

## TENSOR PRODUCT: NUMERICAL EXAMPLE

Link to: [physicspages home page](#).

To leave a comment or report an error, please use the auxiliary blog.

Reference: Moore, Thomas A., *A General Relativity Workbook*, University Science Books (2013) - Chapter 6; Problem 6.4.

It's useful to do a tensor calculation using actual numbers, just to see how they work. Suppose we have a vector with components

$$(1) \quad A^i = [1, 2, -1, 0]$$

where the units are metres, and a second vector given by

$$(2) \quad B^i = [3, -1, 0, -2]$$

where the units are seconds<sup>-1</sup>.

Since the units are different (even using relativistic units where length = time, since vector  $B^i$  has units of 1/time), we cannot add these vectors. However, we can multiply them to get a rank-2 tensor:

$$(3) \quad M^{ij} = A^i B^j = \begin{bmatrix} 3 & -1 & 0 & -2 \\ 6 & -2 & 0 & -4 \\ -3 & 1 & 0 & 2 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

The first row consists of  $A^0$  multiplied by each element of  $B$  in turn, and so on (the indices  $i$  and  $j$  each run for 0 to 3). The units of each element of  $M^{ij}$  are  $\text{m} \cdot \text{s}^{-1}$ .

The question in Moore asks if this product is commutative, which isn't really the right thing to ask, since obviously  $A^i B^j = B^j A^i$ . However, the product is not *symmetric*, in the sense that  $A^i B^j \neq A^j B^i$ . That is, it matters which vector is used to determine the row index and which the column index.

The trace of  $M$  is given by

$$(4) \quad M^i_i = g_{ij} M^{ij}$$
$$(5) \quad = g_{ij} A^i B^j$$

1

This is just the scalar product  $\mathbf{A} \cdot \mathbf{B}$ . If we use the special relativity metric  $\eta_{ij}$ , then

$$(6) \quad \eta_{ij}A^iB^j = -(1 \times 3) + (-1 \times 2) + (-1 \times 0) + (-2 \times 0) = -5$$

We could also have obtained this result from the matrix  $M^{ij}$  directly by calculating  $\eta_{00}M^{00} + \eta_{11}M^{11} = -5$  (the other two diagonal elements are zero).