Physics for Pedestrians

Final examination – Retake

31st August, 2019

Maximum Marks: 30

Instructions:

- **Read the question paper carefully!**
- **No** electronic devices of any kind will be allowed during the examination.
- You are required to answer **THREE** questions in all. **Question 1 is compulsory**.
- Answer **TWO** questions from Questions 2 to 4.
- Please answer all sub-parts of each question together.
- Make sure your answers are ***clear***. In case of derivations, each subsequent step should be clearly marked out. In long answers, your arguments should be lucid.
- Clearly state any assumptions you make when answering questions.

Useful constants and formulae

Constants

$c = 3 \times 10^8$ m/s	$R = 1.097 \times 10^7$ m^{-1}
$G = 6.67 \times 10^{-11}$ m^3/kg/s^2	Mass of a proton, $m_p = 1.6 \times 10^{-27}$ kg
$h = 6.626 \times 10^{-34}$kg m^2/s	Density of air, $\rho_{\text{air}} = 1.225$ kg/m^3
$g = 10$ m/s^2	Density of water, $\rho_{\text{water}} = 10^3$ kg/m^3

Formulae

$$\text{Density}(\rho) = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Area of Circle} = \pi \times r^2$$

$$\text{Volume of Sphere} = \frac{4}{3}\pi r^3$$

Lorentz Transformations:

$$x' = \gamma\left(x - vt\right)$$

$$t' = \gamma\left(t - \frac{v}{c^2}x\right)$$

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

$$F = ma$$

$$F_{12} = -F_{21}$$

$$\text{Gravitational Force} = G\frac{m_1 m_2}{r^2}$$

$$\text{Electrostatic Force} = K_e\frac{q_1 q_2}{r^2}$$

$$\text{Centripetal force} = \frac{mv^2}{r}$$

$$\text{Escape Velocity } = \sqrt{\frac{2GM}{R}}$$

$$\text{Terminal velocity: } v_t = \sqrt{\frac{mg}{\rho_{\text{air}} A}}$$

Potential Energy $= mgh$	Rydberg Formula: $\frac{1}{\lambda} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$
Kinetic Energy $= \frac{1}{2}mv^2$	Photoelectric Effect: K.E. $= hf - \phi$
Angular Momentum: $L = mvr$	De Broglie wavelength: $\lambda = \frac{h}{mv}$
Energy of a photon: $E = hf$	

ROUGH WORK

1 Compulsory (10 marks)

1. Find the dimensions of Newton's Gravitational constant G, Planck's constant h, and the speed of light c. Explain every step *clearly*. **(5 marks)**
2. Consider the room you are currently sitting in:
   (a) What is the volume of air in this room? **(1 mark)**
   (b) Now imagine that this room was filled with water:
      i. What is the total volume of water? **(2 marks)**
      ii. What is the total mass of water? **(2 marks)**

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2 Orders of Magnitude and Dimensions (10 marks)

1. Suppose you were shrunk by a factor of 10 in every direction, so that you became a tiny scale model of yourself. Describe the challenges you would face. Keep in mind your body temperature, the strength of your bones, your vision, and the difficulties posed by water, among other things. **(5 marks)**
2. Consider a 100 rupee note: **(3 marks)**
   (a) Estimate its length and breadth.
   (b) Estimate its thickness.
   (c) Estimate its volume
3. How heavy is a suitcase filled with 100 rupee notes? **(2 marks)**

3 Newton's Laws and Relativity (10 marks)

1. Imagine you are in a lift. Now imagine the lift starts from the ground floor, and moves up to the tenth floor and comes to rest. Describe what you would feel, and relate this to Newton's three laws. **(5 marks)**
2. Consider the Galilean or "Common-Sense" Transformations, given by

$$x' = x - vt$$
$$t' = t$$

   The convention used is the same as that given in the notes: x' and t' are the coordinates measured by an observer in S', which is moving at a speed v with respect to an observer in S who measured x and t.

   (a) Imagine both observers (the one in S and the one in S') measuring the speed of a dog that is running. Show that the speed measured by the observer in S' (let's call this u') is related to the speed measured by the observer in S (let's call this u) by

$$u' = u - v$$

(b) Now (using the definition of acceleration) show both the observers would agree on the *acceleration* of the dog. i.e. show that

$$a' = a$$

Why is this important for Newton's Laws? **(5 marks)**

4 The Quantum World and Gravity (10 marks)

1. Estimate the density of a hydrogen atom. **(1 mark)**
2. Describe the surprising results of the photoelectric effect that suggested that light was not a classical wave but was instead composed of small particles (called photons). **(3 marks)**
3. Contrast the discrepancies found with the orbits of Uranus and Mercury at the end of the 19^{th} century, and describe how they were finally explained. **(3 marks)**
4. What are standard candles? Explain why they deserve their name, and how they show us that the universe is accelerating. **(3 marks)**

ROUGH WORK