Activity prepared by the KCL EPAP group
Experimental Particle and Astroparticle Physics

How many neutrinos???

Calculation activity

The Sun – a ν_e generating nuclear reactor

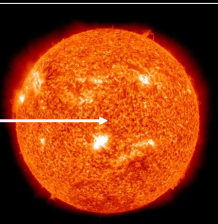
The Flux of solar neutrinos on Earth

- The Sun produces 10^{35} neutrinos per second!
  - These are emitted in all directions (isotropically) so consider them spreading out on the surface of a sphere
- The Sun is 152 million kilometers away from Earth

How many neutrinos per second pass through a $1m^2$ area here?

Surface area of a sphere
$A = 4\pi r^2$

$r = 1.5 \times 10^{11}$ m



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May be useful to demonstrate this with a balloon – draw spots on it and blow it up

Calculations

- How many solar neutrinos travel through you every second?
  - Estimate your area
  - Does it make a difference if you stand up or lie down?
  - Does it make a difference if it is day or night?

- The chance of any single neutrino interacting with you is 1 in 10^{22} = 10^{-22}
  - How likely is it that a neutrino will interact with a person in their lifetime?
    - Average UK life expectancy ~80 years
  - How likely is it that somebody in this room has already had an interaction with a neutrino?

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Area of sphere at Earth's distance from the sun, $A=4\pi.1.5e11^2=2.827e23$
Flux of neutrinos at Earth is 10^{36} / A =3.537e12 /m^2/s

For simplicity, let's say my area (facing the sun) is 1m^2 (that is probably an over-estimate!)
So through me in 1 s is 3.537e12 neutrinos

If I live to 80 years, that is 80*365.25*24*60*60 = 2.5246e9 seconds

In that time 2.5246e9*3.537e12 = 8.93e21 neutrinos will pass through me in my lifetime
Chance of interaction = 8.93e21/10^{22} = 0.89

Average age of people in room = T years
Number of people = N
Average area of a person = A m^2

Probability = T(*365.25*24*60*60 to be in seconds) * N * A (in m^2) / 10^{22}

More calculations ☺

Velocity = distance / time

$$c = \frac{d}{t}$$

- Neutrinos travel at ~ the speed of light $c = 3{\times}10^8 m/s$
- The time each neutrino spends in you $t = \frac{d}{c}$
  - Estimate the average distance through your body
- Given how many neutrinos are passing through you each second, and how long each one spends in you, what is the probability there is a neutrino inside you at one instant?
- What volume box do you need to be sure there is always a solar neutrino in it?

The ~ is because we know from oscillations that neutrinos are not quite massless. They are very light but do have a tiny mass that will slow them down fractionally – only massless particles (like photons) can travel at exactly the speed of light, and nothing can travel faster

Average distance = 50cm (reasonable guess as they are going at all different angles)
Average time for one neutrino = 0.5 / 3e8 = 1.7e-9 seconds

From last slide I have 3.537e12 neutrinos going through me each second and if they all spend 1.7e-9 seconds that gives = 3.537e12*1.7e-9 = 5895 seconds, or 5895 at once. So the probability that there is 1 is essentially 1.

Number of neutrinos N = flux * area * time = f.A.t
From before, flux = f = 3.537e12 neutrinos passing through $1m^2$ per second

Volume of a box = Area * depth = A.d
And time t = d / c
Rearranging gives d = c.t
So substituting we can write volume of the box as V = A.c.t or A.t = V/c

Substituting this in N = f.A.t = f.V/c
And we want N = 1 so rearrange V = 1.c/f = 3e8 /3.537e12 = 8.48e-5 m^3

Try a box that is 5cm*5cm*3.4cm

Supernova – an astronomical ν-generating nuclear explosion

A supernova is a powerful explosion when a massive star runs out of fuel.

A supernova can produce 10^{58} neutrinos in just a few seconds!

https://spaceplace.nasa.gov/supernova/en/

Supernova Calculation

- The star IK Pegasi B is the nearest known supernova candidate, located about 150 light-years from our sun and solar system.
- A light year is the distance light (or neutrinos) travelling at $c = 3\times10^{8} m/s$ would travel in a year – how far is this in km?
- If IK Pegasi B went supernova and produced 10^{58} neutrinos, how many would pass through you?

1 light year = 3e8*365.25*24*60*60 / 10^3 = 9.46e12km = 9.46e15m

Area at earth = 4π.9.46e15^2 = 1.125e33m^2

Flux at Earth's surface = 10^{58} / 1.125e33 = 8.9e24!