps - qr & 0 \\ 0 & ps - qr \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

$$= I$$

For you:

what is the inverse of A?

$$A = \begin{pmatrix} 2 & -3 \\ -2 & 4 \end{pmatrix}$$

Check by calculating $A^{-1}A$.

How can this help us solve simultaneous equations?

Remember we started out looking at these? Consider an example

$$5x + 4y = 7$$
$$3x - y = 11$$

We can rewrite this as $A\underline{r} = B$ where $\underline{r}$ is the vector $\begin{pmatrix} x \\ y \end{pmatrix}$:

$$\begin{pmatrix} 5 & 4 \\ 3 & -1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 7 \\ 11 \end{pmatrix}$$

(check that if we multiply it out we get the same simultaneous equations).

To solve the equation, we simply have to multiply both sides by the inverse of A as this will yield $\underline{r} = A^{-1}B$.

What is the inverse of A?

$$A^{-1} = \frac{1}{-5-12} \begin{pmatrix} -1 & -4 \\ -3 & 5 \end{pmatrix}$$
$$= -\frac{1}{17} \begin{pmatrix} -1 & -4 \\ -3 & 5 \end{pmatrix}$$
$$= \frac{1}{17} \begin{pmatrix} 1 & 4 \\ 3 & -5 \end{pmatrix})$$

Then we multiply both sides of our simultaneous equations in matrix form by A^{-1}. Although we know that $A^{-1}A = I$, let's do it explicitly this time to show how it works.

$$\frac{1}{17} \begin{pmatrix} 1 & 4 \\ 3 & -5 \end{pmatrix} \begin{pmatrix} 5 & 4 \\ 3 & -1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \frac{1}{17} \begin{pmatrix} 1 & 4 \\ 3 & -5 \end{pmatrix} \begin{pmatrix} 7 \\ 11 \end{pmatrix}$$
$$\frac{1}{17} \begin{pmatrix} 5+12 & 4-4 \\ 15-15 & 12+5 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \frac{1}{17} \begin{pmatrix} 7+44 \\ 21-55 \end{pmatrix}$$
$$\frac{1}{17} \begin{pmatrix} 17 & 0 \\ 0 & 17 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \frac{1}{17} \begin{pmatrix} 51 \\ -34 \end{pmatrix}$$
$$\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 3 \\ -2 \end{pmatrix}$$
$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 3 \\ -2 \end{pmatrix}$$

Thus $x = 3$ and $y = -2$ and we have solved the equations. This seems a bit cumbersome for just a pair of simultaneous equations but it is highly efficient for large families of simultaneous equations with many unknown variables since the method is identical; the matrices are just bigger.

Application of matrices in geometric transformations

Another place where matrices come in very useful is in image manipulation, which is increasingly relevant as microscopy becomes driven by software and image recognition techniques. These examples are for your information and are not examinable.

For example, in 2-dimensions, any point $\underline{r} = \begin{pmatrix} x \\ y \end{pmatrix}$ can be scaled by a factor k using a matrix $\begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix}$ since

$$\begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} kx \\ ky \end{pmatrix}$$

Many other transformations are also possible, e.g. rotating by an angle, θ clockwise about the origin can be done via

$$\begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} x\cos\theta - y\sin\theta \\ x\sin\theta + y\cos\theta \end{pmatrix}$$

Below $\underline{r} = \begin{pmatrix} 1 \\ 2 \end{pmatrix}$ and by using the general form of the rotation matrix in 2-dimensions it is computationally straightforward to rotate $\underline{r}$ by $10°$ and draw the new vector in red and then repeat.
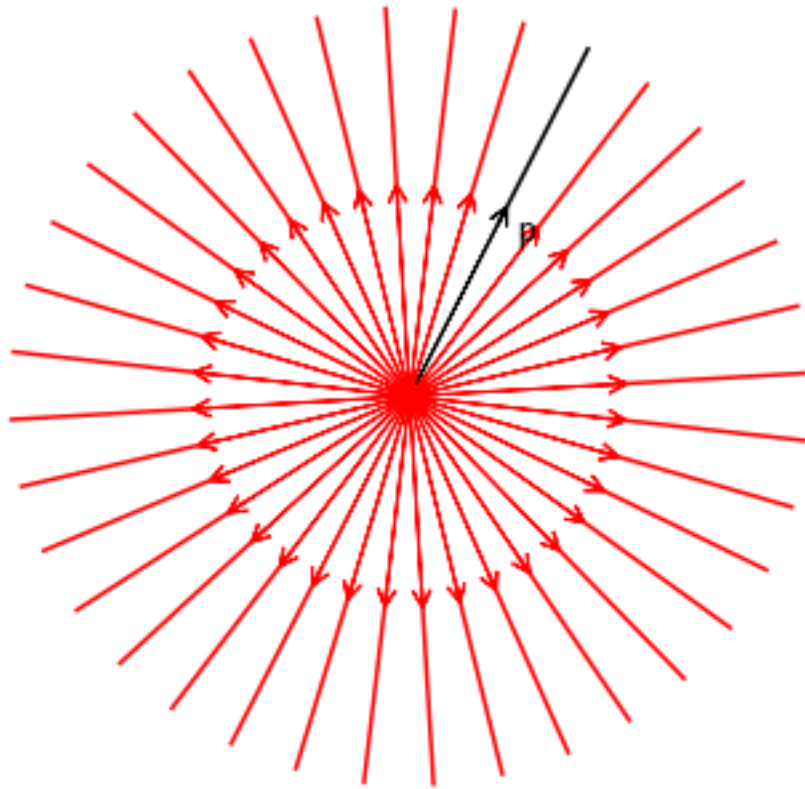
> **Thought:**
>
> 🤔 If biochemistry is getting more quantitative, that means that we need to not only be proficient in some parts of mathematics, but also that we can use computers to do calculations at scale on e.g. images or experimental data.

A final note on units and SI prefixes

- 'T' (tera) denotes 10^{12}
- 'G' (giga) denotes 10^{9}

- 'M' (mega) denotes 10^{6}
- 'k' (kilo) denotes 10^{3} (note lower case 'k')
- 'd' (deci) denotes 10^{-1}
- 'c' (centi) denotes 10^{-2}
- 'm' (milli) denotes 10^{-3}
- 'μ' (micro) denotes 10^{-6}

- 'n' (nano) denotes 10^{-9}
- 'p' (pico) denotes 10^{-12}
- 'f' (femto) denotes 10^{-15}

Obviously in Biochemistry we typically deal with length- and time-scales much shorter than our everyday world e.g. nm, ms.

There are other prefixes in common use, for example the Angstrom which specifically means 10^{-10} m

The departmental assesssment next term

Although you all are required to have a high level of experience in Chemistry, we've found over the years that the level of experience people have in mathematics varies much more widely.

So that we can identify who might need some additional support and help, we run a departmental assessment early next term. It is NOT AN EXAM. All we care about is finding out who might have found the pace of this course too fast and might benefit from extra help. It is no bearing *whatsoever* on your Prelims.

> **Common misconception:**
>
> Curtis says: "IT IS NOT AN EXAM!"

Before last, this would have been a paper-based assessment, however the pandemic forced us to use a Canvas Quiz last year and it worked well. The exact details will be confirmed closer to the time, but the plan at present is

- the assessment will take the form of a Canvas Quiz hence you will then have to login into Canvas using your Oxford SSO
- the quiz will be open to complete from noon to 8pm on Wed 26 January 2022 (week 2)
- you will have a generous time limit (2 hr).
- it will be multiple choice only and each question always has the additional option "I don't know how to tackle this problem"; if you genuinely don't know, please tick this option.

Canvas example

We will now look at last year's quiz in Canvas to give you a feel for how it will work.

> **Common misconception:**
>
> Curtis says: "IT IS STILL NOT AN EXAM!"

Will I be told my mark?

We will score the assessment in the same way as the practicals i.e. S+,S,S-,NS such that a score of NS means we think you would benefit from some extra help (and we will talk to you about this!) and a score of S- means we think you don't need extra help but you weren't far off so keep practicing!

What about my working? How will you give credit for that?

We won't be able to do that, but we don't expect that to matter much since the aim of the assessment is to find the people who need extra help not to accurately assess your attainment and understanding.

Many of the questions will be fairly short, or split into parts, to avoid the problem of using the right method but making a mistake right at the end and thereby choosing the wrong answer.

How much revision should I do?

Going back to Lecture 1, I would say *revision* is the wrong word. For maths the right word is *practice.*

If you've come to all the lectures and done all the problem sheets, *well done!* You have surfed the wave and at this very minute you are competent at maths. If you don't do any maths between the end of term and the assessment you will get *rusty* and things that are currently second-nature will become unfamiliar.

I'd recommend doing some *practice* to keep your maths skill level up and to stop the rustiness setting in. Alongside Problem Sheet 8 (which is due in at the start of week 1 next term) you will find a Christmas Practice sheet. If you are experienced at Maths, doing the questions on that sheet over the course of the holidays should be enough. Or you might choose to redo the odd question off a problem sheet. The important thing is NOT to do a lot - you'll need a break which is also really important - but to do a little quite often.

The Christmas Practice sheet will NOT be marked so you don't have to do it.

Please don't 'read' the lecture notes. That might *feel* like learning, but it is only by *doing* mathematics that you keep your skill-level up.

This applies to preparing for the Prelims as well; better to do a little maths here and there rather than do none for months and then try and revise a week before the exam. This might work for a subject where it is more about remembering facts but not for mathematics.

Imagine training for a marathon that way!

This applies *regardless* of your level of mathematical experience: all of us who teach on the course start out a little rusty but recover our competence by doing the questions, just like you.

What you want to avoid is thinking "well, if only I could have sat the exam in December I'd have done much better, but I'm a bit rusty now"

Course feedback

Please also complete the "Quantitative Biochemistry Lecture Feedback" survey on Canvas that will be availabe from Mon 29 Nov until midnight Mon 6 Dec; I've lectured for over ten years and always ask the students questions in the last lecture whilst it is all fresh in your mind. I will (and have) change the course depending on what you say.

A last word from xkcd