Basic Physics Problems

[A] Basic Physics : Classical Mechanics

(1) Consider the motion of planet with mass of m in the gravitational potential together with the additional potential of $\frac{\alpha}{r^2}$. Note that the additional potential is not integrable. The total gravitational potential becomes

$$U(r) = -\frac{GMm}{r} + \frac{\alpha}{r^2} \tag{1}$$

where M denotes the mass of the sun.

(i) Find an exact solution of the Newton equation.

(ii) Prove that the orbit should have a discontinuity.

(2) The Newton equation with non-integrable potential must be solved in a perturbation theory.

(i) Find a perturbative solution of the planet orbit.

(ii) Explain the behavior of orbit perihelion shifts.

[B] Basic Physics : Electromagnetisms

(1) Describe some physical properties of Poynting vector.

(2) Is the Poynting vector related to the electromagnetic wave or not ?

(i) If yes, then explain its reason.

(ii) If no, then explain the physical picture why the Poynting vector is not related to photon.

(3) Explain any physical reasons why the vector potential must be quantized.

(4) Dirac field must be quantized with the anti-commutation rule. Explain the physical reason of this quantization method.

(5) The equation of motion of free photon can be written as

$$\partial_\mu F^{\mu\nu} = 0, \quad \textbf{with} \quad F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu \tag{2}$$

where $F^{\mu\nu}$ denotes the electromagnetic strength. In this case, the number of freedoms of vector potential A^μ is four while photon has only two. Explain why the two degrees of freedom are lost.

[C] About the right-hand side of Einstein equation.

(1) Suppose the state vector is denoted by $\Psi(x)$. In this case, write explicitly the energy-momentum tensor $T^{\mu\nu}$.

(2) In classical mechanics, the energy-momentum tensor $T^{\mu\nu}$ cannot be defined. Explain this reason.

(3) In Einstein equation, the energy-momentum tensor $T^{\mu\nu}$ is defined. Answer as to why it can be defined.

(4) Questions for star formation and star distribution function.

- **(i) Explain any interactions that determine the star formation and star distribution function.**
- **(ii) Describe the properties of these interactions.**
- **(iii) For the star formation, which interaction may play what role?**
- **(iv) For the star distribution, which interaction may play what role?**

(5) Black Hole is not defined as a star. Explain why people believed that the Black Hole is a star.