

I. (10 Pts) Who's Who?

Match the following names to the descriptions. (Enter the letter.)

A. Copernicus	D. Newton	G. Eddington	J. Thomson
B. Wheeler	E. Bohr	H. Hubble	K. Schwarzschild
C. Planck	F. Kepler	I. Maxwell	L. Ptolemy

- a. He found that the universe was expanding. H
- b. Person who named black holes. B
- c. Provided a planetary theory of the atom. E
- d. Predicted electromagnetic waves. I
- e. Introduced heliocentric system. A
- f. Promoted geocentric view of solar system. L
- g. Introduced spherical solution of spacetime equations. K
- h. Discovered ^{laws of} classical planetary motion. F
- i. Father of classical physics. D
- j. He confirmed the bending of light in 1919. G

II. (10 pts) The Movie: Match the following: (Enter the letter.)

A. Mann	D. Edmunds	G. Miller	J. John
B. Joseph	E. Murph	H. Romilly	K. Tom
C. Ranger	F. Endurance	I. Donald	L. Amelia

- a. What was the name of the water world? G
- b. Who led the Lazarus team? A
- c. What is Professor Brand's first name? J
- d. Who was Professor Brand's daughter? L
- e. What spaceship went into Gargantua? C
- f. Who was left alone for 23 Earth years? H
- g. Who was Cooper's father? I
- h. What was the name of the second planet visited? A
- i. Who believed there were ghosts? E
- j. What planet did Cooper not visit? D

III. (10 Pts) Terms Match

Find the best match and place the letter in the space provided.

A. Dark Energy	B. Doppler Effect	C. Jets	D. Blackbody radiation
E. Hubble	F. Homogeneous	G. Isotropic	H. Light Spectrum
I. Webb	J. Sputnik	K. Photon	L. Event Horizon
M. Relativity	N. Voyager	O. Time Dilation	P. Accretion disk

- a. What is quantum of light? K
- b. The universe looks the same from any location. F
- c. What is used to detect composition of stars/ H
- d. What is the point of no return near a black hole? L
- e. Quasars have this feature. C
- f. What space telescope has been in operation for 20 years? E
- g. What is the cause of stars being redshifted? B
- h. What space probe has left the solar system? N
- i. What is the theory about space and time? M
- j. What was the first successful space satellite to leave Earth? J

IV. (5 Pts) Numbers

- a. How old is the universe? 14 billion yrs
- b. How many galaxies are there? 100 billion
- c. How fast does light travel in a vacuum? 3×10^8 m/s
- d. What is the escape velocity from the Earth?¹ 11 km/s or 25000 mph
- e. What is the radius of Gargantua? 150 billion m

¹ $M_E = 5.9722 \times 10^{24}$ kg, $R_E = 6,378$ km, $G = 6.67 \times 10^{-11}$ Nm²/kg²

V. (10 pts) Short Answers:

a. A star is approaching the Earth. Is the light red-shifted or blue-shifted?

blue

b. If black holes cannot be seen, why do we believe that they exist?

c. The atomic clocks on a GPS satellite do not record the same time as one on the Earth. Explain the time dilation effects due to Special and General Relativity noting whether, or not, the clocks tick faster or slower on the satellite.

GR - faster
SR - slower

d. When a star dies, what determines it's final state?

mass

VI. (8 pts) Black Hole Image

Describe what you see in this picture as completely as possible.



VII. (22 pts) Science: Fill in the blanks with the best answer.

- a. Electromagnetic waves can be viewed as particles called photons.
- b. General relativity is a theory of gravity.
- c. Name three possible final states of dying stars:
white dwarf, neutron star, black hole.
- d. The point of no return for a black hole is called a event horizon.
- e. One consequence of general relativity is the perihelion shift. Which planet was key in verifying this? Mercury.
- f. Two stars that rotate about each other are called binary.
- g. The remnant of radiation from the hot early universe is called the CMB.
- h. What experimental characteristic of ionized Hydrogen gas was explained by Bohr's model of the atom? spectrum.
- i. According to recent experiments, it is believed that the expansion of the universe is which of the following: slowing down, increasing, constant.
increasing.
- j. Planets travel in ellipses.
- k. Give two examples of electromagnetic waves. radar, microwave...
- l. What is M31? Andromeda
- m. Name three consequences of Special Relativity.
 1. Time dilation
 2. Length contraction
 3. $E=mc^2$
- n. What equation is important in determining the energy released in the combination of two hydrogen atoms to form helium? $E=mc^2$
- o. What does IMBH stand for? intermediate mass black hole
- p. Null geodesics are paths light rays take.
- q. A fish underwater sees a bird flying above the water. Is the image further from or closer than the actual bird? further

VIII. (9 pts) Calculations

- a. Jupiter is 588 million km (365 million miles) from the Earth. How long did it take Cassini to send a signal back to the Earth from Jupiter?

$$\frac{\text{dist}}{\text{Speed}} = \frac{588 \times 10^9 \text{ m}}{3 \times 10^8 \text{ m}} = 2000 \text{ s}$$

- b. The Klingons are traveling in 500 meter long spaceship at half the speed of light towards the spaceship Enterprise. The Klingon captain notes that he will catch up to the Enterprise in half an hour.

- i. Describe the length of the Klingon spaceship as seen by the captain of the Enterprise compared to the given length.

shorter

- ii. Scotty, the Enterprise's engineer, needs half an hour to get the weapons system repaired. Will this be enough time? Explain.

Time on Earth is longer => Yes
moving objects tick slower



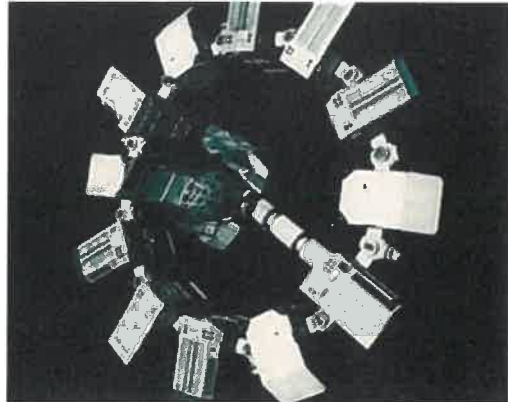
IX. (10 Pts) Short Essay – Pick one of the following topics and write a coherent essay describing the topic, listing at least six important facts. You can continue on back of page.

- Gravitational slingshots.
- Disasters on Cooper's Earth.
- Visualization of the lensed accretion disk around a black hole.

X. (6 pts) Images. Name the objects/locations in the figures below.



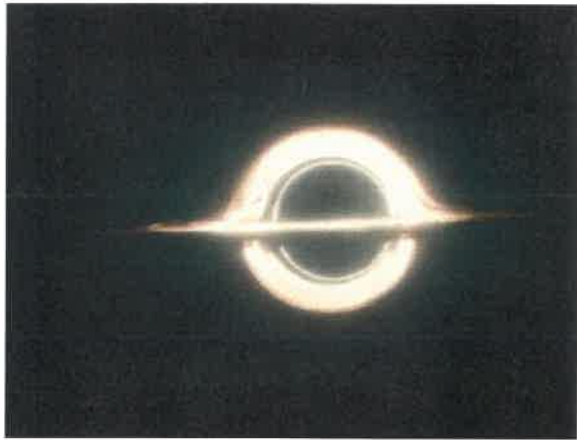
Accretion Disk



Endurance



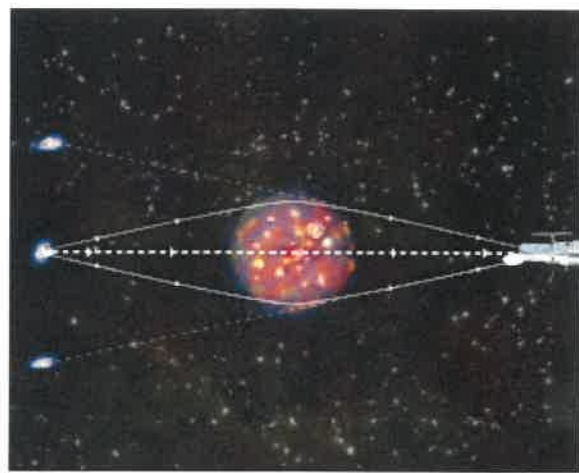
Miller's Planet



Jargantua



Einstein Ring



gravitational Lensing