

**M.Sc. PHYSICS**  
**FOURTH SEMESTER**  
**GENERAL THEORY OF RELATIVITY & ASTROPHYSICS**  
**MSP – 402**

( Use Separate Answer Scripts for Objective & Descriptive )

Duration: 3 hrs.

Full Marks: 70

( PART-A: Objective )

Time: 20 min.

Marks: 20

*Choose the correct answer from the following:*

**1X20=20**

1. Two photons approach each other. Their relative velocity will be
  - a. 0
  - b. c
  - c. c/2
  - d. 2c
2. The velocity of a rocket ship is 0.1 c. The rocket ship is contracted to its length by
  - a. 49%
  - b. 98%
  - c. 99%
  - d. 1%
3. Which one of the following expression is correct for surface charge density
  - a.  $\sigma' = \frac{\sigma}{\sqrt{1-\beta^2}}$
  - b.  $\sigma' = \sqrt{1-\beta^2}$
  - c.  $\sigma' = \sigma \sqrt{1-\beta^2}$
  - d.  $\sigma' = \sigma$
4. In four-dimensional manifold, the value of the expression  $\delta_\sigma^\mu \delta_\mu^\sigma$  is
  - a. 1
  - b. 2
  - c. 3
  - d. 4
5. The conjugate metric tensor  $\begin{pmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & r^2 \end{pmatrix}$  is
  - a.  $\frac{-1}{r^2} \begin{pmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & r^2 \end{pmatrix}$
  - b.  $\frac{-1}{r^2} \begin{pmatrix} r^2 & 0 & 0 \\ 0 & -r^2 & 0 \\ 0 & 0 & r^2 \end{pmatrix}$
  - c.  $\frac{-1}{r^2} \begin{pmatrix} r^2 & 0 & 0 \\ 0 & -r^2 & 0 \\ 0 & 0 & -1 \end{pmatrix}$
  - d.  $\frac{-1}{r^2} \begin{pmatrix} r^2 & 0 & 0 \\ 0 & r^2 & 0 \\ 0 & 0 & -r^2 \end{pmatrix}$
6. The metric component  $g_{rr}$  in the line-element  $ds^2 = \alpha^2 dr^2 + \alpha^2 r^2 d\varphi^2$  is
  - a.  $\alpha^2 r^2$
  - b.  $r^2$
  - c.  $\alpha^2 / r^2$
  - d.  $\alpha^2$
7. The number of independent components in the Einstein tensor  $G^{\alpha\beta}$  is
  - a. 8
  - b. 7
  - c. 10
  - d. 6
8. The number of independent components of the Riemann curvature tensor  $R_{\alpha\beta\gamma\delta}$  is
  - a. 15
  - b. 19
  - c. 17
  - d. 20

9. The rank of the mixed tensor  $\delta_{\alpha}^{\tau} \delta_{\sigma}^{\mu} A_{\rho\tau}^{\sigma}$  is
- |      |      |
|------|------|
| a. 2 | b. 3 |
| c. 4 | d. 5 |
10. The Kronecker delta is a mixed tensor of rank
- |      |      |
|------|------|
| a. 0 | b. 1 |
| c. 2 | d. 3 |
11. The duration for a star to get back to the same position in the sky it was the night before is
- |                   |                   |
|-------------------|-------------------|
| a. 24 hrs         | b. 24 hrs 4 mins  |
| c. 23 hrs 30 mins | d. 23 hrs 56 mins |
12. The declination ( $\delta$ ) of north celestial pole is
- |                 |                  |
|-----------------|------------------|
| a. $0^{\circ}$  | b. $-45^{\circ}$ |
| c. $90^{\circ}$ | d. $-60^{\circ}$ |
13. The mass defect in H to He conversion is counted to be
- |               |               |
|---------------|---------------|
| a. 0.0286 amu | b. 1.0078 amu |
| c. 4.0028 amu | d. 1 amu      |
14. Position of the solar system from the centre of our galaxy is
- |                        |                      |
|------------------------|----------------------|
| a. $\sim 1,00,000$ LYs | b. $\sim 28,000$ LYs |
| c. $\sim 3,000$ LYs    | d. $\sim 0$ LYs      |
15. The points at which ecliptic and equator intersect is called
- |            |            |
|------------|------------|
| a. solstic | b. equinox |
| c. zenith  | d. arctic  |
16. If the current time in UTC is 05:30 PM, then the time in IST is
- |             |             |
|-------------|-------------|
| a. 10:00 AM | b. 12:15 PM |
| c. 11:00 PM | d. 7:30 AM  |
17. Which of the following is/are the process of production of energy in stars?
- |                              |                      |
|------------------------------|----------------------|
| a. gravitational contraction | b. chemical reaction |
| c. nuclear reaction          | d. all of these      |
18. A fast rotating neutron star with an intense and large dipolar magnetic field is called a
- |              |               |
|--------------|---------------|
| a. Pulsar    | b. Black hole |
| c. Supernova | d. Quasar     |
19. The radio telescope array deployed to capture the image of black hole at our Galactic Centre is
- |                            |                       |
|----------------------------|-----------------------|
| a. RATAN-600               | b. 30 meter telescope |
| c. Event Horizon Telescope | d. Lovell Telescope   |
20. The escape velocity of a typical neutron star is
- |                                   |             |
|-----------------------------------|-------------|
| a. $c$ (i.e. $3 \times 10^8$ m/s) | b. $0.66 c$ |
| c. $3.5 c$                        | d. $9.8 c$  |

**( PART-B : Descriptive )**

Time : 2 hrs. 40 min.

Marks : 50

*[ Answer question no.1 & any four (4) from the rest ]*

1. a. What is meant by a metric tensor? 2+8=10  
b. By considering the variation of  $\int ds$ , derive the equation of geodesics in the form  
$$\frac{d^2x^\mu}{ds^2} + \Gamma_{\nu\sigma}^\mu \frac{dx^\nu}{ds} \frac{dx^\sigma}{ds} = 0.$$
2. a. Define apparent ( $m$ ) and absolute ( $M_v$ ) magnitudes of a star, and state how they are related to each other. 3+5+2  
=10  
b. If the apparent magnitude of the Sun is  $-26.73$ , then calculate its absolute magnitude. (given  $1AU = 4.85 \times 10^{-6}$  pc).  
c. When the time in Greenwich is 9h 40m 20s, it is 15h 47m 33s at USTM. Calculate the longitude of USTM.
3. a. Define Christoffels 3-index symbols. 2+4+4  
=10  
b. Show that  $\Gamma_{\mu\nu}^\mu = \partial_\nu (\ln \sqrt{-g})$ .  
c. If  $A_\mu$  is a tensor, then show that  $\partial_\nu A_\mu - \Gamma_{\mu\nu}^\sigma A_\sigma$  is also a tensor. What is the nature of this tensor?
4. a. Explain the three main regions of H-R diagram. 4+6=10  
b. The Luminosity of our Sun is  $L_\odot = 3.85 \times 10^{26}W$ , and its surface temperature  $T = 6000K$ , find its radius using Stefan's Law.
5. a. Show that  $G_{\nu;\mu}^\mu = 0$ , where  $G_\nu^\mu$  is the Einstein tensor. 6+2+2  
=10  
b. Write the relation between the Einstein tensor and the Ricci tensor.  
c. What is the cyclic property of the Riemann curvature tensor?
6. What do you understand by Hydrostatic Equilibrium of a star? 2+8=10  
From the equation of hydrostatic equilibrium establish the Virial theorem of stars.

7. a. Find all the Christoffel symbol for the metric tensor of line-element  $ds^2 = -A(r)dt^2 + B(r)dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2)$  6+2+2  
=10
- b. Under what condition this line-element is flat space?
- c. For a Schwarzschild solution writes the function A(r) and B(r).
8. a. Calculate the amount of energy released when hydrogen fuses to produce helium in main sequence stars. 2+4+4  
=10
- b. Discuss the steps involve in the fusion reactions below:  
 Proton-Proton (P-P) chain reaction,  
 Carbon-Nitrogen-Oxygen (CNO) reaction.

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