Roll No. ..... Total Printed Pages -12

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C.B.S. (Tenth Semester)
EXAMINATION, May - June, 2022
GENERAL RELATIVITY AND COSMOLOGY
(PE-1002)

Time : Three Hours] *[Maximum Marks:40*

Note: Attempt all section as directed.

(Section - A)
(Objective/Multiple Choice Questions)

(0.5 mark each)

Note: Attempt all questions.

Choose the correct answer:

1. According to general relativity, time operator differently is a gravitational field. What happens?
   (A) Time slows down
   (B) Time speeds up
   (C) Time stops
   (D) None of these

2. The components of the Riemann curvature tensor are given by:
   (A) $-R^i_{jkl} = \Gamma^i_{jk,l} - \Gamma^i_{jl,k} + \Gamma^m_{jk}\ \Gamma^i_{lm} - \Gamma^m_{jl}\ \Gamma^i_{km}$
   (B) $R^i_{jkl} = \Gamma^i_{jk,l} + \Gamma^i_{jl,k} + \Gamma^m_{jk}\ \Gamma^i_{lm} - \Gamma^m_{jl}\ \Gamma^i_{km}$
   (C) $-R^i_{jkl} = \Gamma^i_{jk,l} - \Gamma^i_{jl,k} + \Gamma^m_{jk}\ \Gamma^i_{lm} + \Gamma^m_{jl}\ \Gamma^i_{km}$
   (D) $-R^i_{jkl} = \Gamma^i_{jk,l} - \Gamma^i_{jl,k} + \Gamma^m_{jk}\ \Gamma^i_{lm} - \Gamma^m_{jl}\ \Gamma^i_{km}$
3. Christoffel symbol is given by:
   (A) $\frac{1}{2}\, g^{\alpha r}(g_{\alpha\beta,\mu} - g_{\alpha\mu,\beta} - g_{\beta\mu,\alpha}) = \Gamma^r_{\beta\mu}$
   (B) $\frac{1}{2}\, g^{\alpha r}(g_{\alpha\beta,\mu} + g_{\alpha\mu,\beta} - g_{\beta\mu,\alpha}) = \Gamma^r_{\beta\mu}$
   (C) $\frac{1}{2}\, g^{\alpha r}(g_{\alpha\beta,\mu} + g_{\alpha\mu,\beta} + g_{\beta\mu,\alpha}) = \Gamma^r_{\beta\mu}$
   (D) $\frac{1}{2}\, g^{\alpha r}(g_{\alpha\beta,\mu} - g_{\alpha\mu,\beta} + g_{\beta\mu,\alpha}) = \Gamma^r_{\beta\mu}$
4. The g_{ij} are the components:
   (A) Metric tensor
   (B) Fundamental tensor
   (C) Both (A) and (B)
   (D) None of the above

5. The Schwarzchild radius is given by:

(A) $R_s = \frac{2GM}{mc^2}$

(B) $R_s = \frac{2GM}{c^2}$

(C) $R_s = \frac{2GMm}{mc^2}$

(D) $R_s = \frac{2GM^2}{mc^2}$

6. Tensors follow which of the following rules for frame/co-ordinate transformation?

(A) $A^{i'}_{j'} = \frac{dx^{i'}}{dx^i}\frac{dx^{j'}}{dx^i}A^i_j$

(B) $A^{i'}_{j'} = \frac{dx^{i}}{dx^{i'}}\frac{dx^{j}}{dx^{j'}}A^i_j$

(C) $A^{i'}_{j'} = \frac{dx^{i}}{dx^{i'}}\frac{dx^{j'}}{dx^{j}}A^i_j$

(D) $A^{i'}_{j'} = \frac{dx^{i}}{dx^{i}}\frac{dx^{j}}{dx^{j'}}A^i_j$

7. Value of 10 J is natural unit:

(A) $11\times10^{-16}kg$

(B) $11\times10^{-16}g$

(C) $1{\cdot}1\times10^{-16}kg$

(D) $1{\cdot}1\times10^{-16}g$

8. For stress-energy tensor, $T^{\circ\circ}$ component is:

(A) Energy density

(B) i Momentum density

(C) Energy flux across x^i surface

(D) Flux of i momentum across j surface

9. If you draw a space time diagram, the world line of an object that is accelerating away from you is:

(A) Vertical

(B) Horizontal

(C) Slanted

(D) Curved

10. Einstein's general theory of relativity suggest that gravity is:

    (A) A force of attraction that acts at a distance between two masses

    (B) Caused by Curvature of space time

    (C) $= G \times M_1 \times M_2 / d^2$

    (D) One of four fundamental forces in nature

11. Which of the following represents a quantity which in not a tensor?

    (A) g_{ij}

    (B) R_{ij}

    (C) R^{i}_{jkl}

    (D) Γ^{i}_{jk}

12. For stress-energy tensor, T^{oi} components are:

    (A) Energy density

    (B) Energy flux across x^i surface

    (C) i Momentum density

    (D) Flux of i momentum across j surface

13. In our solar system, precession of orbits is easiest to detect in:

    (A) Mercury

    (B) Saturn

    (C) Jupiter

    (D) Pluto

14. For stress-energy tensor, T^{io} components are:

    (A) Energy density

    (B) Energy flux across x^i surface

    (C) i Momentum density

    (D) Flux of i momentum across j surface.

15. An electron is moving with a velocity of 0.85C in the same direction as that of a moving photon. The relative velocity of the electron with respect to photon is:

    (A) C

    (B) - C

    (C) 0.15 C

    (D) - 0.15 C

16. Which piece of evidence supports the Big Bang theory?

(A) The more distant galaxies are moving the slowest

(B) The more distant galaxies are moving towards us

(C) The more distant galaxies are moving the quickest

(D) Galaxies and space is not changing

17. According to the special theory of relativity, the speed v of a particle of mass m and total energy E is:

(A) $V = c\sqrt{1-\frac{mc^2}{E}}$

(B) $V = \sqrt{\frac{2E}{m}}\left(1+\frac{mc^2}{E}\right)$

(C) $v = c\sqrt{1-\left(\frac{mc^2}{E}\right)^2}$

(D) $V = c\left(1+\frac{mc^2}{E}\right)$

18. The Schwarzchild solution in vacuum gives

(A) $ds^2 = -\left(1-\frac{R_S}{r}\right)dt^2 + \left(\frac{1}{1-\frac{R_S}{r}}\right)dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2)$

(B) $ds^2 = -\left(1-\frac{r}{R_s}\right)dt^2 + \left(\frac{1}{1-\frac{r}{R_s}}\right)dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2)$

(C) $ds^2 = -\left(1-\frac{R_s}{r}\right)dt^2 - \frac{1}{\left(1-\frac{r}{R_s}\right)}dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2)$

(D) $ds^2 = -\left(1-\frac{r}{R_s}\right)dt^2 - \frac{1}{\left(1-\frac{r}{R_s}\right)}dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2)$

19. Value of Hubble constant is about:

(A) $70\ Mpc \mid s \mid km$

(B) $70\ km / s$

(C) $70\ km \mid s \mid Mpc$

(D) $70\ s / Mpc$

20. Which of the following is not an implication of Hubble's law?

(A) The universe is expanding

(B) We are is the center of universe

(C) The universe had a beginning

(D) The universe was once denser than it is now

Section - B

(Very Short Answer Type Questions)

(0.75 marks each)

Note: Attempt all questions.

1. General relativity explain which natural phenomenon.
2. What is zero - rank tensor and one-rank tensor?
3. What is the metric tensor?
4. Define covariant and contra-variant tensor.
5. What do you mean by gravitation lensing.
6. Write the Einstein's field equation.
7. Write the relationship between Relativistic energy and momentum.
8. What is curvature? What is curvature of a straight line?
9. What is gravitational red-shift?
10. What is Schwarzchild solutions?

Section - C

(Short Answer Type Questions)

(1.25 marks each)

Note: Attempt at questions.

1. What is principle of equivalence?
2. What is Ricci tensor?
3. Using Geodesic equation, show that the Geodesic on a 2D spherical surface (say a smooth plane) are great circle?
4. Show that $g_{\beta}^{\alpha} = s_{\beta}^{\alpha}$?
5. What are Euclidean and Minkowski space?
6. What is Lorentz transformation? Derive its matrix form.
7. What is geodesic & why it is important?
8. Describe qualitative features of orbits?
9. What is Hubble parameter? Explain.
10. In the laboratory frame a particle 'P' at rest mass 'm_0'is moving in the positive x - direction with speed of $\frac{5c}{19}$. It

approaches an identical particle 'Q' moving in the negative x - direction with a speed of $\frac{2c}{5}$

(A) What is speed of the particle 'P' in the rest frame of the particle 'Q'.

(B) What is energy of the particle 'P' in the rest frame of the particle?

Section - D

(Long Answer Type Questions)

(2 marks each)

Note: Attempt any five questions.

1. Draw the 't' and 'x' axes of the space- time coordinates of an observer 'S' and then draw-

   (A) The 't' and 'k' axes of an observer 'S' who moves with velocity 0.5 in the positive x - direction relative to 'S' and whose origin $(x' = t' = 0)$ coincides with that 'S'.

   (B) The locus of events all of which occur at time $t' = 2m$ (simultaneous as seen by S').

   (C) The world line of a photon which is emitted from the event $t = 1\,m, x = 0$, travels in the negative

$x-$ direction, is reflected which it encounters a mirror located at x' = 1m, and is absorbed when it encounters a detector located at $x = 0.75\,m$.

2. How do cosmological results differ for matter dominated, radiation dominated and $\wedge$ dominated universe?
3. Discuss space & time in special relativity.
4. Write the eq^n for energy as $\frac{1}{2}\left(\frac{dr}{dt}\right)^2 = E - V(r)$

   Plot the effective potential $V(r) = \frac{h^2}{2r^2} - \frac{GM}{r}$ and discuss the qualitative features of orbits.
5. Obtain the Bianchi identity.
6. Derive the expression for cosmological Red-shift.
7. Derive the Fridmann equation from the FRW metric.
8. Explain stress-Energy - momentum tensor. Show that the stress tensor components t^{ik} are symmetric.
9. What is one - form tensor. Discuss in general properties ?
10. Discuss the thermal history of early universe.