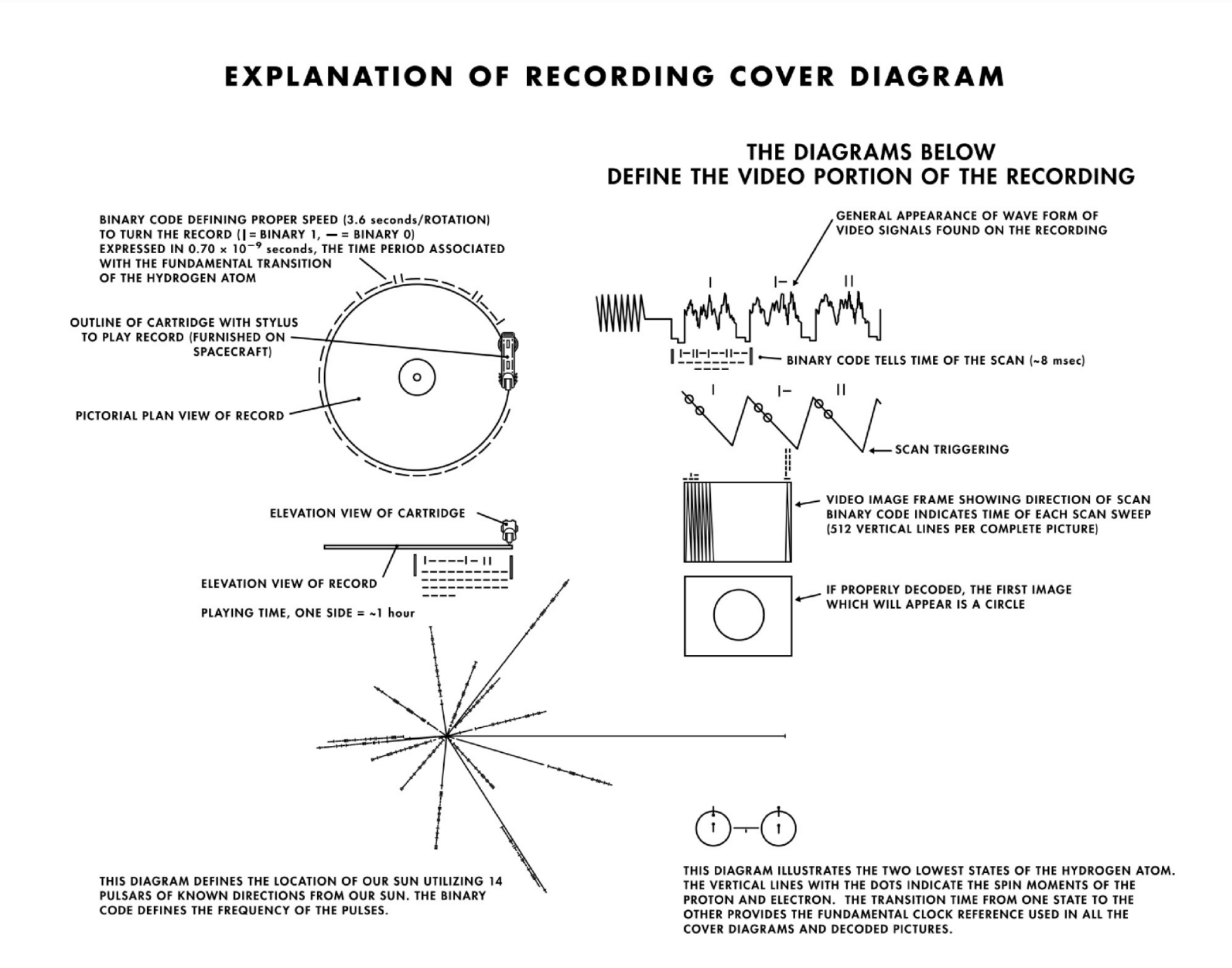
Recruitment Test
dhRuVa

The Astrophysics and Astronomy Club of RVCE



Abstract

Why are you here?

When you look at the night sky, do you see an endless void—or a tapestry of unanswered questions? For those who are curious, for those who wonder, we are your next chapter.At the Astrophysics Club, we are more than a community—we are an institution of seekers. From building telescopes and decoding gravitational waves to hosting immersive stargazing events, we explore the universe's greatest mysteries through science, passion, and collaboration.

What Awaits You Here?

For the ***technically inclined***, you'll delve into advanced projects—crafting cutting-edge optical and radio telescopes, analyzing data from world-renowned observatories, and publishing research that pushes the boundaries of astrophysics. You will gain hands-on experience with tools and ideas that define the future of this field.
For those whose ***talents lie beyond technical expertise***, this is where your journey matters just as much. You can lead public outreach campaigns, orchestrate celestial events, design immersive marketing strategies, or ensure seamless logistics and production. Every role is integral to achieving our shared vision: making the cosmos accessible and awe-inspiring for all.

Who Are We Looking For?

We are not a club of passersby. We are builders of telescopes, curators of ideas, and explorers of what lies beyond. If your curiosity burns brighter than mere fascination—if you are ready to commit to discovery, creation, and the joy of collaboration—you belong here.The cosmos doesn't wait for the hesitant. Every project we undertake, every star we map, every discovery we make is a step toward answering humanity's oldest questions. What you do here has the potential to shape not only your future but the collective understanding of the universe. The stakes are nothing less than the pursuit of truth itself.

Contents

Nomenclature

Constants

Notation	Description	Unit
k	constant of Boltzmann	$1.381 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
c	speed of light	$2.998 \times 10^{8}\,\mathrm{m\,s^{-1}}$
e	elementary charge	$1.602 \times 10^{-19}\,\mathrm{C}$
ϵ_0	vacuum permittivity	$8.854 \times 10^{-12}\,\mathrm{C^2\,kg^{-1}\,s^2}$
G	gravitational constant	$6.674 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$
m_0	atomic mass unit	$1.661 \times 10^{-27}\,\mathrm{kg}$
$M_{B\odot}$	absolute B-band magnitude of the sun	5.48
m_e	rest mass of an electron	$9.109 \times 10^{-31}\,\mathrm{kg}$
m_p	rest mass of a proton	$1.673 \times 10^{-27}\,\mathrm{kg}$
$M_{V\odot}$	absolute visual magnitude of the sun	4.83
$m_{V\odot}$	apparent visual magnitude of the sun	-26.75
N_A	constant of Avogadro	$6.022 \times 10^{23}\,\mathrm{mol^{-1}}$
h	constant of Plack	$6.626 \times 10^{-34}\,\mathrm{J\,Hz^{-1}}$
R	gas constant	$8.314\,\mathrm{J\,K^{-1}\,mol}$
σ_{SB}	constant of Stefan-Boltzmann	$5.670 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$
σ_e	Thomson crossection of an electron	$6.652 \times 10^{-29}\,\mathrm{m^2}$
$T_\odot$	effective temperature of the sun	$5778\,\mathrm{K}$

Units

Notation	Description	Unit
	Ångström	$10^{-10}\,\mathrm{m}$
$'$	arcminute	$\frac{1}{60}\,^\circ$

Notation	Description	Unit
$''$	arcsecond	$\frac{1}{3600}{}^\circ$
AU	astronomical unit	1.496×10^{11} m
ρ	density	kg m^{-3}
eV	electronvolt	1.602×10^{-19} J
F	flux	J s^{-1} m^{-2}
Gyr	billion years (gigayear)	1×10^{9} year
$L_\odot$	solar luminosity	3.828×10^{26} J s^{-1}
L	luminosity	J s^{-1}
mas	milliarcsecond	$0.001''$
$M_\oplus$	Earth mass	5.972×10^{24} kg
M_J	Jupiter mass	1.898×10^{27} kg
$M_\odot$	solar mass	1.988×10^{30} kg
κ	opacity	m^2 kg^{-1}
pc	parsec	3.086×10^{16} m
I	intensity	J s^{-1} m^{-2} sr^{-1}
$R_\oplus$	Earth radius	6.378×10^{6} m
R_J	Jupiter radius	7.149×10^{7} m
$R_\odot$	solar radius	6.957×10^{8} m
F_λ	spectral flux	J s^{-1} m^{-3}
F_ν	spectral flux	J s^{-1} Hz^{-1} m^{-2}
I_λ	specific intensity	J s^{-1}m^{-3} sr^{-1}
I_ν	specific intensity	J s^{-1} Hz^{-1} m^{-2} sr^{-1}

Formulae

1. **Solid Angle (Ω):**
$$\Omega = 2\pi\left(1 - \cos\theta\right)$$
where θ is the angle subtended at the center.

2. **Energy Density (u):**
$$u = \frac{E_{sr}}{A}$$
where E_{sr} is the energy steradian and A is the area.

3. **Energy Steradian (E_{sr}):**
$$E_{sr} = \frac{E_{\text{Total}}}{\Omega}$$
where E_{Total} is the total energy and Ω is the solid angle.

4. **Stefan-Boltzmann Law (Power radiated per unit area):**
$$P = \sigma T^4$$
where P is the power radiated per unit area, σ is the Stefan-Boltzmann constant, and T is the absolute temperature.

5. **Gravitational Force (F_{Grav}):**
$$F_{\text{Grav}} = \frac{G m_1 m_2}{r^2}$$
where G is the gravitational constant, m_1 and m_2 are the masses, and r is the distance between the two objects.

6. **Snell's Law:**
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
where n_1 and n_2 are the refractive indices of the two media, and θ_1 and θ_2 are the angles of incidence and refraction.

7. **Refractive Index Law (related to distances):**

$$d_1 n_1 = d_2 n_2$$

where d_1 and d_2 are the distances traveled in the respective media, and n_1 and n_2 are the refractive indices.

8. **Lens Formula:**

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

where f is the focal length, v is the image distance, and u is the object distance.

9. **Lens Power Formula:**

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where R_1 and R_2 are the radii of the surfaces of the lens, and n is the refractive index of the lens material.

10. **Schwarzschild Radius (R_s):**

$$R_s = \frac{2GM}{c^2}$$

where R_s is the Schwarzschild radius, G is the gravitational constant, M is the mass of the object, and c is the speed of light.

11. **Relativistic Doppler Shift:**

$$f' = f\sqrt{\frac{1 + v_d/c}{1 - v_d/c}}$$

where f' is the observed frequency, f is the emitted frequency, v_d is the velocity of the source, and c is the speed of light.

1. Hello there

Darth Vader, the formidable Sith Lord, commands the Executor, a Super Star Destroyer capable of interstellar travel at near-light speeds. In pursuit of a rebel fleet, Vader orders the ship to a region near a binary star system, where one of the stars is a neutron star emitting intense X-ray radiation. While positioning the Executor for battle, sensors detect an impending gamma-ray burst (GRB) originating from the neutron star's magnetic poles.

Figure 1.1: *Anakin Skywalker was a Jedi Knight who fell to the dark side of the Force, becoming the Sith Lord Darth Vader*

Despite the warning, Vader remains unyielding, confident in the Empire's advanced shielding technology. However, the gamma-ray burst's energy levels are unlike any previously recorded, threatening to disrupt the ship's power and communication systems. The Imperial scientists aboard scramble to calculate the potential energy impact and advise on defensive maneuvers.

1.1 Given that the gamma-ray burst emits energy at 10^{45} Joules in a narrow beam spanning 5 degrees, calculate the energy density that would hit the Executor if it were located 0.5 light-years away from the burst's source. Assume no energy dissipation over distance for simplicity.

1.2 Describe the physical phenomena that the crew might experience due to the GRB's interaction with the ship's electromagnetic shielding. What key properties of the burst could pose the greatest threat?

1.3 Assume the GRB alters the gravitational field of the neutron star momentarily, creating a space-time distortion. How could this distortion affect the Executor's trajectory and communication systems? Outline a strategic plan that Darth Vader could use to navigate through this unexpected cosmic event and maintain fleet coordination.

2. Aptitude

2.1 At what time after 4pm is the minute's hand of a clock exactly aligned with the hour's hand?

2.2 A shopkeeper sold a T.V set for Rs. 17,940 with a discount of 8 percent and earned a profit of 19.6 percent. What would have been the percentage of profit earned if no discount was offered?

2.3 A company offered its 350 employees a bonus of Rs 10 to each senior and Rs 8.15 to each junior. All the juniors accepted but a certain percentage of seniors refused to accept. The total bonus paid was independent of the number of seniors. What was the total amount paid to the juniors (in rupees)?

2.4 If $100^{48} = x$, $100^{70} = y$ and $x^z = y^2$, then the value of z is close to
(a) 1.45 (b) 1.88 (c) 2.9 (d) 3.7

2.5 A boat can travel with a speed of 13 km/hr in still water. If the speed of the stream is 4 km/hr, find the time taken by the boat to go 68 km downstream.

3. Technical

3.1 You may be familiar with the analogy between the electrostatic field theory and the gravitational field theory. For example, both Coulomb's law and Newton's Law both relate force and distance in a similar fashion.

$$F \propto \frac{1}{r^2}$$

3.1.1 The electrostatic theory deals with two kinds of charges whereas the gravitational field theory deals with mass only. With that being said, which of the two theories involve more complexity. State the reason for your assumption.

OR

3.1.2 The term "linear" in context of field theories means that the system obeys the principle of superposition (combined effect of multiple sources is simply the sum of their individual effects). The gravitational field theory is said to be less linear than the electrostatic field theory. What could be the reason(s)?

3.2 The simplified optical diagram of an arm of a binocular can be considered as a telescope, which consists of two lenses of focal lengths f_1 = 25 cm (objective) and f_2 = 5 cm (eyepiece). The normal observer's eye is intended to be relaxed and the nominal focal length of the eye lens is taken to be f_o = 40 mm. The first prism is placed 5 cm away from the objective and the two prisms are separated by 2 cm.

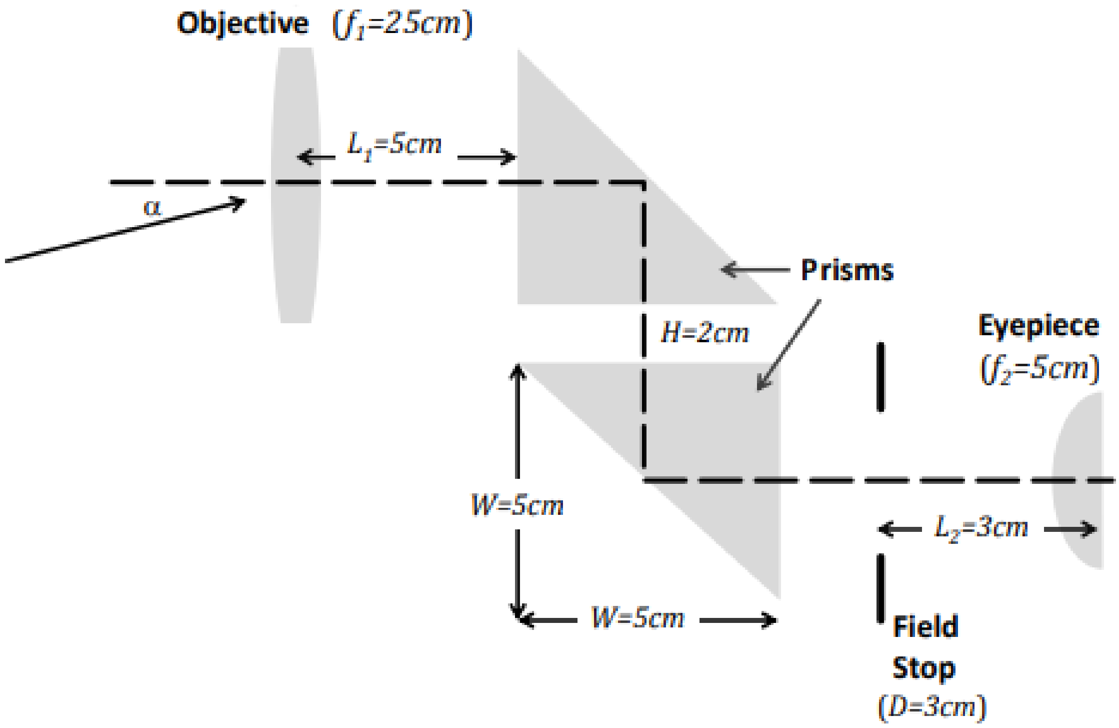


Figure 3.1: *Image for reference*

3.2.1 In order to make the binocular compact, a pair of 45o prisms (5cm wide) are used, each of them is designed for total internal reflection of incoming rays. Estimate the index of refraction needed to meet such a requirement under paraxial beam approximation.

3.2.2 Estimate the distance from the eyepiece to the back side of the second prism. **(Assume the index of refraction of both prisms is 1.5.)**

4 . Bonus Questions

4.1 Radio Division

Imagine you're a scientist working with a cutting-edge radio telescope, confidently listening to the whispers of the cosmos. One day, you detect a signal at a frequency of 1.42 GHz, which corresponds to the well-known 21 cm hydrogen line. It's a reliable frequency, often used in radio astronomy to study distant galaxies. But just when you think everything is straightforward, your telescope surprises you by picking up two additional frequencies: 1.22 GHz and 1.62 GHz. At first, you suspect these signals might be coming from two separate stars in different regions of space. However, after further analysis, you make a startling discovery: both frequencies are coming from the same star. And that star? Betelgeuse—one of the most famous red supergiants in the constellation Orion, located about 640 light years away from Earth.

Betelgeuse is not your average star. It's known for its periodic fluctuations in brightness, and astronomers have long predicted that it could go supernova soon. This massive, evolving star spins at incredibly high speeds, contributing to the complex nature of its light emissions. As you continue to investigate, you realize that Betelgeuse's dynamic behavior is responsible for these unusual frequency shifts.

4.1.1 Calculate the shifts of the two frequencies received, and also comment on whether they are red or blue shifted . (take the speed of light, $c = 3 \times 10^8$ m/s)

4.1.2 In not more than two lines, explain how a single source, like Betelgeuse, might emit two different frequencies at the same time.

4.1.3 After calculating the rotation speed of Betelgeuse using Doppler shifts, you and your team obtain unusually high values for its rotational velocity. Given this result, what is your assessment of the star's rotation speed? Is it physically plausible for Betelgeuse to have such a high rotational velocity, considering the constraints of normal physics? Could there be an explanation for this finding, or is something being overlooked? Provide your reasoning and support your answer.

4.2 Optical Division

Imagine you stumbled upon a genie while stargazing one night. He offers you a single wish, and naturally, you wish for immortality—not because you're afraid of dying, but because you can't bear the thought of missing a single moment of the sky's wonders. Fast forward a few centuries, and you're now the ultimate celestial observer, cataloging every new discovery the universe has to offer.

One night, you spot something exciting: a new star, bright and beautiful, just born in the depths of space! You rush to document it, setting up your best telescope for a closer look. But—oh no!—just a few days later, the star vanishes without a trace. You wonder if it was a cosmic illusion, but you continue to watch, because, well, you've got all the time in the world.

Decades pass. And then, 65 years later, you're gazing through your telescope when you spot the same star, bright as ever, in the exact same spot where you first saw it. The universe is full of mysteries, and this one has a story to tell. This time you also notice a nearby star near to this new star which you are documenting currently.

4.2.1 What astronomical phenomenon could explain the reappearance of the same star after 65 years of apparent absence?

4.2.2 In what ways might the nearby star you observe affect the new star you're documenting? Could their proximity have any impact on the star's visibility or behavior, and if so, how?

4.2.3 Over large timescales, how might the intervals between appearances of the new star evolve? Would you expect these intervals to increase or decrease, and what factors in astrophysics could cause such a change?

4.2.4 Given the rare and unusual nature of this phenomenon, what do you think will be the eventual outcome of this star's behavior? What cosmic events or changes might bring an end to this cycle?

4.3 DDA division

As the Mission Director of an interplanetary mission, you're overseeing the spacecraft's flyby of a lesser-known moon orbiting Saturn. The team is operating in a calm, controlled environment, gathering routine data on its surface composition, temperature, and icy features. Everything is going smoothly, and you're sipping your coffee, confident the mission is proceeding just as planned.

But suddenly, a notification pops up on your screen— *the magnetic field readings have spiked.* It's not supposed to happen. At first, you chalk it up to a sensor glitch or a stray cosmic ray, but the readings persist. This moon, previously thought to have little to no magnetic activity, is showing signs of a magnetic field. A strong one at that.

The room falls silent for a moment. The science team starts cross-referencing the data, re-checking the readings. Could it be? Magnetic fields often signal something substantial underneath the surface—maybe an underground ocean, or active geological processes. The possibilities are astounding. This unexpected discovery could indicate that this seemingly quiet moon is hiding a world of secrets beneath its icy crust—secrets that could even suggest the potential for life-supporting conditions.

As the mission director, what steps would you take next after discovering the magnetic anomaly on the moon? What types of data would you prioritize your team to collect in order to assess the moon's potential for supporting life, ensuring your approach remains scientifically sound and realistic?

4.4 Research Division

Black holes are some of the most fascinating and mind-bending objects in the cosmos. The very thing that characterizes a black hole also makes it hard to study: its intense gravity. All the mass in a black hole is concentrated in a tiny region, surrounded by a boundary called the "event horizon". Nothing that crosses that boundary can return to the outside universe, not even light. A black hole itself is invisible.But astronomers can still observe black holes indirectly

4.4.1 How are they observed ?

4.4.2 What is the event horizon and what are its main characteristics ?

5. Answer Booklet

1.1 Energy Density Calculation

The solid angle is:

$$\Omega = 2\pi\,(1 - \cos(\theta))$$

The energy density is:

$$u = \frac{E_{\text{total}}}{\Omega \times \text{Surface Area}} = 1.5 \times 10^{13}\ \text{J/m}^2$$

1.2 Potential Hazards from Electromagnetic Overload

The following are key hazards that may arise from electromagnetic overload:

- **Electromagnetic Overload**: The extreme energy density would likely saturate the shielding systems, causing partial failures. This could manifest as arcing and energy surges that disrupt onboard electronic systems.
- **Radiation Hazard**: High-energy gamma rays would induce secondary particle cascades in the shielding, potentially exposing the crew to dangerous levels of ionizing radiation.
- **Thermal Effects**: Absorbed energy could cause localized heating of the ship's hull, leading to structural stress or material degradation.

1.3 Impact of Momentary Gravitational Field Change Due to GRB

A momentary gravitational field change due to the GRB would impact the following:

- **Trajectory Disruption**: The distortion could alter the course of the Executor by warping the local space-time fabric, potentially shifting the ship's trajectory unpredictably.
- **Communication Delays**: Changes in the space-time curvature could lead to signal time dilation or deflection, affecting the coherence and timing of transmitted communications.

- **Navigation Challenges**: Instruments relying on stable gravitational references would experience errors, complicating navigation efforts.

To mitigate these effects, the following actions would be taken:

- **Reorientation Protocol**: Darth Vader could order the ship to immediately reorient to reduce exposure to the incoming GRB beam, positioning the most shielded part of the ship toward the source.
- **Radiation Protection Protocol**: Initiate radiation protection protocols, including securing crew members in shielded compartments and minimizing non-essential electronic operations.
- **Communication Protocol**: Use low-frequency, resilient radio waves to maintain communication, ensuring signal redundancy through relay points unaffected by the immediate GRB impact.

2.1 Clock Hands Alignment at 4:00 PM

A clock has 12 hours equivalent to 360 degrees, so each hour corresponds to 30 degrees. At 4:00 PM, the hour hand is at 120 degrees (since $4 \times 30^\circ = 120^\circ$). The hour hand moves 0.5 degrees per minute (since 30° is covered in 60 minutes). The minute hand moves 6 degrees per minute (since 360° is covered in 60 minutes)

Position of the hour hand: At 4:00 PM, the hour hand starts at 120 degrees, so after t minutes, its position is:

$$\text{Position of hour hand} = 120 + 0.5t$$

Position of the minute hand: At 4:00 PM, the minute hand starts at 0 degrees, so after t minutes, its position is:

$$\text{Position of minute hand} = 6t$$

Condition for alignment: For the hands to align, the positions of the hour and minute hands must be equal:

$$120 + 0.5t = 6t$$

Solving for t:

$$120 = 5.5t$$
$$t = \frac{120}{5.5} \approx 21.81 \text{ minutes}$$

This is approximately 21 minutes and 48 seconds. Thus, both hands align exactly at 4:21:48 PM.

2.2 Cost Price and Profit Calculation

We are given:

- Selling price after discount: Rs. 17,940.
- Discount: 8%, so the selling price before discount is higher.
- Profit: 19.6%.

Let the marked price be M and the cost price be C. Since the selling price after discount is 92% of the marked price:

$$M \times 0.92 = 17,940 \quad \Rightarrow \quad M = \frac{17,940}{0.92} = 19,500$$

The marked price is Rs. 19,500. The selling price is 119.6% of the cost price:

$$C \times 1.196 = 17,940 \quad \Rightarrow \quad C = \frac{17,940}{1.196} = 15,000$$

The cost price is Rs. 15,000. If no discount were given, the selling price would have been the marked price, i.e., Rs. 19,500. The profit percentage is:

$$\text{Profit Percentage} = \frac{19,500 - 15,000}{15,000} \times 100 = 30\%$$

Thus, if no discount had been offered, the profit would have been 30%.

2.3 Calculation of Total Bonus Paid to Juniors

We are given the following information:

- The total number of employees is 350.
- The bonus amount for each junior is Rs 8.15.

Let the number of seniors be s and the number of juniors be j. The total number of employees is the sum of seniors and juniors:

$$s + j = 350$$

We are tasked with calculating the total bonus paid to the juniors. The total bonus paid to the juniors is given by:

$$\text{Total amount paid to juniors} = j \times 8.15$$

Since the total bonus paid is independent of the number of seniors, the total bonus paid to juniors only depends on the number of juniors and the bonus per junior. We are told that the number of juniors is 175. Therefore, the total amount paid to the juniors is:

$$175 \times 8.15 = 1426.25$$

Thus, the total bonus paid to the juniors is Rs 1426.25.

2.4 Calculation of z

We are given $100^{48} = x$, $100^{70} = y$, and $x^z = y^2$.
Express x and y as powers of 10:

$$x = 100^{48} = 10^{96}, \quad y = 100^{70} = 10^{140}.$$

Substitute into $x^z = y^2$:

$$(10^{96})^z = (10^{140})^2 \quad \Rightarrow \quad 10^{96z} = 10^{280}.$$

Equating exponents:

$$96z = 280 \quad \Rightarrow \quad z = \frac{280}{96} = \frac{35}{12} \approx 2.9.$$

Thus, the value of z is approximately 2.9.
The correct answer is $\boxed{(c)\,2.9}$.

2.5 Boat's Downstream Journey Time Calculation

Given: - The still water speed of the boat is 13 km/hr. - The speed of the stream is 4 km/hr.

The actual speed of the boat downstream is the sum of the still water speed and the stream speed:

$$\text{Downstream speed} = 13 + 4 = 17 \text{ km/hr}$$

The distance to travel downstream is 68 km. The time taken to travel this distance is given by:

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}} = \frac{68 \text{ km}}{17 \text{ km/hr}} = 4 \text{ hrs}$$

Thus, the time taken to travel 68 km downstream is 4 hours.

3.1 Comparison of Gravitational and Electrostatic Field Theories (For both 3.1.1 and 3.1.2)

The gravitational field theory is more complex than electrostatic theory due to its inherent non-linearity. While electrostatics deals with two types of charges (positive and negative), gravity only involves mass, which is always positive. This might seem simpler, but the real complexity of gravity arises from its interaction with spacetime itself.

In electrostatics, the forces between charges are linear, meaning that the force between two charges can be predicted by simple addition when a third charge is introduced. However, gravity behaves differently because of the curvature of spacetime. According to Einstein's General Theory of Relativity, massive objects

like stars and planets bend the fabric of spacetime around them, and this curvature is what we perceive as gravity.
In Einstein's theory, gravity is not just a force between masses; it's the result of how mass and energy influence spacetime. This leads to increased complexity:

$$\text{Einstein's equations:} \quad G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

where $G_{\mu\nu}$ describes spacetime curvature and $T_{\mu\nu}$ represents the energy-momentum tensor. Mass and energy curve spacetime, and this curvature dictates how objects move.

Unlike electrostatic fields, where only charges generate forces, gravity is self-interacting. Gravitational energy contributes to the gravitational field itself. As Einstein suggested, any energy stored in the gravitational field acts like mass, further bending spacetime. This leads to what could be called "fieldlets"—tiny gravitational fields created by gravitational energy, which interact with each other in a feedback loop, making the equations governing gravity non-linear.

Thus, while electrostatic fields are governed by linear equations, making them easier to solve and predict, gravitational fields follow non-linear equations, accounting for spacetime curvature. This non-linearity makes gravitational field theory much more complex, particularly in systems with strong gravitational fields like black holes or neutron stars.

3.2 Binoculars Optics Calculation

3.2.1 Refractive Index of the Prism

In the case of binoculars, rays from a sufficiently far distance are assumed to be parallel when they reach the lens. The lens converges these rays, and the resulting rays strike the prism at different angles.
To calculate the refractive index of the prism, we can use Snell's Law at the interface of the prism. However, since the incoming angle after passing through the lens is not given, we approximate the incident angle as $45°$.
Using Snell's Law:

$$n_{\text{prism}} \sin 45^\circ = 1 \sin 90^\circ$$

$$n_{\text{prism}} \times \frac{1}{\sqrt{2}} = 1 \quad \Rightarrow \quad n_{\text{prism}} = \sqrt{2} \approx 1.41$$

Thus, the refractive index of the glass is approximately 1.4.

3.2.2 Optical Path Length Calculation for Binoculars

The purpose of the prisms in binoculars is to reduce the focal distance of the image as seen through the eyepiece. To estimate the distance from the backside of Prism 2 to the eyepiece, we need to calculate the optical path length (OPL) of the rays exiting Prism 2.

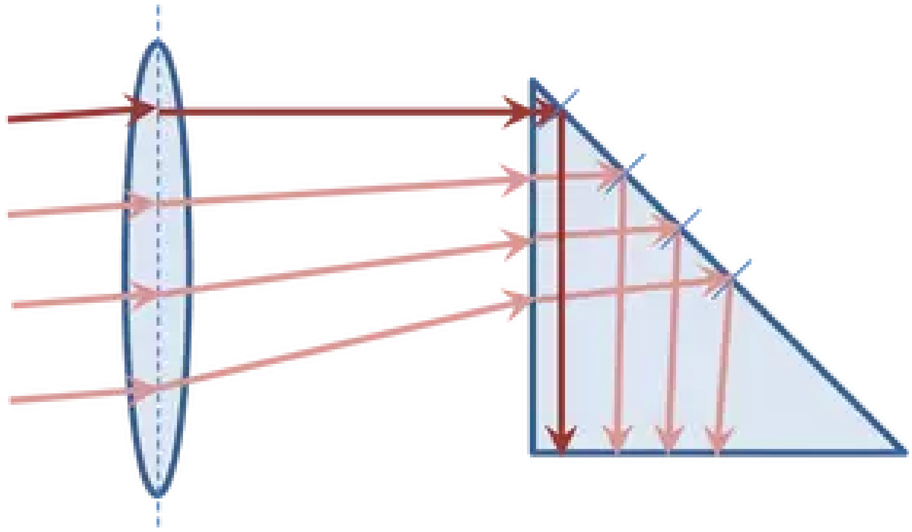


Figure 5.1: image for reference

To match the optical path length that light takes in the binocular system with the focal length of the eyepiece, we need to convert the path through the prisms into an equivalent optical path through air. This adjustment ensures that the entire path in the binocular system is considered as if it occurs in air along the optical axis.
The optical path length in air OPL_{air} is related to the optical path length in the prism as follows:

$$OPL_{\text{air}} = OPL_{\text{prism}} \quad \Rightarrow \quad d_{\text{air}} n_{\text{air}} = d_{\text{prism}} n_{\text{prism}}$$

Given the following: - $d_{\text{air}} = 5\,\text{cm}$ - $n_{\text{air}} = 1$ - $n_{\text{prism}} = 1.5$
We calculate the equivalent distance of the path through the prism:

$$5 \times 1 = d_{\text{prism}} \times 1.5 \quad \Rightarrow \quad d_{\text{prism}} = \frac{5}{1.5} = \frac{10}{3}\,\text{cm}$$

The total optical path length from the objective lens to the focal plane along the binocular system is:

$$OPL = L_1 + d_{\text{prism}} + H + d_{\text{prism}} + D$$

where: - L_1 is the distance from the objective lens to Prism 1 - H is the distance between the prisms - D is the distance from Prism 2 to the focal plane
For a prism index of 1.5, the equivalent optical path length is:

$$OPL = 5 + \frac{10}{3} + 2 + \frac{10}{3} + D = \frac{41}{3} + D$$

Now, we equate this to the focal length of the objective lens, which is 25 cm:

$$\frac{41}{3} + D = 25$$

Solving for D:

$$D = 25 - \frac{41}{3} = \frac{75}{3} - \frac{41}{3} = \frac{34}{3} \approx 11.33\,\text{cm}$$

Thus, the distance from Prism 2 to the focal plane is approximately 11.33 cm.

4.1 Radio Division

4.1.1 Blueshift of Radio Signal

The signal with a frequency of 1.62 GHz is blueshifted relative to its original frequency. The higher frequency indicates that the source of the signal is moving toward the observer, as observed in the blueshift phenomenon.

4.1.2 Doppler Shifts in Betelgeuse's Atmosphere

The complex atmosphere of Betelgeuse, characterized by large-scale convection cells and rapid rotation, can result in regions moving toward and away from the observer simultaneously. This motion creates Doppler shifts that lead to both red- and blue-shifted frequencies observed from the same star. The varying velocities within the star's atmosphere cause different parts of the star to shift in different directions relative to the observer, resulting in a combination of red and blue shifts.

4.1.3 Instability of Betelgeuse Due to High Rotation Velocity

If Betelgeuse were rotating at an unusually high velocity beyond certain physical limits, it would become unstable. For a star as massive and expanded as Betelgeuse— with a radius approximately 1,000 times that of the Sun— extreme rotational speeds could cause the star to exceed the centrifugal limit. This would lead to significant consequences, such as the ejection of parts of its outer layers, destabilizing the star's structure.

4.2 Optical Division

4.2.1 Possible Explanations for the Observed Phenomenon

Eclipsing Binary Star System: This could involve a binary system where one star periodically eclipses the other from Earth's viewpoint. As a result, the observed star's brightness would vary over time as the stars pass in front of each other.
Pulsating Variable Star: A pulsating variable star undergoes changes in brightness over long periods, often due to periodic expansion and contraction of the star's outer layers, resulting in fluctuating luminosity.
Gravitational Lensing: If a massive object, such as a black hole or another dense star, passed between the observed star and Earth, it could cause gravitational lensing effects. These effects can distort the light from the distant star, causing temporary variations in its observed brightness. the observer, as observed in the blueshift phenomenon.

4.2.2 Gravitational Interaction and Mass Transfer in Close Binary Systems

If the stars in a binary system are close enough, their gravitational interaction can lead to tidal forces that affect their shape and behavior. These forces can cause increased activity and mass transfer between the stars. If one of the stars is a compact object, such as a white dwarf or neutron star, and the other star is in close proximity, material can be transferred from the normal star to the compact object. This process can create phenomena such as novae or X-ray bursts, leading to periods of sudden brightness followed by dimming as the accretion process stabilizes.

4.2.3 Effects of Tidal Forces and Mass Transfer on Orbital Period

Tidal forces, gravitational interactions, or mass loss can alter the orbital period of a binary star system over time. For instance, mass loss from the system could cause the stars to drift apart, resulting in a lengthening of the period between eclipses. On the other hand, if the stars are transferring mass, orbital decay could lead to shorter intervals as they spiral closer together.

4.2.4 Possible Outcomes of Close Binary Star Interactions

Merger Event: If the stars are on a collision course due to gradual orbital decay, they could eventually merge. This would likely result in a dramatic event such as a stellar merger, producing a luminous burst and possibly forming a new, more massive star or even an exotic object like a black hole.
Supernova Explosion: If one of the stars is a massive, aging star, it could end in a supernova explosion. This would disrupt the system permanently, leaving behind a neutron star or black hole, and potentially dispersing any companion stars in the system.
Stability or Quiescence: In some cases, the interactions between the stars may stabilize over time, leading to a more predictable, less dramatic system. The stars might move far enough apart or shed enough mass that they no longer significantly impact each other, resulting in a quieter, more stable orbital arrangement.

4.3 DDA division

1. Verify Instrument Accuracy: Ensure that the magnetic field readings are not due to instrument error. Confirm calibration and functionality of the instruments to rule out measurement inaccuracies.
2. Cross-Check with Other Data: Verify the anomaly using available data from other sources (e.g., spacecraft sensors, remote observations) and rule out external factors that could influence the magnetic readings.
3. Adjust Mission Plan for Prolonged Observation: Modify the mission trajectory to prioritize flybys or orbit changes that allow for prolonged observation of the magnetic region. This will provide more time for accurate measurements.
4. Initiate Priority Data Collections:

- **Salinity and Conductivity Measurements:** Measure salinity and conductivity levels to identify potential briny water, which could be essential for maintaining liquid water under icy crusts.
- **Organic Molecule Detection:** Deploy instruments capable of detecting complex carbon-based molecules or signs of chemical interactions typically associated with biological processes.
- **Heat Source Identification:** Look for localized heat sources that could maintain liquid water and support chemical reactions conducive to life.
- **Surface and Subsurface Structure Analysis:** Investigate any formations indicative of tectonic or cryovolcanic activity, which could create an environment suitable for extremophiles.

4.4 Research Division

Black holes can be observed indirectly by studying the effects of gravity on nearby stars, how gravity pulls matter into orbits, and by observing how light emitted by surrounding matter does not cross the event horizon. The Event Horizon Telescope (EHT) produced the first images of the black holes at the centers of both the M87 galaxy and the Milky Way.

The Event Horizon: The event horizon is often referred to as the "point of no return" around a black hole. It is not a physical surface, but rather a spherical boundary surrounding the black hole where the escape velocity equals the speed of light. The radius of this boundary is known as the Schwarzschild radius. Once matter crosses the event horizon, it is drawn inexorably toward the center of the black hole.
Due to the intense gravitational forces, matter that falls inside the event horizon is compressed to an extremely small point with an infinitely high density, known as the **singularity**. This singularity represents a state where the laws of physics as we understand them likely break down, making it one of the most mysterious and extreme objects in the universe.