



IPhO 2018
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Detailed Marking Scheme Theory Problem 2

Where is the neutrino?

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v1.2

Confidential

Where is the neutrino? (10 points)

Part A. ATLAS Detector physics (4.0 points)

A.1

Magnetic force as centripetal force	0.2
Velocity in terms of the kinetic energy	0.2
Final expression for the radius	0.1
Total	0.5

A.2

Recognize that $m \rightarrow \gamma m$	0.2
Expression for p	0.1
Radius of the circular motion is half the radius of the inner part of the detector	0.1
Final numerical expression for p	0.1
Total	0.5

A.3

Acceleration for the particle	0.2
Replace a in the given expression for P	0.2
Use $E = \gamma mc^2$	0.2
Final expression for P with identification of ξ, n, k	0.4
Total	1.0

A.4

Power emitted by the particle	0.3
Solve the integral to get $\frac{1}{E(t)} - \frac{1}{E_0} = \alpha t$	0.4
Arrive at expression for $E(t)$ and identify α	0.3
Total	1.0

A.5

Electron moving in a straight line	0.1
Time of flight	0.1
Expression for the energy lost	0.2
Final numerical value for energy lost	0.1
Total	0.5

A.6

$v \simeq c$ (ultrarelativistic limit)	0.1
$E \simeq pc$ (ultrarelativistic limit)	0.1
Expression for the frequency	0.3
Total	0.5

Part B. Finding the neutrino (6.0 points)

B.1

Expression for $\vec{p}^{(W)}$	0.3
Expression for $E^{(W)}$	0.3
Write the initial expression for m_W^2	0.3
Arrive at the final expression for m_W^2	0.6
Total	1.5

B.2

Numerical values for $p^{(\mu)}, m_W^2 c^2, p_T^{(\nu)2}, \vec{p}_T^{(\mu)} \cdot \vec{p}_T^{(\nu)}, p_z^{(\mu)}$ (0.2 points each)	1.0
Get the two numerical solutions of the quadratic equation	0.5
Total	1.5

B.3

Expression for $E^{(t)}$	0.1
Expression for $\vec{p}^{(t)}$	0.1
Write the initial expression for m_t	0.2
Arrive at the two possible masses	0.6
Total	1.0

B.4

Estimate the probability for the lighter mass	0.3
Estimate the probability for the heavier mass	0.3
Conclude about the most likely candidate	0.4
Total	1.0

B.5

Numerical value for $E^{(t)}$	0.4
Analytical expression for d	0.4
Numerical value for d	0.2
Total	1.0