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JEE Advanced 2019 - Paper 1 - Physics 11

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Problem ***[Multiple Choice Multiple Correct]***

Let us consider a system of units in which mass and angular momentum are dimensionless. If length has dimension of L, which of the following statement(s) is/are correct?

(A) The dimension of linear momentum is L^{-1}
(B) The dimension of energy is L^{-2}
(C) The dimension of force is L^{-3}
(D) The dimension of power is L^{-5}

What to Observe:

- Mass is dimensionless.
- Angular momentum is dimensionless.
- Length has dimension of L.
- The system of units is such that some physical quantities may have different dimensional representations.

My Approach:

Converting SI System to New System

Thought

To convert any physical quantity from one system to another, we need to establish a dimensional equivalence between the two systems.

In the new system, **mass is dimensionless**. Therefore,

$$m \Rightarrow [M^0L^0T^0]$$

Next, consider the expression for angular momentum:

$$\text{Angular Momentum} = mvr$$

As **angular momentum is dimensionless** in the new system:

$$mvr \Rightarrow [M^0L^0T^0]$$

Since mass is dimensionless, it follows that:

$$vr \Rightarrow [M^0L^0T^0]$$

Thus, the velocity has dimensions:

$$v \Rightarrow \frac{1}{r} \Rightarrow [M^0L^{-1}T^0]$$

In the SI system, the dimension of velocity is:

$$v_{\text{SI}} \Rightarrow [L^1T^{-1}]$$

Equating the two expressions for velocity:

$$[L^1T^{-1}]_{\text{SI}} = [M^0L^{-1}T^0]_{\text{new}}$$

From this, we can isolate the time dimension:

$$[T^{-1}]_{\text{SI}} = [M^0L^{-2}T^0]_{\text{new}} \Rightarrow [T]_{\text{SI}} = [M^0L^2T^0]_{\text{new}}$$

This gives the equivalence for time in the SI system in terms of the new system.

Checking The Options

Thought

We have established the following equivalences:

- Mass: $[M^1L^0T^0]_{\text{SI}} = [M^0L^0T^0]_{\text{new}}$
- Length: $[M^0L^1T^0]_{\text{SI}} = [M^0L^1T^0]_{\text{new}}$
- Time: $[M^0L^0T^1]_{\text{SI}} = [M^0L^2T^0]_{\text{new}}$

Now, let us determine the dimensions of various physical quantities in the SI system and convert them to the new system.

Linear Momentum ($p = mv$):

$$[p]_{\text{SI}} = [M^1L^1T^{-1}]$$

Substituting each base unit:

$$\Rightarrow [M^0L^0T^0] \cdot [M^0L^1T^0] \cdot [M^0L^2T^0]^{-1} = [M^0L^{-1}T^0]_{\text{new}}$$

Therefore, **Option A is correct**.

Energy ($E = \frac{1}{2}mv^2$ or Fd):

$$[E]_{\text{SI}} = [M^1L^2T^{-2}]$$

Substituting:

$$\Rightarrow [M^0L^0T^0] \cdot [M^0L^1T^0]^2 \cdot [M^0L^2T^0]^{-2} = [M^0L^{-2}T^0]_{\text{new}}$$

Therefore, **Option B is correct**.

Force ($F = ma$):

$$[F]_{\text{SI}} = [M^1L^1T^{-2}]$$

Substituting:

$$\Rightarrow [M^0L^0T^0] \cdot [M^0L^1T^0] \cdot [M^0L^2T^0]^{-2} = [M^0L^{-3}T^0]_{\text{new}}$$

Therefore, **Option C is correct**.

Power ($P = \frac{E}{t}$):

$$[P]_{\text{SI}} = [M^1L^2T^{-3}]$$

Substituting:

$$\Rightarrow [M^0L^0T^0] \cdot [M^0L^1T^0]^2 \cdot [M^0L^2T^0]^{-3} = [M^0L^{-4}T^0]_{\text{new}}$$

Therefore, **Option D is incorrect**.

Conclusion

Based on the detailed analysis and the computed expression for the physical quantity under consideration:

Options A,B and C are correct.

Option D is incorrect because the calculated value does not agree with the value stated in that option.

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