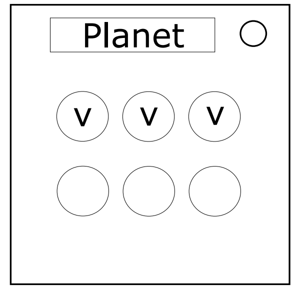
On the Subject of Neutrinos



When the light hits your eye like a subatomic pie, that's neutrinooo...

This module consists of a screen, which displays the destination planet, and 6 circular buttons.

Tips for Success

- In order to solve this module, you need to determine the flavor of 3 neutrinos after travelling from the sun, to a planet in our solar system.
- The top 3 buttons of the module display the three neutrinos and their flavors at the start of their journey.
- The bottom 3 buttons, when pressed, will cycle through all 6 combinations of neutrinos.
- Make sure you do **NOT** press the bottom 3 buttons or the planet screen until you are ready to solve the module.
- When you are certain of the solution to the module, you will cycle the bottom 3 buttons to the correct neutrinos, in order, and then press the planet screen to submit your answer.
- If you press one of the bottom three buttons out of order, or the screen when the solution is incorrect, then you will incur a strike, but otherwise no changes will be made to the module.
- The top 3 buttons are inoperable, as it is not possible to change the starting neutrinos.
- In order to determine the correct flavors of the neutrinos, you will need to know how much time it took them to arrive at the destination planet. The following section of the manual will teach you how to calculate the travel times of each of the three neutrinos.
- Neutrinos exist in 3 "flavors": **e**, **μ**, and **τ**. They also each have a corresponding anti-neutrino which is denoted with a bar above.
- Neutrinos and anti-neutrinos of the same flavor can annihilate one another, just like with other particles and anti-particles.
- The 3 flavors of Neutrino have near-indistinguishable masses (**1.2 mu**), and as a result they have a probability of changing flavor. This concept is called "Neutrino Oscillation".
- Because neutrinos travel at such high speeds, the distances they travel contract. You may notice that the distances travelled by each neutrino will be different even though they are taking the same journey to the same destination.
- During the process of solving this module, you will make some relativitistic calculations, however the units of some of the values may not be recognizable. This has no impact on solving the module.

Calculating the Travel Time

1. Perform the following steps for each neutrino. First, you must determine the momentum. Use the table below to determine values a, and b. c is equal to the position of the button (1,2,3 from left to right).

c		a	b	Global Modulo
Position of button from left to right	1	Number of Battery Holders modulo 10	Number of Ports modulo 10	301
	2	Number of Port Plates modulo 10	Number of Batteries modulo 10	302
	3	Number of Unlit Indicators modulo 10	Number of Lit Indicators modulo 10	333

2. Values a, b, and c should be concatenated together (abc) and then apply the global modulo to this new 3-digit number. Then divide by 1000. The momentum is:

$$p = 1.2 - (abc/1000 \ \% \ \text{Global Modulo})$$

3. Next calculate the speed (β) by dividing the momentum by the neutrino mass. If you get a speed of **1** then you broke physics, press submit and don't tell anyone. Make sure you round each of the following calculations to 3 decimal places (ex. 1.87746 ≅ 1.877, 1.87756 ≅ 1.878)

$$\beta = p/1.2$$

4. Find the Lorentz factor (γ) (sqrt means square root):

$$\gamma = 1/\text{sqrt}(1-\beta*\beta)$$

5. Calculate the contracted distance (L) travelled by the neutrino (you can find the distance of each planet from the sun in Appendix A):

$$L = \text{Distance from Sun}/\gamma$$

6. The travel time is then the distance (L) divided by the speed (β). For this calculation only, round down to the nearest integer:

$$\text{Travel Time} = L/\beta$$

7. Take the travel time modulo 10 + 1. To prevent confusion, call this the final time. Use this value in the next section to find the final flavor of the neutrino.

Determining the Final Flavor

1. In the table below, begin in the cell which is in the center of the starting flavor of the neutrino.
2. Beginning with this cell, if the condition is true, subtract 1 from the final time. If the final time is not zero, continue moving down along the rows of the table repeating this step, wrapping around as necessary.
3. If the neutrino you are using for this step is an anti-neutrino, then go up the table instead of down.
4. Once you have reached a cell which reduced the final time to 0, the corresponding flavor is the new neutrino flavor. Anti-neutrinos will still be anti-neutrinos even though the flavor may have changed.
5. A lap is considered reaching a cell for a second time. The lap count is increased before checking the condition of the cell.

	If this is the first lap
e	If this is an anti-neutrino
	If the serial number contains 'E'
	If the serial number contains 'T'
τ	If the planet is closer than Jupiter
	If there are more than 2 ports
	If there are more than 2 batteries
μ	If the serial number contains 'M'
	If this is not the first lap

1. Once you have the new flavors of each neutrino, you can solve the module. You must cycle each of the bottom buttons so that the flavor matches the final flavor of the neutrino above it.
2. **IMPORTANT:** You must interact with each neutrino button in the order they arrived. Start with the one with the smallest travel time (not the final time). If you press a button corresponding to a neutrino which arrived later you will get a strike. Once all neutrinos are set properly, press the planet screen to submit.
3. **IMPORTANT:** If two of the final neutrinos are neutrino anti-neutrino pairs (ex. e and e bar) then they will annihilate. You should leave the flavors of these neutrinos blank. If all 3 should annihilate, only the first two in order of arrival will annihilate and the third neutrino will be unaffected.

Appendix A: Planet Distances from the Sun

Planet Name	Distance (mau)
Mercury	387
Venus	723
Earth	1000
Mars	1524
Jupiter	5203
Saturn	9582
Uranus	19201
Neptune	30047