PHY6B13:RELATIVISTIC MECHANICS AND ASTROPHYSICS

A Part

1. State the postulates of special theory of relativity.
2. Mention why Michelson-Morley experiment is important for the development of theory of special relativity.
3. Mention two reasons why we need to modify galilean relativity?
4. What is the concept of 'universal velocity'?
5. What is the importance of Newton's first law in relativity?
6. Mention the significance of Michelson-Morley experiment in relativity.
7. What was the need for ether medium?
8. What was the aim of Michelson-Morley experiment?
9. Give the equations of Galilean transformation.
10. Give the equations of Lorentz transformation.
11. State two major differences between Galilean and Lorentz transformation.
12. Which physical quantities are invariant under Galilean transformations, explain?
13. What is meant by space-like interval? Explain with an example.
14. What is meant by time-like interval? Explain with an example.
15. What is meant by simultaneity? How does the status of simultaneity change in relativistic and non-relativistic physics?
16. What are space-like, time-like and light-like intervals?
17. What happens to the length of rod oriented perpendicular to the motion of frame?
18. What is Lorentz length contraction?
19. What is rest length? The rest length of an object is the largest length it can have in any inertial frame. Justify this statement.
20. Give two practical examples of time dilation.
21. What is time dilation?
22. Explain time dilation.
23. What is proper time interval?
24. Write the relativistic velocity transformation formula. Briefly explain the importance of the formula.
25. Write down the equations corresponding to the relativistic law for the addition of velocities.
26. Show that the velocity of light is the same for all observers using the concept ' relativistic transformation of velocity'.
27. What is Doppler effect? Explain with an example.
28. What is meant by Doppler effect? Write the formula for relativistic Doppler effect.
29. Why is the Doppler effect signifcant in relativistic physics? Explain.
30. Give the expressions for relativistic energy and momentum. How is the energy and momentum is related in relativistic physics.
31. Show that massless particle always travels with speed of light using the expression for relativtistic momentum of a particle.

32. Show that massless particle always travels with speed of light.
33. At what speed does the kinetic energy of a particle equal its rest energy?
34. What is mass-energy equivalence? Give an example where mass is converted to energy.
35. Mention any two effects in nature which illustrate the particle nature of photon.
36. What is the meant by Photoelectric effect?
37. Write the expression for energy of photon in terms of momentum.
38. State the equivalence principle.
39. Differentiate inertial mass and gravitational mass.
40. What is weak equivalence principle.
41. In a curved spacetime, geometrical relations among open and closed lines/figures are affected. How?
42. Write Einstein's field equation.
43. What is superior conjunction?
44. Write a note on helium fusion.
45. What is the connection between a neutron star and heavy elements?
46. What is Chandrasekhar limit?
47. How does quantum mechanics rescue a white dwarf from total collapse?
48. Write equations of Fermi energy and radius of a neutron star.
49. Why should the time period of pulses from a pulsar decrease? How does this verify the theory of formation of pulsars?
50. What are binary pulsars?
51. Define a black hole.
52. Schwarzschild radius is often called the event horizon. Why
53. Normal black holes may not emit particles. Why?
54. What is cosmology?
55. Define Cosmological principle.
56. What is Hubble constant? What is its value, as per most recent observations?
57. What do you mean by saying that the Universe is expanding? Is it like some blast that occurred at some point in space?
58. What is the connection between energy density of photons in CMBR and Stefan's constant?
59. According to theoretical guesses what kinds of objects make up dark matter?
60. What is distance scale factor?
61. Write Friedmann equation.
62. How is the distance scale factor connected with time in a (i) matter dominated Universe and (ii) radiation dominated Universe?
63. What is the connection between Hubble constant and distance scale factor?
64. Which are the parameters with which we can characterize the Universe?

65. Write the equation equation that relates the age of the early Universe to its temperature.
66. How did radiation and matter interact in the early Universe?
67. What is stellar parallax?
68. Give the relation between parallax and distance.
69. Define 1 AU. What is the value of 1 AU in parsecs?
70. What is meant by Luminosity of a star? What is its unit?
71. Distinguish between luminosity and apparent brightness.
72. Write down the relation between luminosity, distance and apparent brightness.
73. How size of star can be measured?
74. Explain why we expect a blue star to be more hotter than redstar?
75. Explain what is meant by magnitude of stars.
76. How apparent magnitude and brightness ratio are related?
77. Write down the relation between between apparent magnitude and absolute magnitude.
78. Explain what is meant by color of stars.
79. What is the relation between colour and temperature of stars?
80. State the Wien's law. How it is related with color of stars?
81. State Stefan-Boltzmann law. How it is useful for stars?
82. Distinguish between luminosity and flux of stars.
83. Write down the relation between luminosity, flux and radius of a star.
84. Explain why stellar parallax cannot be used to measure distance outside milky-way galaxy
85. What is the relation between luminosity and mass of a star?
86. Is it correct to say that a big star is always luminous than smaller star?Explain why or whynot.
87. The sun is a G2 spectrum star. Explain why?
88. What are Franhauffer lines in Sun's spectra? Why Sun's spectra shows this lines?
89. Write down the spectral classes of stars in the order of increasing temperature?
90. What is an H-R diagram?
91. What is main sequence?
92. What are the four branches of H-R diagram?
93. How naming a star is done?
94. How is spectroscopy used to find the composition of stars?
95. Why do very hot stars have no hydrogen lines?
96. Why do very cool stars have no hydrogen lines?
97. What is the main reason why some stars have strong (dark) hydrogen lines and others have weak (light) hydrogen lines?
98. What is the trend in the stellar diameters vs. temperature for main sequence stars?

99. What is the range of temperatures found on the surface of main sequence stars?
100. Do bright things have larger or smaller magnitudes than fainter things?Explain
101. Some stars have temperatures of only 3000 K but have over 100× more luminosity than the Sun. How is this possible?
102. What is interstellar medium?
103. What is a protostar?
104. What is meant by stellar evolution?
105. What is meant by gravitational/hydrostatic equilibrium in a star?
106. What is a supernova?
107. Name the three origins of triggering star formation.
108. What is a brown dwarf?
109. What is a nebula?
110. What is an galactic/open cluster? Give an example.
111. Write down the lower and higher limits of masses, which prevents star formation.
112. Distinguish between type I and II supernovae.
113. Describe the Core of the Sun.
114. What is Proton-Proton chain reaction?
115. Why the brightness of the Sun is independent of the energy production?
116. What is radiation zone of the Sun?
117. what are the layers of sun
118. What is plasma
119. What is Electron degeneracy pressure?
120. What is a red giant? Give one example.
121. What are binary stars? Give an example.
122. What is an eclipsing binary? Give an example.
123. What is a spectroscopic binary?
124. What is astrometric binary? Give an example.
125. What is a visual binary?
126. Define the position angle of binary stars.
127. What is shell Hydrogen burning?
128. What is Helium burning?
129. What is Helium flash in red giants?
130. How the age of a star cluster can be found?
131. Distinguish between galactic and globular clusters.
132. What is a pulsating variable star?

133. What are cephied variable stars
134. What is the relation between size and period of a Cepheid?
135. Distingush between Type 1 and Type 2 Cepheid
136. Name different types of variable stars.
137. What is a blackhole
138. What are the 3 characteristics of a blackhole.
139. Explain the rotation of neutron stars.
140. Explain the magnetic field of neutron stars.
141. How does Neutron star pulsate?
142. What is meant by singularity?
143. How can we detect a black hole?
144. What is an AGB star?
145. Draw the structure of an AGB star.
146. Distinguish between a red giant and an AGB star?
147. What is event horizon of a black hole?
148. What is photo-disintegration process?
149. What is Neutron capture?
150. What are galaxies?
151. Name the different galaxies based on their shapes.
152. Sketch the tuning fork diagram for galaxies.
153. What is a spiral galaxy?
154. What is a elliptical galaxy?
155. What is an irregular galaxy?
156. What is a lenticular galaxy?
157. Distinguish between spiral and elliptical galaxies.
158. Why the age of the stars in spiral galaxies are relatively smaller?
159. Distingush between population I and population II stars?
160. Sketch the visibility symbols of galaxies based on inclination.
161. What are active galaxies?
162. What is an active galactic nucleus (AGN)?
163. What all factors on which characteristics of an AGN depend?
164. What is a seyfert galaxy?
165. What is gravitational lensing?
166. What is meant by clusters of galaxies?

167. What is a quasar?

168. Explain the phenomenon of mass accretion.

169. Sketch the visibility symbols of galaxies based on inclination.

170. Differentiate between galactic cluster and galactic supercluster

171. When the galaxy is designated as easy?

172. When the galaxy is designated as moderate?

173. When the galaxy is designated as difficult?

174. What is meant by merging of two galaxies

B Part

175. Suppose a spaceship heading directly towards the Earth at half the speed of light sends a signal to us on a laser-produced beam of light. Given that the light leaves the ship at speed c as observed from the ship, calculate the speed at which it approaches the Earth.

176. Suppose a spaceship heading directly towards the Earth at quarter the speed of light sends a signal to us on a laser-produced beam of light. Given that the light leaves the ship at speed c as observed from the ship, calculate the speed at which it approaches the Earth.

177. Discuss the postulates of special relativity.

178. What are the main postulates of special relativity?

179. How did Einstein interpret the null result of Michelson-Morley experiment?

180. Show that Galilean transformation is incompatible with constancy of speed of light postulate.

181. Compare between Galilean and Lorentz transformation.

182. An event occurs in S at $x = 1 \times 10^8 m$, and in S' at $x' = 6 \times 10^8 m$ and t' = 4 s. Find the relative velocity of the systems.

183. An event occurs in S at $x = 3 \times 10^8 m$, and in S' at $x' = 6 \times 10^8 m$ and t' = 3 s. Find the relative velocity of the systems.

184. Obtain the Galilean transformation equations for position, velocity and acceleration.

185. Compare Galilean and Lorentz transformations.

186. Show that Galilean transformation equations are incompatible with special relativity.

187. What is the significance of the observer in relativity?

188. How is Lorentz transformation different from Galiliean transformation?

189. A spacecraft is moving relative to the earth. An observer on the earth finds that, between 2 P.M. and 3 P.M. according to her clock, 3602 s elapse on the spacecraft's clock. What is the spacecraft's speed relative to the earth?

190. Explain the relative nature of simultaneity with a suitable explanation.

191. Classify the order of events to timelike and spacelike intervals with the corresponding conditions.

192. An observer detects two explosions that occur at the same time, one near him and the other 50 km away. Another observer finds that the two explosions occur 80 km apart. What time interval separates the explosions to the second observer?

193. Consider two events as observed in S frame which have the spatial coordinate difference,$L = 6 \times 10^4 m$ and time difference between the events is $T = 2 \times 10^{-6} s$. Determine whether the events are timelike or spacelike.

194. An observer detects two explosions, one that occurs near him at a certain time and another that occurs 1.00 ms later 100 km away. Another observer finds that the two explosions occur at the same place. What time interval separates the explosions to the second observer?

195. Events that are simultaneous in one inertial frame need not be simultaneous in another frame. Demonstrate this statement using an example.

196. An airplane is flying at 372 Km/h. How much time must elapse before the clock in the airplane and one on the ground differ by 1 s?

197. A spacecraft receding from the earth at 0.97c transmits data at a rate 1×10^4 pulses/s. At what rate are they received?

198. A spacecraft approaching the earth at 0.97c transmits data at a rate 1×10^4 pulses/s. At what rate are they received?

199. A spacecraft approaching the earth at 0.97c transmits data at a rate 3×10^4 pulses/s. At what rate are they received?

200. If a rod travels with a speed$v = 0.8\,c$ along its length, by how much does it shrink?

201. What is muon decay? Explain how the muon decay is relevant as an illustration for time dilation.

202. How the muon decay is relevant as an illustration for time dilation? Explain briefly.

203. How fast must a spacecraft travel relative to the earth for each day on the spacecraft to correspond to 1.5 days on the earth?

204. Explain the paradox in the twin paradox problem.

205. How can the twin paradox problem be solved?

206. How can we use time dilation to explain how mesons are found in the lower atmosphere?

207. Mesons are found in the lower atmosphere, eventhough their life time prevents them from reaching the lower atmosphere. Explain.

208. The mean life-time of muons at rest is found to be about $2.2\mu s$, while the mean life time of muons in a burst of cosmic rays from which they are produced is found to be $15\mu s$. What is the speed of these cosmic ray muons?

209. A Spacecraft is moving at 0.90c with respect to the earth. If another spacecraft is to pass the first one at a relative speed of 0.50c in the same direction, what speed must second spacecraft have with respect to the earth?

210. A Spacecraft is moving at 0.80c with respect to the earth. If another spacecraft is to pass the first one at a relative speed of 0.60c in the same direction, what speed must second spacecraft have with respect to the earth?

211. Photon's velocity in vacuum is c in all inertial frames of reference. Explain with relativistic velocity transformation equations.

212. A spacecraft is moving at 0.40c with respect to the earth. If another spacecraft is to pass the first one at a relative speed of 0.10c in the same direction, what speed must the second spacecraft have with respect to the earth?

213. A Spacecraft is moving at 0.50c with respect to the earth. If another spacecraft is to pass the first one at a relative speed of 0.30c in the same direction, what speed must second spacecraft have with respect to the earth?

214. Using relativistic velocity transformation law, show that the photon's velocity in vacuum is c in all inertial frames of reference.

215. Let the angle between the direction of motion of a light source (of frequency ν_0) and the direction from it to an observer is theta. What is the frequency as observed by the observer?

216. A car moving at 100 km / h is approaching a stationary police car whose radar speed detector operates at a frequency of 10 GHz. What is the frequency change detected by the speed detector?

217. A vehicle moving at 180 km / h is approaching a stationary police car whose radar speed detector operates at a frequency of 10 GHz. What is the frequency change detected by the speed detector?

218. Let θ be the angle between the direction of motion of a light source (of wavelength λ_0) and the direction from it to an observer. What is the wavelength as observed by the observer?

219. Verify that v/c = pc/E.

220. An electron whose speed relative to an observer in a laboratory is 0.800c is also being studied by an observer moving in the same direction as the electron at a speed of 0.500c relative to the laboratory. What is the kinetic energy (in MeV) of the electron to each observer?

221. What is the energy of a photon whose momentum is the same as that of an electron whose kinetic energy is 12 MeV?

222. What is the energy of a photon whose momentum is half as that of an electron whose kinetic energy is 12 MeV?

223. Describe the experiment used to verify velocity dependence of mass of a particle.

224. An object in motion has a mass of 12 kg and travels in the air with a velocity 0.82c. What would be its rest mass?

225. What is the energy of a photon whose momentum is one third as that of an electron whose kinetic energy is 12 MeV?

226. What is the energy of a particle with mass $3.2 \times 10^{(} - 27)$ kilograms and velocity 0.9c?

227. Calculate the energy and momentum of a photon with a frequency of $5 \times 10^{(}14)$ Hz.

228. Calculate the wavelength of a photon with energy 3 eV.

229. Find the energy and momentum of the photon if the wavelength is 300 nm.

230. The red light from a helium-neon laser has a wavelength of 633 nm. What is the energy of one photon?

231. How much energy is contained in a particle that has a mass of $m = 1\mu g$?

232. Suppose that the mass of a neutral Uranium atom is measured and found to be 235.0349amu. However, after adding up the mass of all constituent protons, neutrons, and electrons, the predicted mass of a Uranium atom is expected to be equal to 236.9601amu. Based on this information, what is the nuclear binding energy of a uranium atom?
1 amu=$1.66 \times 10^{(} - 27)$kg.

233. Two grams of helium are completely converted into energy and used to power a 5000kg vehicle. If all of this energy is converted into kinetic energy of the vehicle, how fast will the vehicle move?

234. Explain equivalence principle. Give an example.

235. The equivalence principle is valid only locally. Why? What happens if the lab is quite large?

236. Does the frequency of a photon moving in a gravitational field change? Explain.

237. Explain an experiment that will demonstrate the frequency shift for a photon moving in a gravitational field.

238. Explain an experiment to show that light is bent by gravity.

239. What is equivalence principle? Explain with an example.

240. What is the importance of general theory of relativity? Explain.

241. Explain how general relativity explains the precession of perihelion of Mercury.

242. How does general relativity explain the precession of perihelion of Mercury?

243. Explain Equivalence Principle with an example.

244. The frequency of a photon moving in a gravitational field changes. Explain.

245. Write a note on stellar birth.

246. Explain the processes occurring in a star that has become stable and is in the middle ages of its life.

247. What is solar neutrino problem? How was it solved?

248. Write a note on fusion of carbon and heavier elements. Where does this reactions stop?
249. Based on the theory of stellar evolution, what are the predictions that can be made about the abundance of elements in the Universe? How were they verified?
250. How are odd atomic number elements created in the Universe?
251. How are elements Production of elements heavier than Fe^{56} created in the Universe?
252. Briefly explain the components of energy of a white dwarf. Also obtain the radius of a white dwarf.
253. What are neutron stars? How are they created? How were they discovered?
254. How can general relativity be tested using pulsars?
255. Derive an expression for Schwarzschild radius.
256. What are supermassive black holes?
257. How can a black hole emit particles?
258. Find the radius of a black hole if it was formed from (a) the sun (b) the earth.
259. How did we come to know that the Universe is expanding?
260. Explain Hubble's law.
261. Prove the connection between Hubble's constant and the age of the Universe.
262. A Universe where Hubble's law is valid should be expanding. Justify this statement.
263. Compare Big bang theory and Steady state theory. How did Big bang theory become accepted by almost everyone?
264. What is Cosmic Microwave Background Radiation (CMBR)? How does it support the Big bang theory?
265. Derive an expression for Number density of photons in CMBR.
266. Derive an expression for energy density of photons in CMBR.
267. How was the existence of CMBR experimentally discovered?
268. What is dark matter? How was it discovered?
269. By listing the events that happened during the evolution of the Universe backwards, reach the point where the Universe had a unified force.
270. Which are the factors that maintained the neutron to proton ratio 1 microsecond after the Big bang?
271. Describe the time period when all anti-matter was annihilated.
272. How and when were neutrinos decoupled from other particles in the Universe?
273. Find the relative number of protons and neutrons at $t = 1s$ after the Big bang.
274. How and when were Weak interactions almost decoupled from particle interactions in the Universe?
275. Explain how deuterons were created in the Universe.
276. How and when did electromagnetic interactions become insignificant during particle interactions? What happened to this field?
277. How will neutrinos, when detected by future instruments become a supporting evidence for Big bang model?
278. The presence of 24\% helium is support for Big bang model. How?
279. Write a note on anti-matter.
280. How does the inflationary model of the Universe predict formation of stars and galaxies in the Universe?

281. Show that for a flat Universe, its age is only 2/3rd of the current estimate.

282. Use Hubble's law to estimate the wavelength of the 590.0 nm sodium line emitted from a galaxy whose distance from us is $ 1.0 \times 10^9 $ light years.

283. The parallax of our nearest star Proxima Centauri is $0.785''$. Find its distance in parsecs, light years, astronomical units and kilometres.

284. Explain the stellar parallax method of measuring distances, with the help of diagram.

285. Find the brightness of star Sirius, which is at a distance of 8.6 l.y and whose luminosity is 3.86×10^{26} watts.

286. The apparent magnitude of a star is observed to be +3.3 and its parallax is $0.025''$. Find the absolute magnitude of the star. Compare the luminosity of this star with that of the Sun (Given absolute magnitude of the Sun is +5.0).

287. A star at a distance of 4 pc has an apparent magnitude 2. What is its absolute magnitude? If the Sun has a luminosity $3.9 \times 10^{26} W$ and has an absolute magnitude of +5, find the luminosity of the star.

288. Find the brightness of *Sirius*, which is at a distance of 8.6 light years and whose luminosity is \(3.86\times 10^{26}\) watts.

289. The mysterious star Zubeneschamali belongs to Libra constellation has a temperature of 11,000K. What is its peak wavelength?

290. A star whose apparent magnitude 10 is located at a distance of 32.6 ly. What is its absolute magnitude?

291. Two stars, α Canis Majoris and o Ceti, have a temperature of$9200\ \mathrm{K}$ and $1900\ \mathrm{K}$, respectively. What are their peak wavelengths?

292. Sirius has a temperature of about $9200\ \mathrm{K}$ and luminosity of about $23\ L_\odot$. Calculate the radius of Sirius with reference to that of the Sun. Take $T_\odot$=5800K.

293. Sirius is at a distance of 2.63pc and has an apparent magnitude of -1.44 . Calculate its absolute magnitude.

294. Explain the features of Hydrogen atom spectrum. How stars are classified based on spectra.

295. Draw an H-R diagram and indicate stellar radius and explain the diagram.

296. Explain how H-R diagram is related to stellar luminosity.

297. Describe how a star is born.

298. Describe the four different life track phases of a Sun-like star.

299. Explain Helium burning and Helium flash.

300. Describe the Trumpler classification of star clusters.

301. Describe the Proton-Proton chain reaction in the Sun.

302. How does energy in the Sun transport from the core to the surface?

303. Describe the internal structure of Sun. Explain the mechanism responsible for production of energy in sun

304. Explain Helium burning and Helium flash.

305. What are the properties of globular clusters?What all information can be obtained from colour-magnitude H-R diagram of globular clusters?

306. Describe binary star systems and their features. Explain how masses of stars can be determined?

307. Determine the main-sequence lifetime of Sirius, which has a mass of $2.12\ M_\odot$,

308. Explain how Chandrasekhar limit affect end stages of different stars?

309. Explain the rotation and magnetic field of neutron stars.
310. Explain how heavier elements are formed in the universe?
311. What are variable stars. Distinguish between Cepheid-I and Cepheid-II stars.
312. What is a pulsating variable star?What is the main cause of pulsations in pulsating variable stars?
313. What is Cepheid variable star?What is period-luminosity relationship?
314. Explain how an AGB star is formed.Explain the end of an AGB star's life?
315. How planetary nebulae are formed?What are different types of planetary nebulae?
316. What are supernovae. Describe different stages of supernova explosion.
317. What are black holes. Explain its features. How we can detect them?
318. Explain the various types of galaxies.
319. Describe the structure of spiral galaxy?
320. Distinguish between population I and II stars.
321. Describe Hubble classification of galaxies?
322. Distinguish between easy, moderate and difficult classes of galaxies.
323. Briefly explain how an active galaxy gets extra energy?
324. Explain the effects of gravitational lensing?
325. Distinguish between different clusters.
326. How does the red shift and Hubble's law are related?
327. How did the discovery of quasars, changed our view about the universe?
328. Distinguish between small and giant clusters of galaxies.

C Part

329. Discuss the postulates of special relativity. Write a note on Lorentz transformations with examples.
330. Explain Lorentz transformation equations. Use this equations to obtain the inverse transformation equations. Write suitable examples where Lorentz transformation equations are used and show how different the results are compared to that obtained from Galilean transformations.
331. Explain the impact of time dilation in Meson Decay. Also explain the time dilation in atomic clock.
332. Explain the relativistic Doppler effect.
333. Explain the tests of general relativity.
334. Starting with free protons and neutrons, explain the particle phenomena that took place for the formation of helium nuclei.
335. Write a note on the evolution of the universe.
336. List the significant time periods in the evolution of the Universe. Explain the physical processes taking place during each important time period.
337. In addition to CMBR, explain other clues that support the Big bang model.
338. Derive an expression for the energy of the microwave background radiation.
339. Establish that the inverse of Hubble's parameter is a rough estimate of measure of the age of the universe.

340. Describe the H-R diagram for different types of star’s evolution. Write down all information that can be obtained from it.

341. What is an H-R diagram. How the star’s properties such as size, luminosity and mass are explained based on it.

342. Write a note on apparent magnitude and absolute magnitude of stars and derive the relation between apparent magnitude, absolute magnitude and distance.

343. Explain the birth of a star.

344. Explain the internal structure of the sun with a neat diagram. Discuss the proton-proton chain reaction.

345. Describe the evolutionary life track of stars in an H-R diagram. Describe the evolution of protostars, when the mass is equal to, greater than and lower than the mass of the Sun.

346. Discuss the internal structure of the Sun and describe how energy is transported from core to the surface.

347. Explain how red giant stars are formed. Describe the post main sequence evolutionary track of stars with different masses, with the help of an H-R diagram.

348. What is asymptotic giant branch? Explain how an AGB star is formed and later evolved?

349. Explain the formation of heavier elements in high mass stars and describe the end stages of a high-mass star.

350. Describe active galactic nuclei and Quasars. Explain gravitational lensing with examples.

351. What are galaxies? Classify different type of galaxies. Describe the "structure of spiral galaxy? Discuss the factors, which affect the observation of galaxies."

352. How does the red shift and Hubble's law are related? Explain the Hubble classification of galaxies.

D Part

E Part