Physics Mark Scheme

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July 2024

Introduction

This isn't really a mark scheme because that would require me to put in way too much effort for a project I did 3 weeks before my A-Levels. But, the lack of a mark scheme is irksome so this is a pseudo unprescriptive (and definitely not AQA-standard) mark scheme that has all the answers.

1 Particle Physics

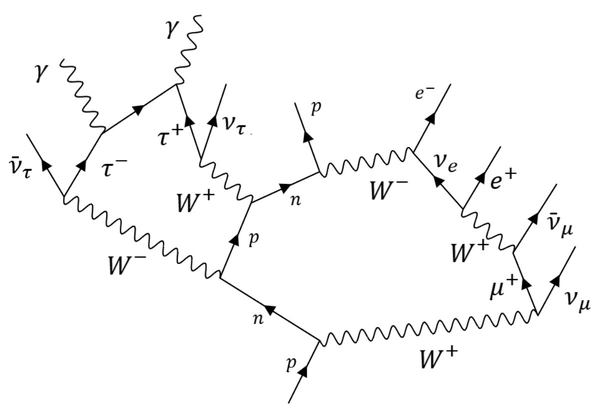
1.1 Decay

This is just beta decay but you could in theory have different lepton types. This yields 3:

- Tau electron and anti-tau neutrino.
- Muon and anti muon-neutrino.
- Electron and anti-neutrino.

The last is most accurate because it requires less energy to begin with.

1.2 Big diagram



Technically there should be ways where particles release random stuff just by releasing a photon and staying the same type of particle but I don't count those. About 3 correct should earn you 1 mark

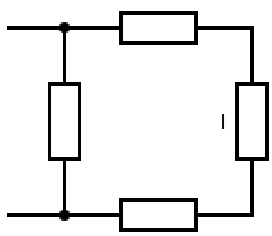
1.3 Why the interaction is impossible?

- It's not energetically favourable as a lot of mass comes from one particle.
- Particles with this energy will be going too fast to interact with the other by-products.

2 Circuits

2.1 Infinite circuit

Assume the circuit has a resistance of I, and substitute an I resistor into the original equation:

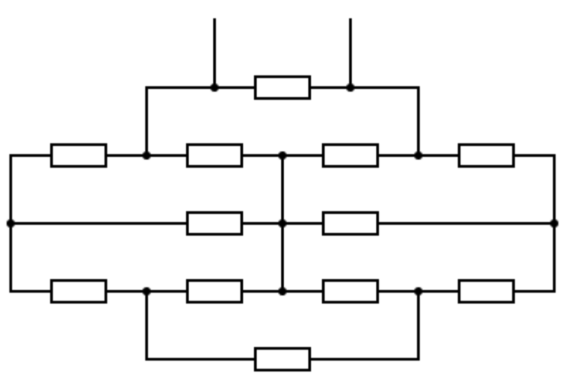


The resistance is as follows:

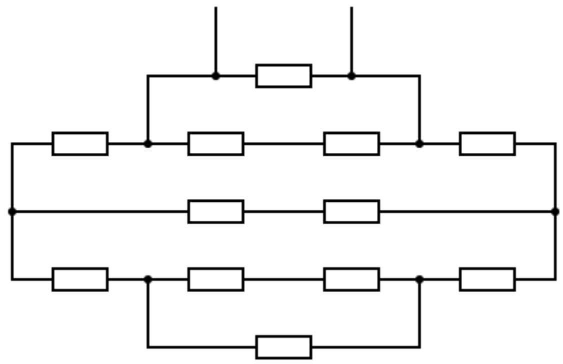
$$\frac{1}{I} = \frac{1}{1} + \frac{1}{1+1+I}$$
$$I = \frac{1}{1+\frac{1}{2+I}}$$
$$I = \frac{2+I}{2+I+1}$$
$$3I + I^2 = 2 + I$$
$$I^2 + 2I - 2 = 0$$
$$I = \sqrt{3} - 1$$

2.2 Hexagonal Circuit

Moving about the resistors we get:

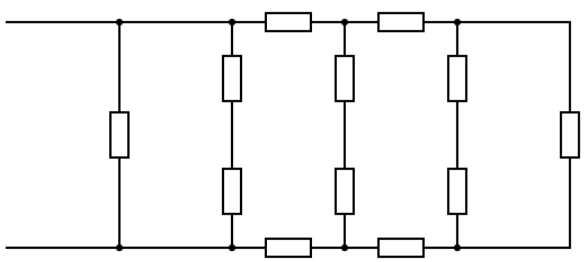


Redundant wires can be removed by symmetry:



2.3 Infinite polygon

The given network had a resistance of $\frac{8}{15}$ and the hexagon had one of $\frac{11}{20}$. Note that the inner connection of a polygon can be separated into symmetrical pairs. Hence the general network is below:



Starting from the back end, we have the sequence:

$$x_1 = 1, \quad x_{n+1} = \frac{1}{\frac{1}{x_n} + \frac{1}{2}} + 2 = \frac{2x_n}{x_n + 2} + 2$$

At the end of the sequence x_N, we get the overall resistance of $\dfrac{1}{\frac{1}{x_N} + 1 + \frac{1}{2}}$. By equating $x_n = x_{n+1}$, we get the solution to the first network:

$$\begin{aligned} x &= \frac{2x}{x+2} + 2 \\ x(x+2) &= 2x + 2(x+2) \\ x^2 - 2x - 4 &= 0 \\ x &= \frac{2 + \sqrt{20}}{2} \\ &= 1 + \sqrt{5} \end{aligned}$$

Putting that into the final equation:

$$\begin{aligned}\frac{1}{\frac{1}{x}+1+\frac{1}{2}} &= \frac{2x}{2+3x} \\ &= \frac{2(1+\sqrt{5})}{2+3(1+\sqrt{5})} \\ &= \frac{2+2\sqrt{5}}{5+3\sqrt{5}} \\ &= \frac{2+2\sqrt{5}}{5+3\sqrt{5}} \\ &= 1-\frac{1}{\sqrt{5}}\end{aligned}$$

3 Tower of Lire

3.1 2 blocks

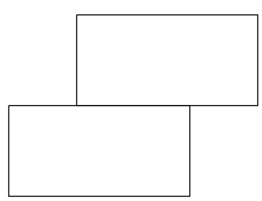
You can put the block halfway across so that the centre of mass is just on the edge.

3.2 3 blocks

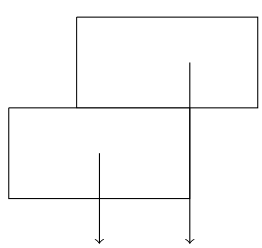
We want to find the effective centre of mass of the stack of 2. Fortunately, that's obviously the centre of the points at which they overlap. They have an overall length of 3 metres across, giving 1.5 metres of leeway.

3.3 n blocks

The easiest way to imagine the centre of mass is to imagine placing a pivot under the below:



The bottom block has a mass of 1kg and the top has a mass of $n-1$kg. The top block substitutes the tower we have already got and is hence non uniform. We already know it is positioned so that its centre of mass lies on the edge. Let us draw the forces on the diagram:



We need to place our pivot between the two arrows such that it is perfectly balanced. We know the distance between the arrows is 1m. Let x denote the distance from the pivot of the left arrow and hence $1 - x$ for the right. We have:

$$\begin{aligned}(n-1)g(1-x) &= 1gx \\ n - nx + x - 1 &= x \\ n(1-x) &= 1 \\ x &= 1 - \frac{1}{n}\end{aligned}$$

The distance from the left of the system to the overall centre of mass is $2 - \frac{1}{n}$. Hence the distance before it is leaning over the base block is $2 - (2 - \frac{1}{n}) = \frac{1}{n}$.

3.4 Distance to 4

The overall distance is given by:

$$1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} + \frac{1}{6} + \frac{1}{7} + \dots$$

We can find an underestimate as follows:

$$1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{4} + \frac{8}{8} + \frac{1}{8} + \frac{1}{8} + \dots$$

Note this is just summing up halves, so we can do this forever! To reach 4m we need to have 6 halves (barring the free 1m), is the sum of $1 + 2 + 4 + 8 + 16 + 32$ more terms which yields 65 blocks total. Any higher justified number works.

4 Projectiles

4.1 Largest Distance

The vertical component is given by $u\sin(\theta)$. Using the below equation:

$$\begin{aligned}s &= ut + \frac{1}{2}at^2 \\ 0 &= u\sin(\theta)t - \frac{1}{2}gt^2 \\ t &= \frac{2u}{g}\sin(\theta)\end{aligned}$$

The horizontal component is given by $u\cos(\theta)$ and the distance covered is speed$\times$time, giving us:

$$d = \frac{2u^2}{g}\sin(\theta)\cos(\theta)$$

Using the given equation we have:

$$d = \frac{u^2}{g}\sin(2\theta)$$

Sine is maximal when it is 1, and that is true when $\theta = 45°$.

4.2 Furthest point

A particle is the furthest point only in the case where its velocity is normal to its displacement. This is because the arc around it must entirely contain the whole trajectory path. If not, it must be at the end of the curve (where it lands).

4.3 Maximal distance

The distance from projection squared, D^2, is given by pythagoras:

$$\begin{aligned} D^2 &= (u\cos(\theta)t)^2 + \left(u\sin(\theta)t - \frac{1}{2}gt^2\right)^2 \\ &= u^2t^2 + \frac{1}{4}g^2t^4 - gt^3u\sin(\theta) \end{aligned}$$

Since we know the velocity must be normal to the displacement, the respective gradients must be equal to one. The horizontal velocity is $u\cos(\theta)$. We can deduce the vertical velocity by:

$$\begin{aligned} v &= u + at \\ v &= u\sin(\theta) - gt \end{aligned}$$

We know that the values multiply to give -1:

$$\begin{aligned} \frac{u\sin(\theta) - gt}{u\cos(\theta)}\frac{u\sin(\theta)t - \frac{1}{2}gt^2}{ut\cos(\theta)} &= -1 \\ \frac{u\sin(\theta) - gt}{u\cos(\theta)}\frac{u\sin(\theta) - \frac{1}{2}gt}{u\cos(\theta)} &= -1 \end{aligned}$$

Let $\theta = 45°$

$$\begin{aligned} \frac{(\frac{u}{\sqrt{2}} - \frac{1}{2}gt)(\frac{u}{\sqrt{2}} - gt)}{\frac{u^2}{2}} &= -1 \\ \frac{(u - \frac{\sqrt{2}}{2}gt)(u - gt\sqrt{2})}{u^2} &= -1 \\ u^2 + g^2t^2 - gut\left(\frac{1}{\sqrt{2}} + \sqrt{2}\right) &= -u^2 \\ g^2\sqrt{2}t^2 - 3gut + 2\sqrt{2}u^2 &= 0 \end{aligned}$$

Let us solve this:

$$\frac{3gu + \sqrt{9u^2g^2 - 16g^2u^2}}{2g^2\sqrt{2}}$$

This must therefore mean that the maximum is attained when it hits the ground, making it $\frac{u^2}{g}$. However, by letting $u = 1$, θ be small and $t = 1$, we get a much longer distance.

4.4 Alternative

Anything will do so long as the numerics are justified in the above equations

5 Multiple Choice

5.1 Resistivity and Young Modulus

Use the below equations:

$$E = \frac{FL}{A\Delta L}$$
$$R = \frac{\rho L}{A}$$
$$F = k\Delta L$$

Rearrange:

$$E = \frac{L}{A} \cdot \frac{F}{\Delta L}$$
$$\frac{R}{\rho} = \frac{L}{A}$$
$$k = \frac{F}{\Delta L}$$

This give us:

$$E = \frac{kR}{\rho}$$
$$E\rho = kR$$

Substituting the new values we get $?4\rho = 2k2R$. Cancelling gives us $? = E$, hence the answer is **A**.

5.2 Material Properties

None of the above, D. Red Herring; sorry.

5.3 Gravity and Electromagnetism

With a distance of 1 metre apart we can use the following equations:

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$$
$$F = G\frac{m_1m_2}{r^2}$$

Equating these together:

$$m = \sqrt{\frac{Q^2}{4\pi\varepsilon_0 G}} = 1.86 \times 10^{-9}$$

Dividing by the mass of the neutron we get a total of 3.5×10^{18}, A.

5.4 Capacitor

The resistor is basically just a wire. Once everything has settled the p.d will be uniform on either side, giving a difference of a half, C.