

REV-01  
MSP/34/17/22

2023/06

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

**SET  
B**

[USE OMR FOR OBJECTIVE PART]

Duration: 3 hrs.

Full Marks: 70

Time: 30 min.

( Objective )

Marks: 20

*Choose the correct answer from the following:*

*1X20=20*

- The equilibrium temperature which both P-P as well as C-N-O cycle possess is found to be
  - $0.08 \times 10^5 K$
  - $1.5 \times 10^6 K$
  - $1.6 \times 10^7 K$
  - $1.99 \times 10^8 K$
- If only the gravitational energy runs our Sun, it would power it up only to \_\_\_\_\_.
  - 13.8 B Yrs
  - 50 K Yrs
  - 30 M Yrs
  - 10 B Yrs
- Gravitational redshift is \_\_\_\_\_ when a photon emitted at a distance  $r=R_{Sch}$  perpendicularly from the surface of a black hole.
  - minimum
  - infinite
  - zero
  - none of these
- Fill in the blank:  $p + e \rightarrow \_ + \nu$  (symbols have their usual meaning)?
  - $e^+$
  - $\gamma$
  - H
  - n
- The typical density of a star with  $1M_{\odot}$  converting to a white dwarf leads to
  - $\rho = 10^6 \text{ gm/cc}$
  - $\rho = 10^{14} \text{ gm/cc}$
  - $\rho = 10^{32} \text{ gm/cc}$
  - $\rho = 10^{101} \text{ gm/cc}$
- The \_\_\_\_\_ of a black hole is the point in space where all the mass of a black hole accumulates.
  - Point of NO return
  - Event Horizon
  - X-ray free zone
  - Singularity
- Which among the following galaxies is most active in star formation?
  - Irregular
  - Spiral
  - Elliptical
  - Lenticular
- The size (diameter) of the Milky Way galaxy is
  - 1000 LY
  - 28000 LY
  - 90000 LY
  - 100000 LY
- A star seen at the zenith at USTM must be towards \_\_\_\_\_ from the Celestial Equator
  - north
  - south
  - east
  - west

10. The covariant derivative of a second rank tensor becomes a tensor of rank
- 1
  - 2
  - 3
  - 4
11. The interval between two events is called time-like if
- $ds^2 > 0$
  - $ds^2 < 0$
  - $ds^2 \geq 0$
  - $ds^2 \leq 0$
12. In a space-time diagram, the angle made by light-like curves with time axis will be
- Equal to  $\frac{\pi}{4}$
  - Less than  $\frac{\pi}{4}$
  - Greater than  $\frac{\pi}{4}$
  - All of these
13. The conjugate tensor of  $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & r^2 \end{pmatrix}$  is
- $\frac{1}{r^2} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & r^2 \end{pmatrix}$
  - $\frac{1}{r^2} \begin{pmatrix} r^2 & 0 & 0 \\ 0 & r^2 & 0 \\ 0 & 0 & 1 \end{pmatrix}$
  - $\frac{1}{r^2} \begin{pmatrix} r^2 & 0 & 0 \\ 0 & r^2 & 0 \\ 0 & 0 & -r^2 \end{pmatrix}$
  - $\frac{1}{r^2} \begin{pmatrix} r^2 & 0 & 0 \\ 0 & -r^2 & 0 \\ 0 & 0 & r^2 \end{pmatrix}$
14. The South Celestial Pole will be on the horizon for an observer who is at the
- north pole
  - south pole
  - USTM
  - equator
15. If the current time in UTC is 06:40 AM, then the time in IST is
- 12:10 AM
  - 12:10 PM
  - 5:10 PM
  - 7:10 AM
16. The assumptions made in the Schwarzschild solution are
- The space-time is vacuum
  - The space-time is asymptotically flat
  - The space-time is spherically symmetric
  - All of these
17. The number of independent components in the Riemann curvature tensor  $R_{\alpha\beta\gamma\delta}$  is
- 15
  - 19
  - 17
  - 20
18. The number of dependent components in the Einstein tensor  $G^{\alpha\beta}$  is
- 8
  - 7
  - 10
  - 6
19. The metric component  $g_{\varphi\varphi}$  in the line-element  $ds^2 = dr^2 + r^2(d\theta^2 + \sin^2\theta d\varphi^2)$  will be?
- $r^2 \sin^2\theta$
  - $r^2$
  - $\sin^2\theta$
  - 1
20. In four-dimensional manifold, the value of the expression  $\delta_{\sigma}^{\mu} \delta_{\nu}^{\sigma}$  is
- 1
  - 2
  - 3
  - 4

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**( Descriptive )**

Time : 2 hrs. 30 mins.

Marks : 50

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

1. Explain the three main regions of H-R diagram. 5+5=10  
The Luminosity of star Sirius is  $25.4L_{\odot}$ , and its surface temperature  $T = 10000K$ , find its radius using Stefan's Law. Given  $L_{\odot} = 3.85 \times 10^{26}W$ .
  
2. a. Derive an expression the Riemann curvature tensor in terms of Christoffel symbols of second kind. 6+2+2  
=10  
b. Find the divergence of a scalar function.  
c. Show that covariant derivative of the metric tensor vanish
  
3. a. Draw the Minkowski space-time diagram showing time-like and light-like curves. 4+3+3  
=10  
b. Define time-like and light-like interval.  
c. Using tensor transformation rule, convert the metric  $ds^2 = dx^2 + dy^2$  into the cylindrical coordinates.
  
4. Discuss how a white dwarf form. Explain briefly on electron degeneracy pressure. 5+5=10
  
5. a. If  $A^{\mu}$  is a tensor, then show that  $\partial_{\nu}A^{\mu} + \Gamma^{\mu}_{\sigma\nu}A^{\sigma}$  is also a tensor. 4+4+2  
=10  
b. Express the field equations in terms of Ricci tensor and stress-energy tensor.  
c. State the cyclic property of the Riemann curvature tensor.
  
6. What do you understand by Hydrostatic Equilibrium of a star? 2+4+4  
=10  
Establish the relation of Hydrostatic Equilibrium between the pull of gravity and outward gas pressure.  
If a star of same size and mass of the Earth converts to a black hole, what would be its Schwarzschild radius?

7. a. Find the Christoffel symbols  $\Gamma_{\mu\nu}^r$  and  $\Gamma_{\mu\nu}^\theta$  using the line-element  $ds^2 = dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2)$ . 4+4+2  
=10
- b. Derive an expression of the effective potential of Schwarzschild vacuum solution.
- c. What do you mean by an event horizon?
8. Discuss the steps involve in the following fusion reactions that runs the energy production process in stars. 5+5=10  
P-P cycle.  
C-N-O cycle

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