Quiz 2 - Solutions

Physics for Pedestrians

30th July, 2019

From the Readings

1. What, according to Einstein, is the problem with saying: "The purpose of mechanics is to describe how bodies change their position in space with time."?
   (a) It is not clear what a "body" means.
   (b) **It is not clear what the words "position" and "space" mean.**
   (c) It is not clear what "change" means.
2. From the reading "Events and Space-time", how many independent numbers are required to completely specify an event?
   (a) 2
   (b) 3
   (c) **4**
   (d) 5
   (e) Depends on the event.

Newton's Laws

1. As you stand in an elevator that is accelerating upwards, you feel:
   (a) Lighter, as the elevator's acceleration is going against the acceleration due to gravity
   (b) **Heavier, as the elevator's acceleration causes a force which adds to the floor's normal reaction force.**
   (c) The same, as at any instance your weight is always mass multiplied by the acceleration due to gravity.
2. What are the dimensions of the Gravitational Constant G?
   (a) **Correct:** $M^{-1}L^3T^{-2}$
   (b) M^2LT^{-2}

(c) MLT^{-2}

Solution: The Law of Gravitation states that the force between two objects depends on the product of the masses and the inverse of the square of the distances between them. In other words,

$$F_g = G \times \frac{m_1 m_2}{r^2}$$

Taking the "dimensions" on either side (which I denote by placing the quantity in square brackets, like so $[F_g]$),

$$[F_g] = [G] \times \frac{[m_1][m_2]}{[r]^2}$$

Both the masses are indeed measures of mass, and so $[m_1][m_2] = M^2$. Similarly, $[r]^2 = L^2$. As for the dimensions of F_g, it is a force and therefore must have dimensions of mass $\times$ acceleration.

If you didn't know the dimensions of acceleration, you would just need to know that acceleration is to velocity what velocity is to position: a change in position in velocity (thus $[v] = L/T$) and a change in velocity is acceleration (so $[a] = L/T/T = L/T^2$.

Thus, $[F_g] = MLT^{-2}$. Rearranging our earlier equation, we get

$$[G] = \frac{[F_g]L^2}{M^2} = \frac{ML^3T^{-2}}{M^2} = \frac{M^{-1}L^3T^{-2}}{}$$

What if you didn't know all of this? Well, you should know at least that

(a) Force = mass $\times$ acceleration, and so $[F_g] = MLT^{-2}$.

(b) The Gravitational Force between two bodies depends on G, as well as the product of their masses, so $[F_g] \propto [G]M^2$.

(c) The only quantities that depend on mass are F_g and $m_1 m_2$. So, $[G] \propto M^{-1}$. There is only one answer with M^{-1}.

3. Which is the closest estimate to the potential energy stored in a person who climbs up to the Programme Team office on the third floor? Potential energy is given by P.E. = mgh:
   (a) 100 kg m^2/s^2
   (b) 500 kg m^2/s^2
   (c) **10,000 kg m^2/s^2**
   (d) 10^6 kg m^2/s^2

Solution: As mentioned, the potential energy is given by `mass`$\times$`acceleration due to gravity`$\times$ `height`.

$$\text{Your mass} \approx 100 \text{ kg}$$
$$\text{Acceleration due to Gravity} \approx 10 \text{ m/s}^2$$
$$\text{Height to the Third Floor} \approx 3 \times \text{Height of a floor} \approx 3 \times 5 \text{ m} \approx 15 \text{ m}.$$

Thus, your Potential Energy is $= 100 \text{ kg} \times 10 \text{ m/s}^2 \times 15 \text{ m} = 15,000 \text{ kg m}^2/\text{s}^2$.

This answer is much closer to 10,000 kg m^2/s^2 than any of the others. In fact, I've probably (unkindly) overestimated your mass, and if you took a more reasonable 60 kg, you'd find that the answer was closer to 9,000 kg m^2/s^2.