

AC2023 Post Mortem

Presented by AC2023 QMs

“Its not about how we make mistakes, but how we correct them.” -- KY

1. Introductions

The AC2023 Family

AC committee

Chairman: Chong Ka Shing (NTUAS)

Deputy Chairman: Yong Fu Hsien (NUSAS)

NUSAS Vice President: Wang Mingchuan

AC QM Community

Head Question Master: Janani Ramachandran (NUSAS)

Deputy Head Question Master: Fredrik Hanson (NTUAS)

Department Heads

Publicity: Nicholas Tan

Head of Administration: Mohamad Hirwan

Deputy Head of Admin: Celeste Ang

Head of Logistics: Troy Tim

Head of Finance: Muhammad Tawakul

AC QM Community

OIC Project: Nicholas Phung-Zhang

OIC Observation: Wang Mingchuan

OIC Teams Round: Fong Ken Rui

OIC Individual Round: Fredrik Hanson

OIC Finals: Trakantannarong (Golf)

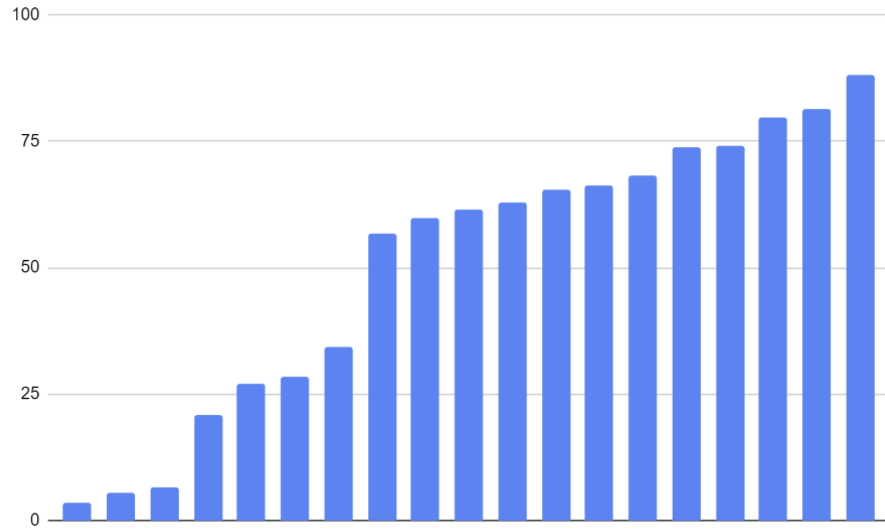
QMs: Lim Kia Yee, Wan Si Chen, Lim Tse Xiong Brendan, Jerry Qu, Lew Choon Hean, Tham Kai Wen, Benjamin Luo

AND ALL THE QUESTION MASTERS !!

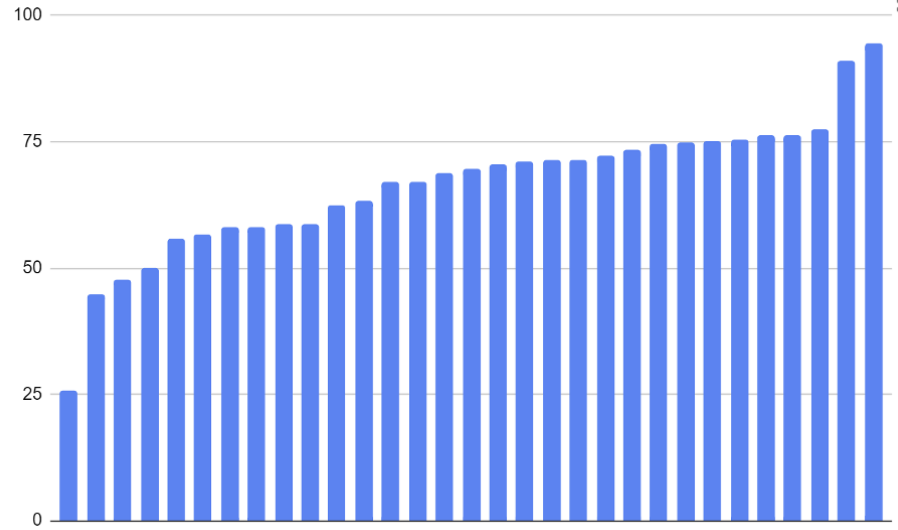


2. Project Round

Junior Distribution



Senior Distribution



Things to note

Citations:

People did not submit citations.

Late:

Quite a few. Teams have been penalized accordingly

Accuracy:

Please make sure that you know the topic at hand and not start smoking.

Other Issues:

Teamwork: one team only had one person for project

Size of the poster

Good projects

The best for Junior RI/2

KEPLER-1658B

ABOUT
Kepler-1658b is a gas planet that was discovered in 2019. It is larger than Earth, with a mass of 5.88 Jupiters and a radius of 1.07 Jupiters. However, it's short orbital radius of 0.0544 AU means that it completes an orbit in only 3.8 days!

ASTROING EXOPLANET!
Kepler-1658b has been observed to have a decreasing orbital period (as detected by its transits), this "dipped" exoplanet will gradually spiral towards its star, reducing its mass than 3 million years. A 2022 scientific study attributed this phenomenon to tidal decay of Kepler-1658b's orbit, with its star's gravitational pull lagging on the planet, causing the inward spiral of Kepler-1658b.

Kepler-1658b

EXOPLANETS part ii

55 CANCRI E

ABOUT
55 Cancri e is a Super Earth with radius 1.875 times of Earth but with a mass 7.99 times of Earth. It orbits a star named Copernicus, 41 light years away from Earth. With an orbital distance of 0.024 AU, it completes an orbit in 0.7 days. Its close distance to its star means that temperatures are really high (as high as 2300 °C). No wonder it has a molten surface, looking suspiciously like lava....

55 Cancri e

DISPUTED NATURE
In 2016, scientists studied data from NASA's Spitzer Space Telescope and speculated that lava would flow freely on the night side (due to the scorching temperatures) and remain hardened on the other side. However, recent analysis has debunked this theory because 55 Cancri e's atmosphere would hide the lava from our view. Instead, scientists are researching and debating the true nature of 55 Cancri e. Does it have an atmosphere? How similar to Earth? Is it a carbon-rich world? Some scientists even speculate it could contain nitrogen, water and oxygen. We can only wait to find out.

2021 LATEST DISCOVERY
From 2017 to 2022, a large group of scientists collectively worked on analyzing K2's light curves as well as data from the Kepler-Transiting Exoplanet Survey Satellite. Working together as a team, they ruled out false positives and came to the safe conclusion that K2-415b is a planet and that it is worth investigating as an Earth-like planet.

K2-415b

EXOPLANET DETECTION
without using google maps

#1 DOPPLER SPECTROSCOPY
Gravity of a planet can cause its star to "wobble" as it orbits slowly. Measuring the Doppler shift can tell us more about the exoplanet.

1036 PLANETS DETECTED

#2 TRANSIT PHOTOMETRY
Planets transit across their star during orbit. We can determine the planet's size and orbital period by measuring the drop in starlight.

3986 PLANETS DETECTED

#3 GRAVITATIONAL MICROLENSING
Light from a solar system is bent by a massive object and magnified.

187 PLANETS DETECTED

#4 DIRECT IMAGING
iPhone 100 pro max.

66 PLANETS DETECTED

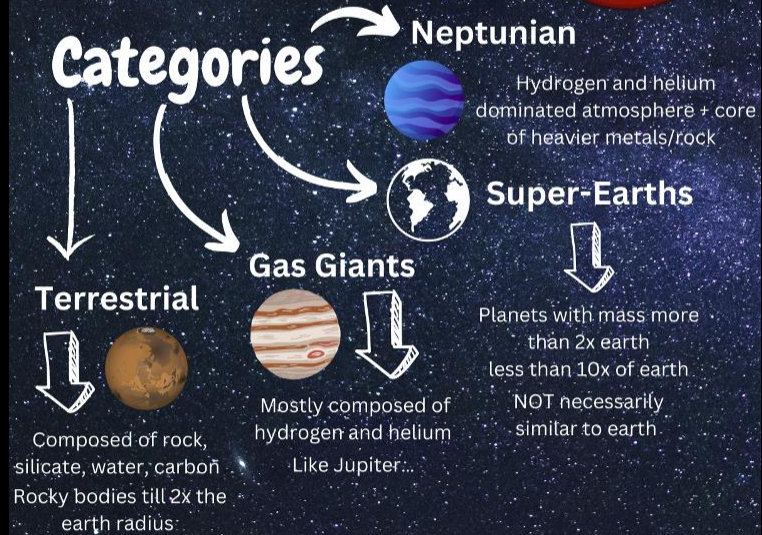
WHAT ARE EXOPLANETS?

DEFINITION

Any planet outside our solar system



Categories



TERRESTRIAL TRAPPIST-1B



GAS GIANT TRES-4B



SUPER EARTH OLIESE 1214 B















NEPTUNIAN HAT-P-26B



Good projects

Junior Honorable Mention NY/1

a brief tour/introduction to Singapore's night sky [8-10pm]

<p>jan perseus [late jan]</p> 	<p>feb fauces [early feb] auriga, orion [mid feb]</p> 	<p>mar canis major, gemini [early mar] canis minor [mid mar]</p> 	<p>apr canis, vela, puppis [early apr] lyrids [mid apr]</p> 
<p>may ete apparido [early may] ursa major, leo [early may]</p> 	<p>jun virgo [early jun] bootes, centaurus, crux [mid jun]</p> 	<p>jul lycus [mid jul]</p> 	<p>aug ophiuchus, scorpius [early aug]</p> 
<p>sep sagittarius [early sep] aquila, lyra [mid sep] cygnus [late sep]</p> 	<p>oct northern faucons [mid oct] orionids [late oct] grus, avianus [late oct]</p> 	<p>nov southern faucons [early nov] foonsids [mid nov] pegasus [mid nov]</p> 	<p>dec geminiids [mid dec] andromeda, aries [mid dec]</p> 

legend [colour-coded]
when local concentration is highest above the horizon
meteor showers

1 [iPhone 12 mini Apr 21 2023 09:14 Bukit Timah]
2 [iPhone 12 May 12 2023 Macpherson]
3 [iPhone 12 May 22 2023 Macpherson]

4 [iPhone 12 mini May 13 2023 05:40 Woodlands]
5 [iPhone 12 mini Apr 26 2023 04:21 Woodlands]
6 [iPhone 12 mini May 11 05:33 Woodlands]

i can't see it, but can i take it?

—is a general rule on a good day stars below magnitude 5.0 can be photographed with your average phone camera, if you're lucky magnitude 6 is also achievable

- use long exposure [min 3s] and tinker with contrast, brightness and exposure for editing
- hand must be steady for long exposure otherwise shot might be blurry
- also remember to focus your camera [on the stars] first, you need not check every star usually as long as one star is focused the rest should be fine

some DSOs

*DSOs or deep sky objects include nebulae, galaxies, open and globular clusters



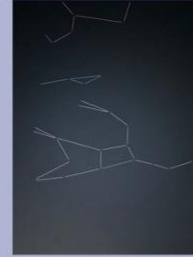
a brief tour/introduction to Singapore's night sky [8-10pm]

spring [apr-jun]

visible spring constellations:
coma berenices, corona borealis, leo, bootes, virgo, corvus

visible circumpolar constellations:
[northern] ursa major
[southern] centaurus, crux, carina, vela

other visible constellations:
[winter] canis major, canis minor, orion, gemini, faurus, auriga, puppis
[summer] ophiuchus, scorpius, lyra, cygnus, aquila, sagittarius, corona australis



[iPhone 11 Mar 28 2023 11:26pm Macpherson - Ursa Major (white), Leo (pink), Leo Minor (blue)]

other visible stars:
cor caroli [Canes venatici], delta crateris [Crater], alphard [Hydra]

visible clusters/DSOs:
coma star cluster [Coma berenices], orion nebula [Orion], pleiades [Taurus], omega centauri [Centaurus], carina nebula [Carina]

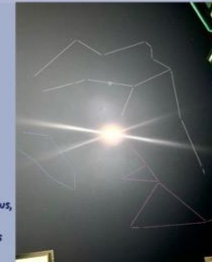
non-visible but photographable constellations:
crater, hydra, columba, lepus, pyxis, leo minor, libra, serpens, canes venatici

autumn [oct-dec]

visible autumn constellations:
pegasus, andromeda, aries

visible circumpolar constellations:
[northern] cassiopeia, perseus
[southern] grus

other visible constellations:
[summer] ophiuchus, scorpius, lyra, cygnus, aquila, sagittarius, corona australis
[winter] orion, faurus, canis major, canis minor, auriga, gemini



[iPhone 12 mini May 13 2023 05:40 Woodlands - Aquarius (white), Capricornus (pink), Piscis Austrinus (blue), Saturn (circled)]

other visible stars:
fomalhaut [Piscis austrinus], diphda & menkar [Cetus], alderamin [Cepheus]

visible clusters/DSOs:
andromeda galaxy [Andromeda], double cluster [Cassiopeia], ptolemy cluster [Scorpius]

non-visible but photographable constellations:
capricornus, aquarius, cepheus, piscis austrinus, phoenix, cetus, telescopium

summer [jul-sep]

visible summer constellations:
lyra, cygnus, aquila, scorpius, libra, ophiuchus, sagittarius, corona australis, hercules

visible circumpolar constellations:
[northern] perseus, cassiopeia, ursa major
[southern] lepus, grus, ara, crux, centaurus

other visible constellations:
[spring] virgo, corvus, bootes, coma berenices, leo, corona borealis
[autumn] pegasus, andromeda, aquarius

other visible stars:
fomalhaut [Piscis austrinus], diphda & menkar [Cetus], peacock [Pavo], cor caroli [Canes venatici], alderamin [Cepheus]

visible clusters/DSOs:
coma star cluster [Coma berenices], omega centauri [Centaurus], ptolemy cluster [Scorpius]

non-visible but photographable constellations:
leo minor, libra, serpens, scutum, canes venatici, crater, hydra, delphinus, telescopium

winter [jan-mar]

visible winter constellations:
taurus, orion, canis major, canis minor, auriga, puppis, gemini

visible circumpolar constellations:
[northern] ursa major, perseus
[southern] carina, vela, crux, centaurus

other visible constellations:
[autumn] aries, pegasus, andromeda
[spring] leo, corvus, virgo

other visible stars:
fomalhaut [Piscis austrinus], diphda & menkar [Cetus], achernar [Eridanus], alphard [Hydra]

visible clusters/DSOs:
orion nebula [Orion], pleiades [Taurus], andromeda galaxy [Andromeda], double cluster [Cassiopeia], carina nebula [Carina]

non-visible but photographable constellations:
columba, pictor, lepus, eridanus, dorado, monoceres, hydra, pyxis, aquarius



[iPhone 12 Jun 15 2023 22:35 MacRitchie - Scorpius (white), Libra (purple), Ophiuchus (blue), Serpens (pink)]



[iPhone 11 Apr 20 2023 20:06 Macpherson - Orion (white), Taurus (pink), Venus (pink circle) Gemini (blue), Mars (blue circle), Auriga (purple)]

Good projects

Junior Honorable Mention RV/1

TI: EXPLAIN WHAT THE FERMI PARADOX IS

"WHERE IS EVERYBODY?"

THE FERMI PARADOX EXPLAINED

WHAT IS THE FERMI PARADOX?

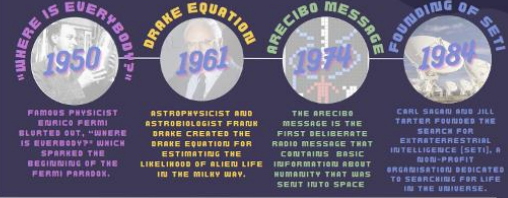
IF WE KNOW THAT LIFE CAN OCCUR ON A PLANET AS AVERAGE AS EARTH, CAN'T IT OCCUR ELSEWHERE?

GIVEN THE SPEED OF ADVANCEMENTS OF TECHNOLOGY ON EARTH AND ESTIMATES OF THE DRAKE EQUATION, WE SHOULD HAVE OBSERVED SIGHTINGS OF OTHER LIFE FORMS IN OUR UNIVERSE BY NOW.

BUT WE SEE NOTHING BUT A DEAD AND QUIET COSMOS. IT'S ONLY MANKIND HERE. THIS PARADOXICAL PHENOMENON IS KNOWN AS THE FERMI PARADOX.

SO... DO ALIENS REALLY EXIST?

HISTORY OF THE FERMI PARADOX



WHY HAS IT REMAINED A MYSTERY?

RECOGNISING OTHER LIFE FORMS IS VERY DIFFICULT DUE TO OUR TECHNOLOGICAL LIMITATIONS, OUR LACK OF UNDERSTANDING OF LIFE OUTSIDE OF EARTH, THE BARRIERS OF TIME AND THE LIMITATION OF SPACE IN OUR OBSERVABLE UNIVERSE. HENCE, THE EXISTENCE OF ALIENS REMAINS A MYSTERY.

THE DRAKE EQUATION

$$N = R_* \cdot F_p \cdot N_e \cdot F_l \cdot F_i \cdot F_c \cdot L$$

N = NUMBER OF DETECTABLE CIVILISATIONS IN THE MILKY WAY

R_* = RATE OF STAR FORMATION IN THE GALAXY

F_p = FRACTION OF STARS THAT HAVE PLANETS

N_e = FRACTION OF PLANETS PER SOLAR SYSTEM WITH AN ENVIRONMENT SUITABLE FOR LIFE

F_l = FRACTION OF SUITABLE PLANETS ON WHICH LIFE ACTUALLY APPEARS

F_i = FRACTION OF LIFE THAT EVOLVES INTELLIGENCE

F_c = FRACTION OF CIVILISATIONS THAT RELEASES DETECTABLE SIGNS OF THEIR EXISTENCE

L = THE LENGTH OF TIME SUCH CIVILISATIONS RELEASE SIGNALS INTO SPACE

POSSIBLE SOLUTIONS TO THE FERMI PARADOX



THE SELF-DESTRUCTION THEORY STATES THAT INTELLIGENCE EVENTUALLY BRINGS ABOUT UNINTENDED BUT IMMINENT SELF-DESTRUCTION DUE TO THE CONSEQUENCES OF THE ADVANCEMENT OF CIVILISATIONS.



THE GREAT FILTER THEORY SUGGESTS THAT THERE IS A BARRIER ALL INTELLIGENT LIFE FACE THAT IS VERY DIFFICULT TO CROSS GIVEN THAT VIRTUALLY NO CIVILISATIONS HAVE DONE IT. MANKIND COULD BE AHEAD OR BEHIND THIS FILTER.



THE DARK FOREST THEORY SUGGESTS THAT EXTRATERRESTRIAL CIVILISATIONS DO EXIST BUT VIEW HUMANITY AS A THREAT, THEREFORE HIDING THE EVIDENCE OF THEIR EXISTENCE SO AS TO AVOID CONTACT WITH US.



THE PLANETARIUM HYPOTHESIS SUGGESTS THAT WE ARE LIVING IN A SIMULATED UNIVERSE CREATED BY ADVANCED ALIEN CIVILISATIONS AND WE ARE THE ONLY INTELLIGENT LIFE IN THIS SIMULATION.

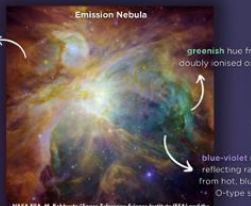


SEARCHING INCORRECTLY SUGGESTS THAT OUR CURRENT TECHNOLOGY IS NOT ADVANCED ENOUGH TO DETECT AND COMMUNICATE WITH EXTRATERRESTRIAL LIFE.

Good projects

The best for Senior RV/2

Case study 1: Orion Nebula (Messier 42)



reddish hue from hydrogen gas, which is energized by radiation from newborn stars


greenish hue from doubly-ionised oxygen

bluish-violet regions reflecting radiation from hot, blue-white O-type stars

M42 is an **emission nebula**, particularly a **HII region**, dominated by positively charged hydrogen ions (H⁺ protons), rather than neutral hydrogen atoms. Electrons that have been stripped from the hydrogen atoms can rejoin atoms and resume the process of Balmer decays all over again. The energy to keep the nebula glowing comes from the very hot young stars in a formation called the **Trapezium** (NASA, Almeida, 2020).

NASA, ESA, M. Bakoš (Space Telescope Science Institute/ESA) and the Hubble Space Telescope Orion Treasury Project Team

Case study 2: The Ring Nebula (Messier 57)



reddish hue from nitrogen and sulfur gas which is radiated from the coolest gas

light blue of the inner ring is the glow of hydrogen and oxygen


deep blue in the centre represents helium

greenish hue from ionised oxygen

The Ring Nebula, a **Planetary Nebula**, has a distinct ring shape when viewed through a telescope. Its glow comes from ionized gas atoms excited by ultraviolet radiation from the central white dwarf (NASA, Garner, 2017).

The Hubble Heritage Team (AURA/STScI/NASA)

Case study 3: The Crab Nebula (Messier 1)



Bluish glow is formed from the electrons whirling at nearly the speed of light around the star's magnetic field lines (Dunbar, B, 2008)

greenish hue from singly ionised sulfur

reddish hue from doubly ionised oxygen

Orange strands are **hydrogen** remnants of a star. (Dunbar, B, 2008)

blue hue from neutral oxygen

The Crab Nebula, a **Supernova Remnant**, has the remnant of a star that was observed to explode in **1054 A.D.** It is located **6,000 light years** away, and is a strong source of wavelengths from radio waves through gamma ray waves (NASA, 2011).

NASA, ESA, J. Hester and A. Loll (Arizona State University)

7. Sources of the different colours observed in photographs of nebulae



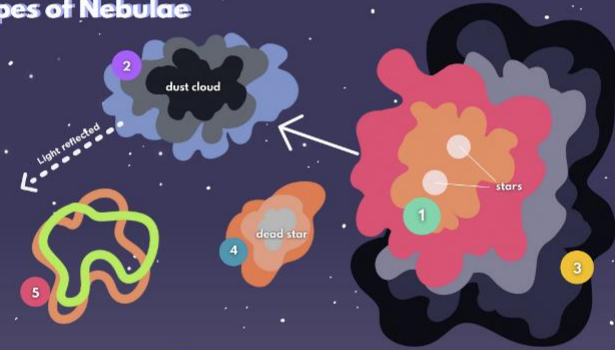
What is a Nebula?

By: Siak Jing Wen, Tiu Xin Yun, Ong Yi Qian, Liu Zhaoran, Tan Yi Jun
River Valley High School

A **nebula** is a giant cloud of dust and gas in space (Miller, 2014). Stars inside these clouds of gas cause them to glow with beautiful colours. These colours are the result of **different elements** within the nebula (Nagwa, n.d).



Types of Nebulae



1 Emission Nebulae

EN are formed of ionized gases that **emit** light of various wavelengths (Swinburne University of Technology (SUT), n.d.). They **tend to appear red**, as they are composed of about 90% hydrogen, with the remaining being helium, oxygen, nitrogen and other elements (Stewart, Suzy., n.d.).

2 Reflection Nebulae

RN are clouds of interstellar dust that **reflects** the light of a nearby star(s), composed of hydrogen, iron, nickel and carbon compounds. They **mostly appear blue**, as blue light is scattered more efficiently by small dust particles within the nebula (SUT, n.d.).

3 Dark Nebulae

DN are interstellar clouds that contains a very **high concentration of dust**. This allows them to scatter and absorb all incident optical light, making them completely **opaque** at visible wavelengths. They mostly comprised of helium and hydrogen (SUT, n.d.; Stewart, n.d.).

4 Planetary Nebulae

PN is a type of emission nebula that consists of an expanding, glowing shell of ionized gas ejected from **red giant stars** ("dying star") at the end of the life, composed of hydrogen, carbon, oxygen, and neon ions. (Esa/Hubble, n.d.) Planetary nebulae usually have relatively high oxygen emission, often making planetary nebulae **appear blue-green** in natural color (Nichols, 2013).

5 Supernova Remnants

SR is the expanding shell of gas and dust formed after a massive star **explodes**, releasing a tremendous amount of energy. They play a significant role in **galactic evolution** and provide insights into the **life cycles** of massive stars, heavy element dispersal, and the impact of supernova explosions (SUT, n.d.).

Good projects

Senior Honorable Mention RI/1

THE FERMI PARADOX

OUR GALAXY SHOULD HAVE THE CONDITIONS NECESSARY FOR LIFE.

High rate of cosmic planet formation



Rate of cosmic planet formation is relatively high across the Milky Way, with high enough metallicity to support the formation of rocky planets best for nurturing life.

No active galactic nucleus



Milky Way's central supermassive black hole, 'Sagittarius A*' is relatively quiescent. There is not much life-threatening radiation emitted from the nucleus or its surrounding gas.

Sufficient time elapsed for intelligent life to emerge



Research suggests that the Earth only formed after 75-80% of other Earth-like planets, hence intelligent life should have already emerged on these other planets.

WHY HAVEN'T WE DETECTED ANY ADVANCED EXTRATERRESTRIALS?

To better frame this question, let us turn to the Drake equation:

$$N = R_* \cdot F_p \cdot N_e \cdot F_l \cdot F_i \cdot F_c \cdot L$$

Number of civilisations we could communicate with

Average star formation rate (0.68-1.45 solar masses of material used per year)

Fraction of those stars possessing planets (-1)

Average number of life-supporting planets each of these stars have (-0.4)

Fraction of planets where life actually emerges

Fraction of those planets that develop intelligent life

Fraction of those civilisations who release detectable signals into space

Duration these civilisations release detectable signals

Completely unknown - Potential Solutions offer values for them

WHAT'S THE SIGNIFICANCE OF THE FERMI PARADOX?

- Construct a roadmap for further technological development and research to attain better estimates of the variables
- Alert us to potential threats to humanity's existence that could have resulted in the wipeout of past civilisations
- Finding life beyond Earth would be a milestone revolutionising our life formation theories
- Possibility of communicating with and learning from another civilisation to advance mankind

1. Zoo Hypothesis

Aliens millions of years ahead of us humans, collectively agreed within their 'galactic empire' to avoid contact with Earth for some reason (eg. protecting Earth's ecology, primitive nature of humans).



2. The Great Filter

Certain requirements for a technologically advanced civilisation may be lacking, forming a 'filter' that reduces their existence. Possible filters include the formation of multicellular life and the ability for space colonisation. If we find remains of more primitive alien life, the filter is likely behind us. Conversely, if we find remains of advanced alien civilisations, humanity's extinction could be ahead.

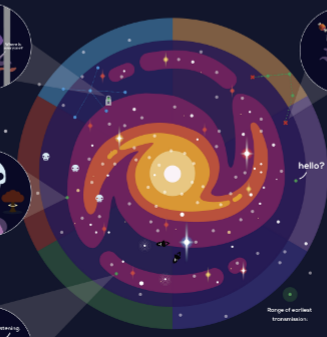


3. The Dark Forest

Alien species intentionally hide, fearing other intelligent species will destroy them - post-like skilled human meeting through a dark forest, unaware of each other.



POTENTIAL SOLUTIONS



4. Superlinear Scaling

Civilisations grow too large to sustain themselves with existing resources, causing them to collapse. Innovation could prevent collapse, but eventually falls behind due to exponential population growth.



5. First in, Last Out

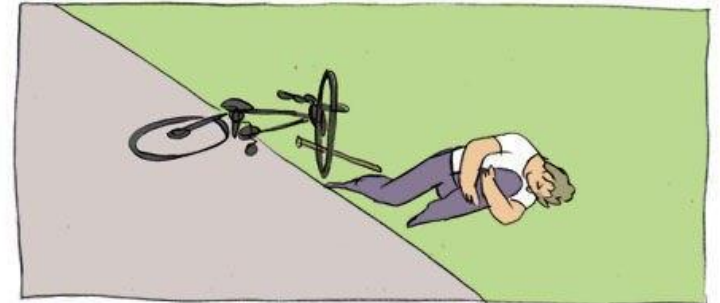
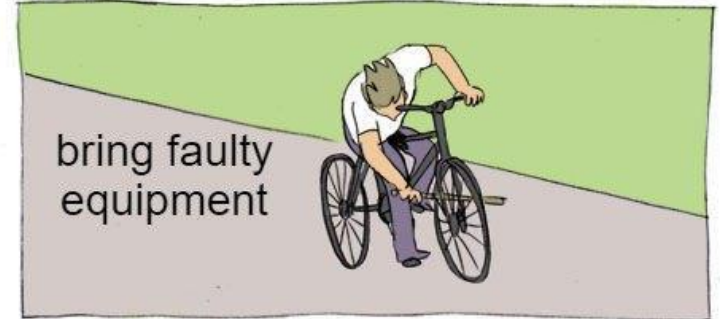
Humans are among the first civilisations to form. a. 'First In' Civilisations unable to form earlier because the universe was more active. b. 'Last Out' Developing civilisations expand to other planets for resources, preventing the formation of other intelligent life.

6. Speed of Light Limit

We have only been transmitting radio for ~100 years, so only the nearest star systems can detect us. Light takes 35000 years to travel across the galaxy, making meaningful communication difficult if not impossible.

3. Observation Round

Practical



Practical

- Section 1 and 2 were generally the same, except some schools who brought a scope that was too low for boresighting
- The main difference maker is section 3
- Some teams were smart enough to spam stars in the last 15mins

stellar marathon (40%)
40
35
20
20
10
5
5
0
0
0

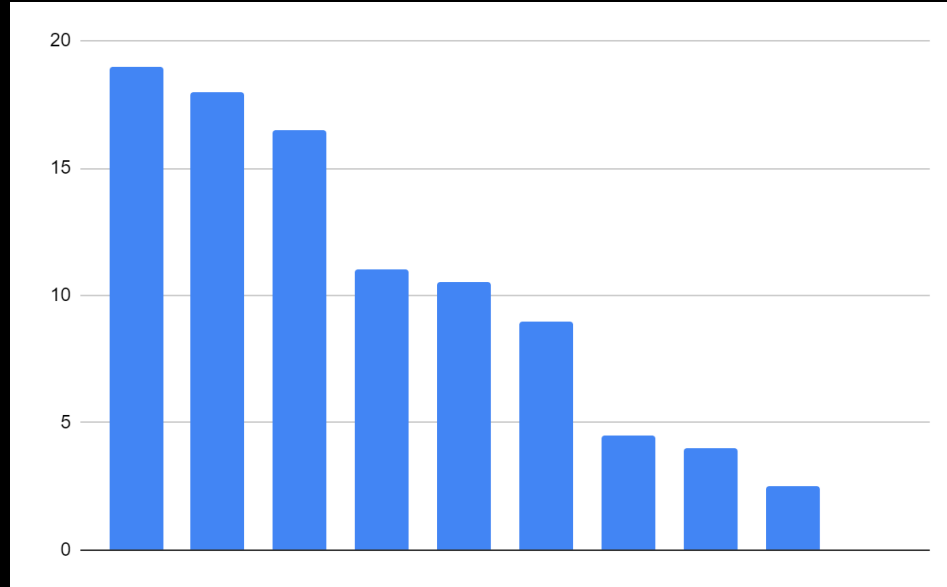
Theory

- Teams were split into 2 to prevent solo carrying



Theory Q1 Cloze Passage

Two teams got full marks, but their other half did not get full



Theory Q1 Cloze Passage

ASTROCHALLENGE 2023 SENIOR OBSERVATION ROUND

Cloze Passage 1 Answers:

A	Orion	✓
B	Boobyonic	✓
C	Rigel	✓
D	Orion's belt	✓
E	Aldebaran	✓
F	Hyades	✓
G	Achernar	✓
H	Betelgeuse	✓
J	Arcturus	✓
K	Small Magellanic Cloud	✓

(10)

ASTROCHALLENGE 2023 SENIOR OBSERVATION ROUND

Cloze Passage 2 Answers:

A	The Tropic	✓
B	Sagittarius	✓
C	M22	✓
D	M13 (Hercules Globular Cluster)	✓
E	The Hercules Ring	✓
F	Ring of Aquarius	✓
G	Aquarius The Great Square of Pegasus	✓
H	The Great Square of Pegasus Alpha Centauri (α Centauri / 5 stars)	✓
J	Andromeda	✓
K	M31 (Andromeda Galaxy)	✓

(10)

Only the full marks team got this correct. Y'all should try finding M22 next time, can be seen Singapore on a good clear sky

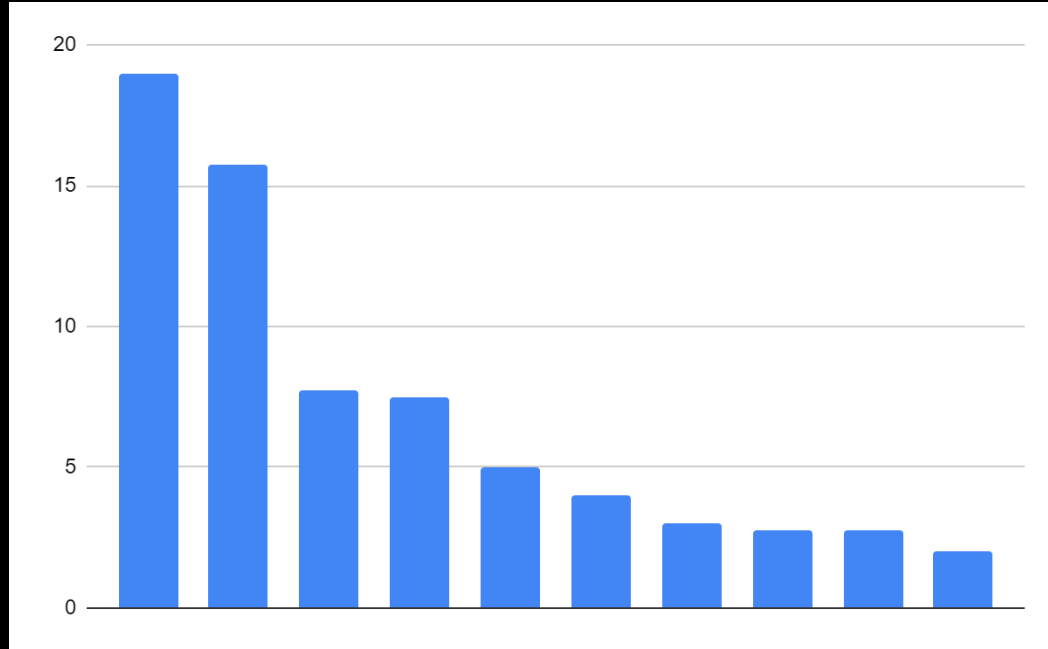
Theory Q2 Finder Charts

3 teams managed to find

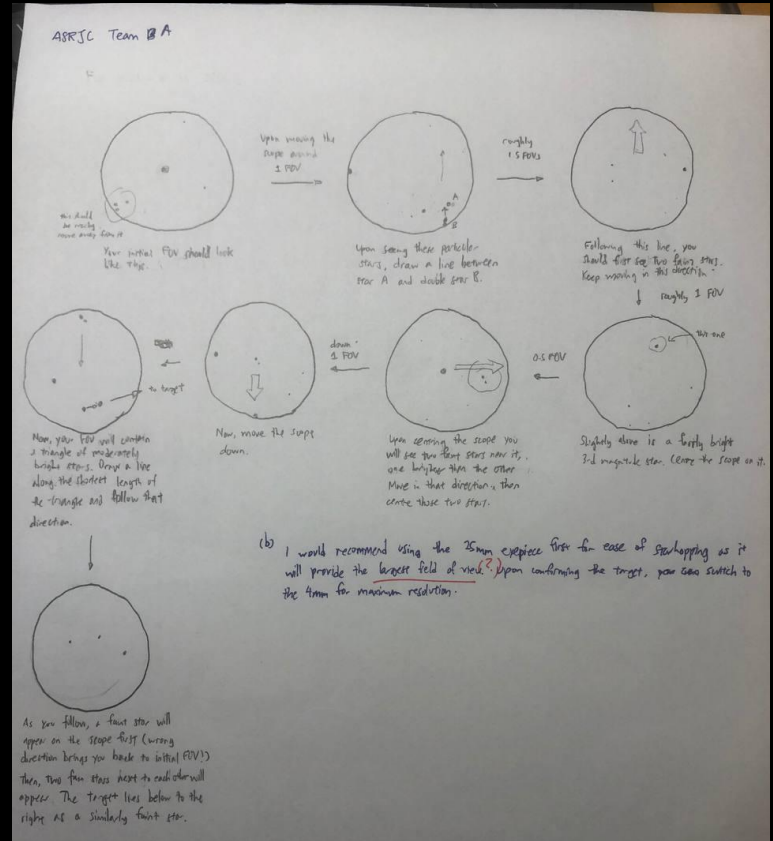
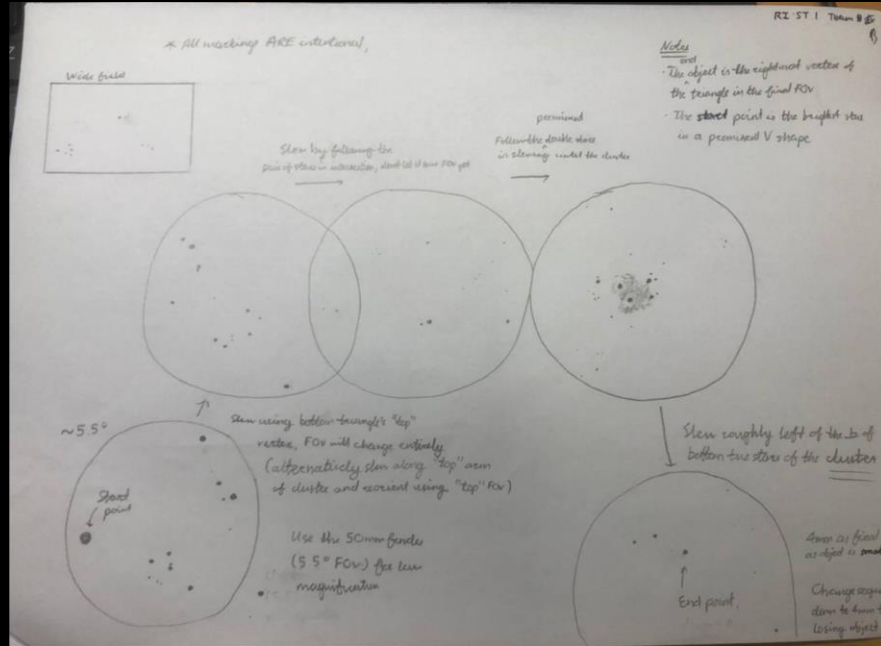
2 of them from the same school

Please have a drawing that can
be read easily >.<

More practice is needed



Theory Q2 Finder Charts



Always use a finder!!!

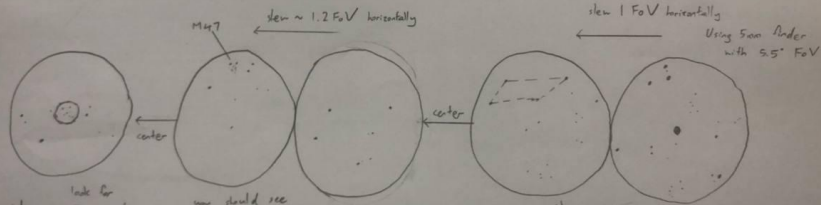
Count number of FOVs!!!

Theory Q2 Finder Charts

Eyepieces focal lengths	Apparent FoV	Magnification	True FoV
4mm	50°	$\frac{600}{4} = 150\times$	$\frac{50}{150} = 0.33^\circ$
15mm	58°	$\frac{600}{15} = 40\times$	$\frac{58}{40} = 1.45^\circ$
25mm	44°	$\frac{600}{25} = 24\times$	$\frac{44}{24} = 1.83^\circ$
50mm Finder	-	5x	5.5°

Sim Xue Hao
Grp B H11

We use the 50mm finder mounted on the Newtonian to star-hop.
It has the largest field of view, and star-hopping would be easier with more guiding stars.



Ending point:
You would see an open cluster over here.

Look for these nearby stars to verify your finding

you should see this cluster of stars at the top

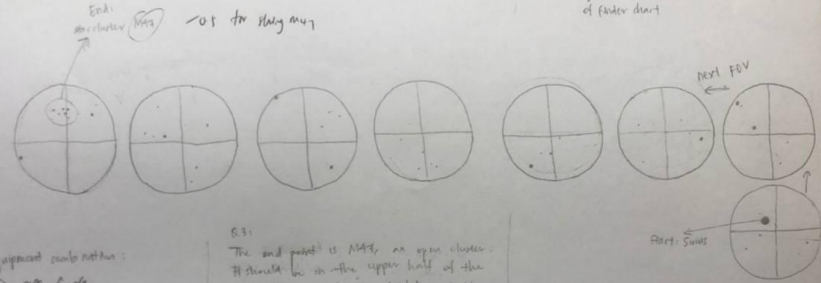
center the finder such that this bright parallelogram is at the center.

Starting point:
Ensure that a very bright star is in the center

Angle - Chuan School (Independent) Team 88

1 FoV up, 6-6.5 to the left

True FoV: 1.83°, approximated of finder chart



6.2: Equipment setup method:

- 50mm finder
 - 125mm diameter, 600mm focal length Newtonian on alt-az mount
 - 2.5m (20 degrees) space
- ↓
produces the largest true field (TFoV) of view
Hence, easier to locate M47 in frame

6.3:

The end point is M47, an open cluster. It should be in the upper half of the FoV. There are 3 or 4 bright stars, and a scattering of fainter stars below them.

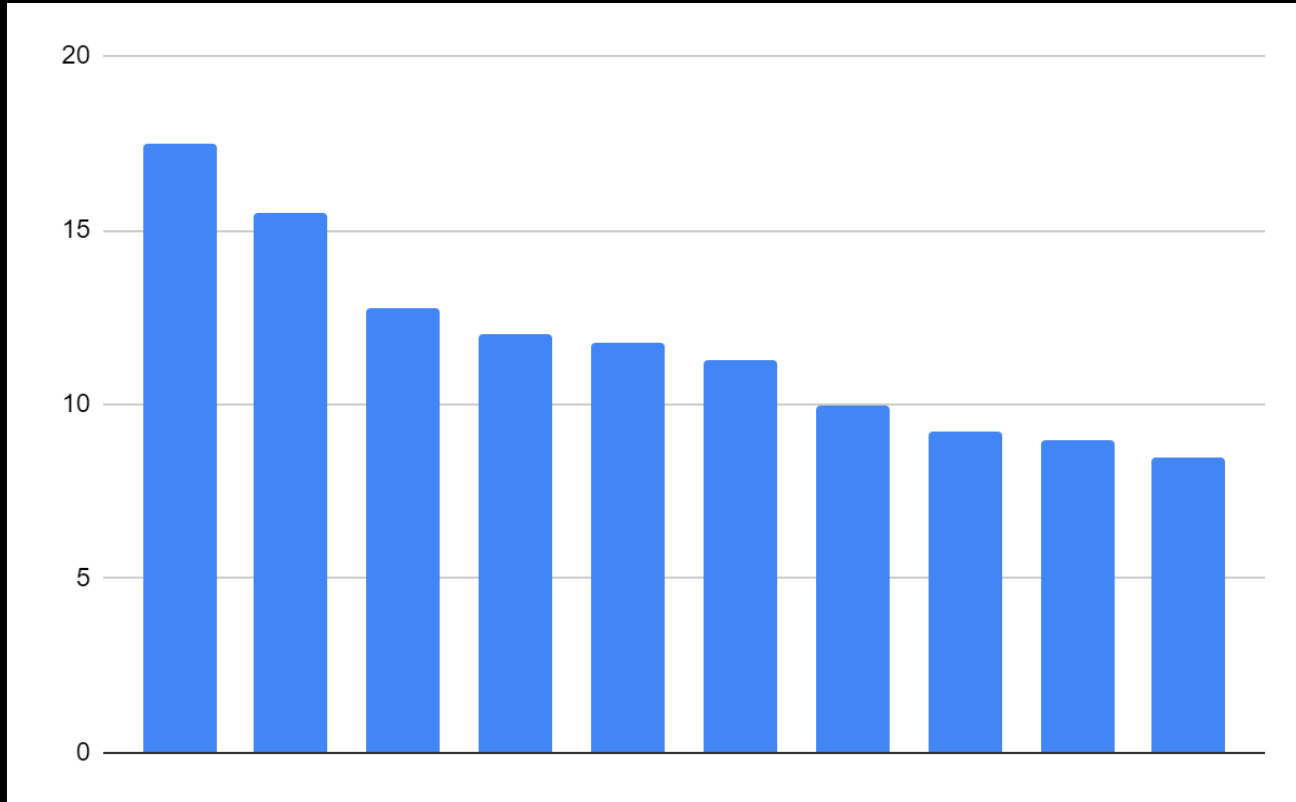
for reference below



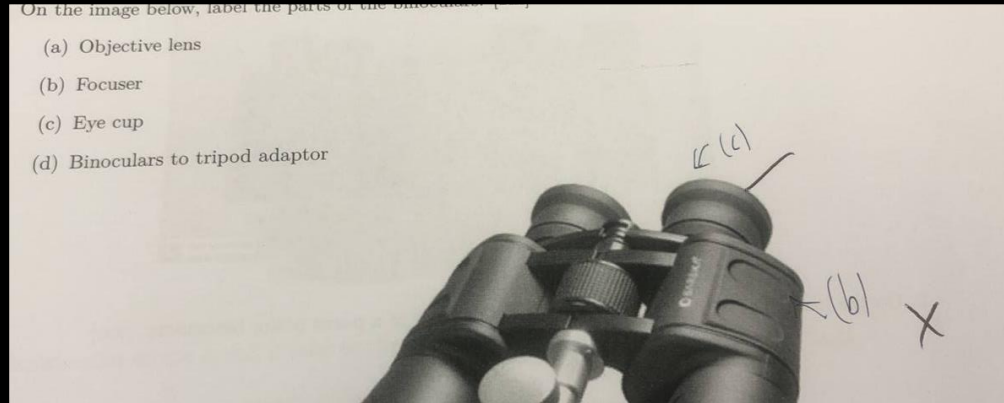
Where do I start and end??

What am i supposed to look out for??

Theory Q3 Equipment

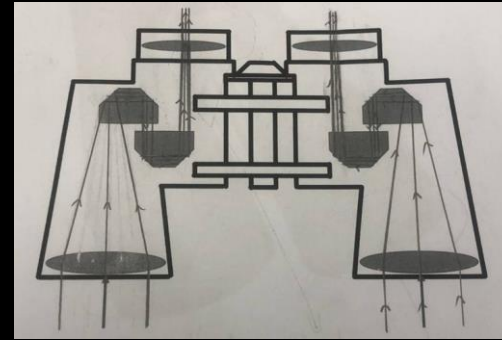
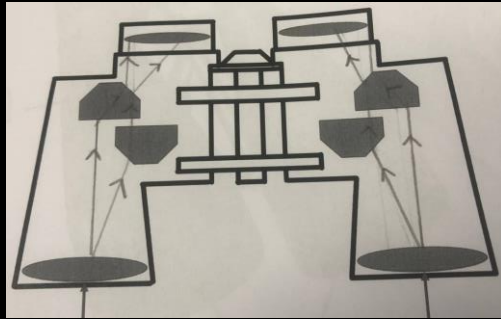
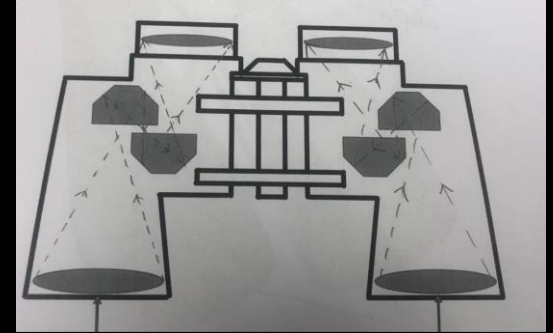
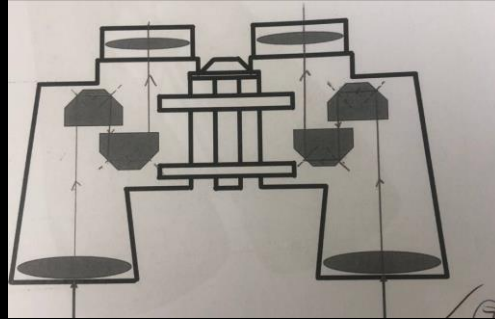
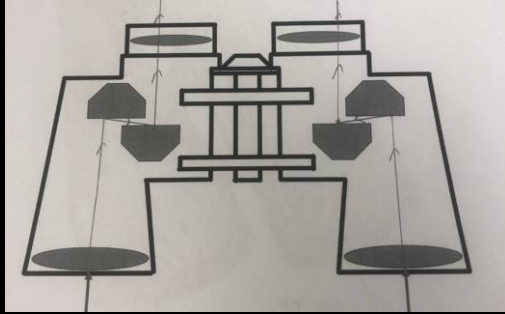


Theory Q3 Equipment



Press rubber to focus?

Theory Q3 Equipment



Which is correct?

Theory Q3 Equipment

specifications is 10×50 .



Eye cups can be magnified

3. Explain what do the A and B refer to. [1m]

A is Magnification of objective lens

B is magnification of ~~eyepiece~~ eye cup.

Other than the specification stated above, many specifications are not printed on the lens. You should still know them as it will affect the view seen through. Exit pupil and eye relief are important factors in the usability and comfort of a pair of binoculars.

4. Given a binocular that has specification of 10×50 , calculate its exit pupil. [1m]

Theory Q3 Equipment

Other than the specification stated above, many specifications are not printed on should still know them as it will affect the view seen through. Exit pupil and eye relief factors in the usability and comfort of a pair of binoculars.

4. Given a binocular that has specification of 10×50 , calculate its exit pupil. [1m]

$$\begin{aligned} \text{Exit pupil} &= 10 \times 50 \\ &= 500 \text{ mm} \end{aligned}$$

Other than the specification stated above, many specifications are not printed on the should still know them as it will affect the view seen through. Exit pupil and eye relief factors in the usability and comfort of a pair of binoculars.

4. Given a binocular that has specification of 10×50 , calculate its exit pupil. [1m]

$$\frac{10^{-1} + 50^{-1}}{2} = 0.06 //$$

Other than the specification stated above, many specifications are not printed on the should still know them as it will affect the view seen through. Exit pupil and eye relief factors in the usability and comfort of a pair of binoculars.

4. Given a binocular that has specification of 10×50 , calculate its exit pupil. [1m]

$$\text{Exit pupil} = \frac{50}{5^2 \pi} = 0.637 \text{ (3sf)}$$

Weird calculations

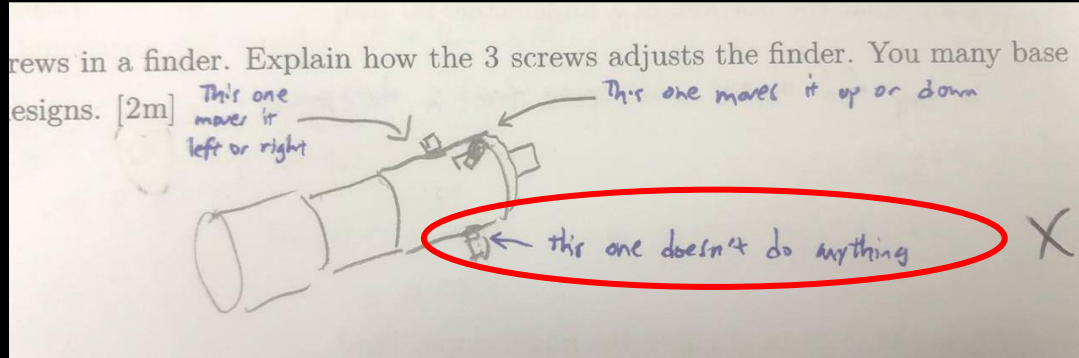
Theory Q3 Equipment

Are your eyes glued to the binos?

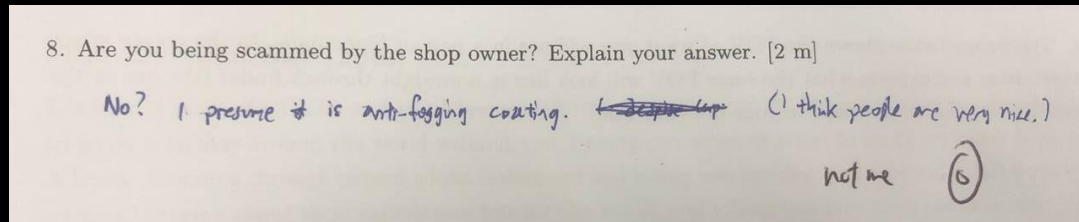
6. Explain the importance of having good (long) eye relief. [1m]

It ensures better safety, with less downward moments exerted on the eyes.

Theory Q3 Equipment

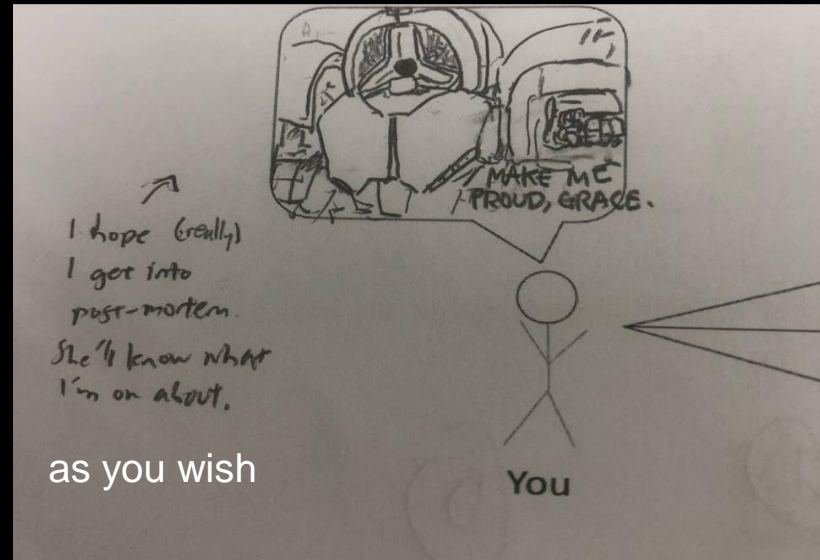
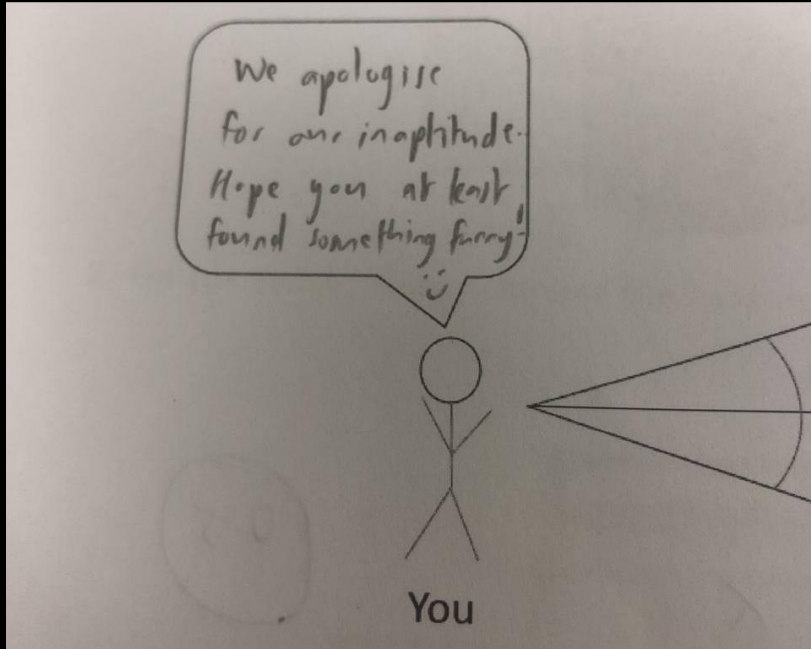


Why have it there if it does not do anything

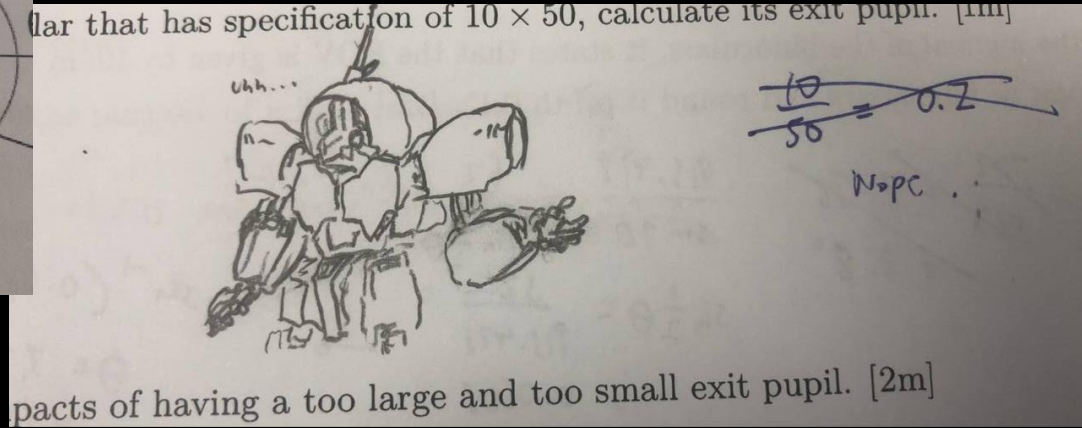


Not so nice

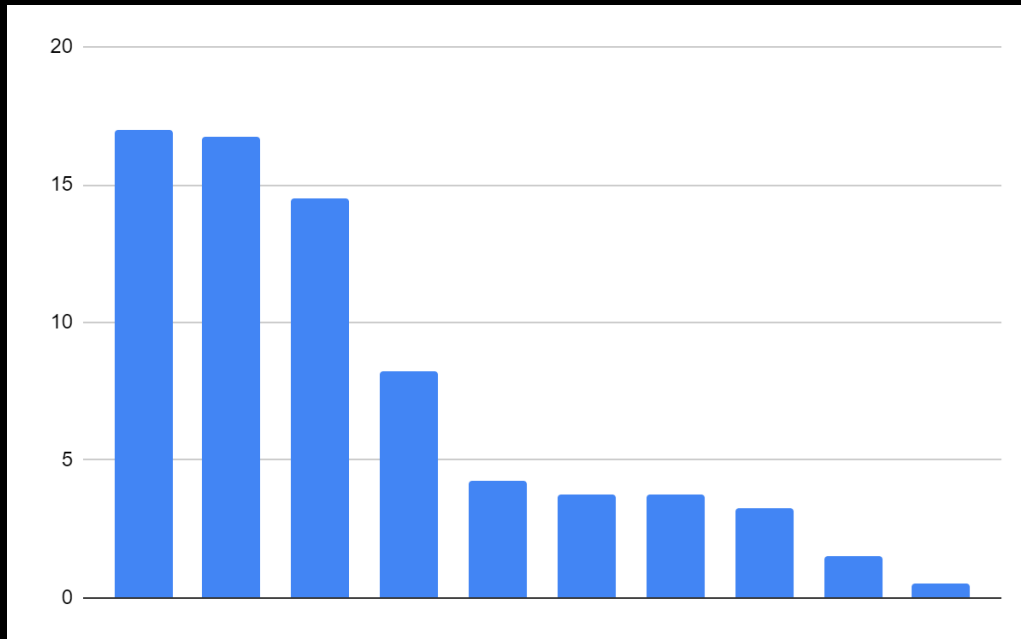
Theory Q3 Equipment



lens that has specification of 10×50 , calculate its exit pupil. [1m]



Theory Q4 Night Sky



Theory Q4 Night Sky

the coordinates, your mom wanted to ask for your help to locate some stuff in the night sky. You can find them using her binoculars. Initially, you wanted to reject this request, but she gave you some souvenirs back for you if you help her.

No, I'll just buy myself a shack.

trace out the Summer Triangle in Figure 1, and label it as ST. [1m]

Label the following stars on Figure 1 using the stipulated letters. [2m]

Star	Letter
Antares	A
Albireo	AB
Arcturus	AC
Alderamin (α Cephei)	AD

Alcoholics Anonymous

Label any 2 constellations, 2 nebulae, 2 star clusters and 2 galaxies. You may not use

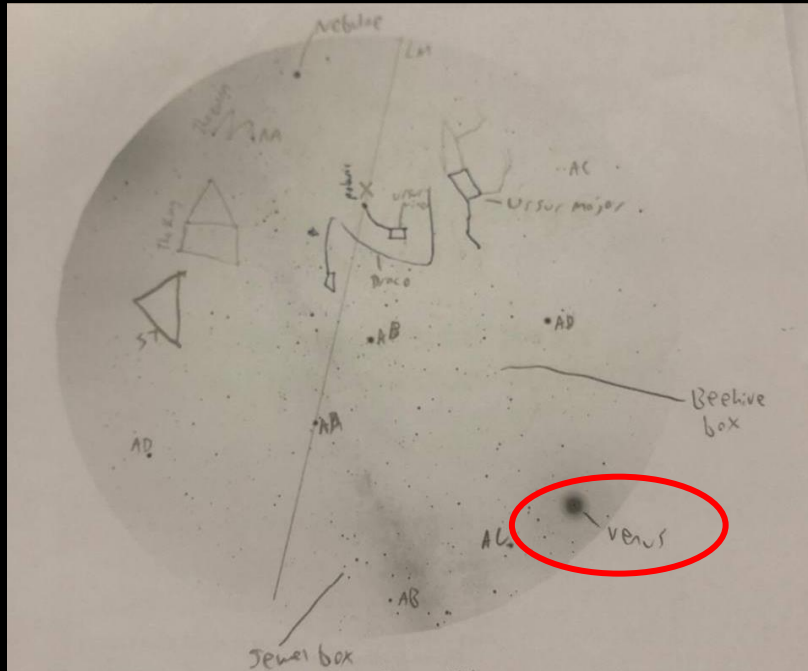


Figure 1: Moon (bottom right)

Latitude:
 Hour Angle: 3h15m
 Local Time: ?

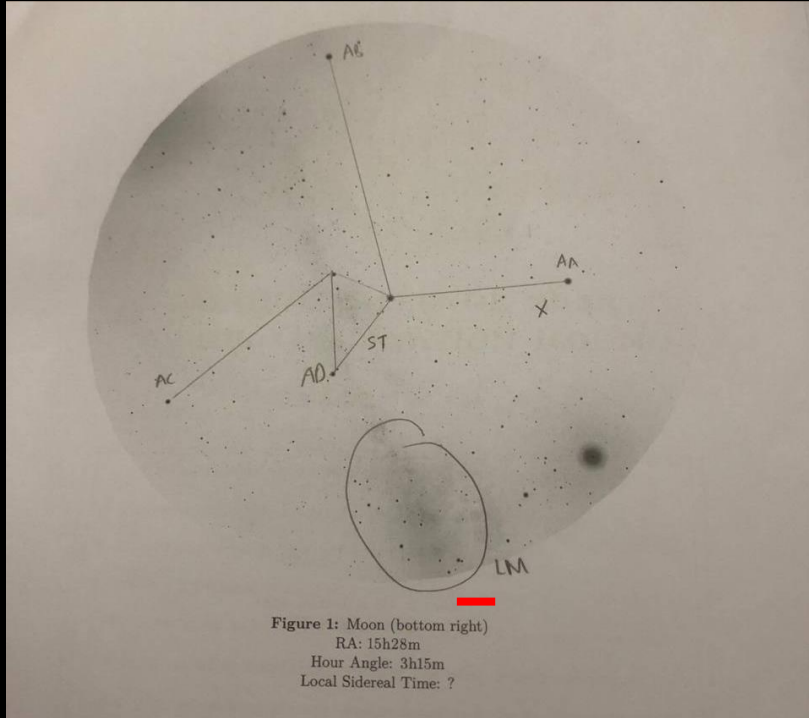
6. Estimate the latitude coordinate that your parents are at using Figure 1. Give your answer to the closest 10°. [1m]

40° N ?

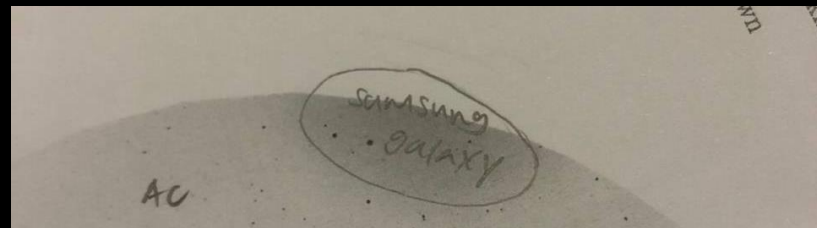
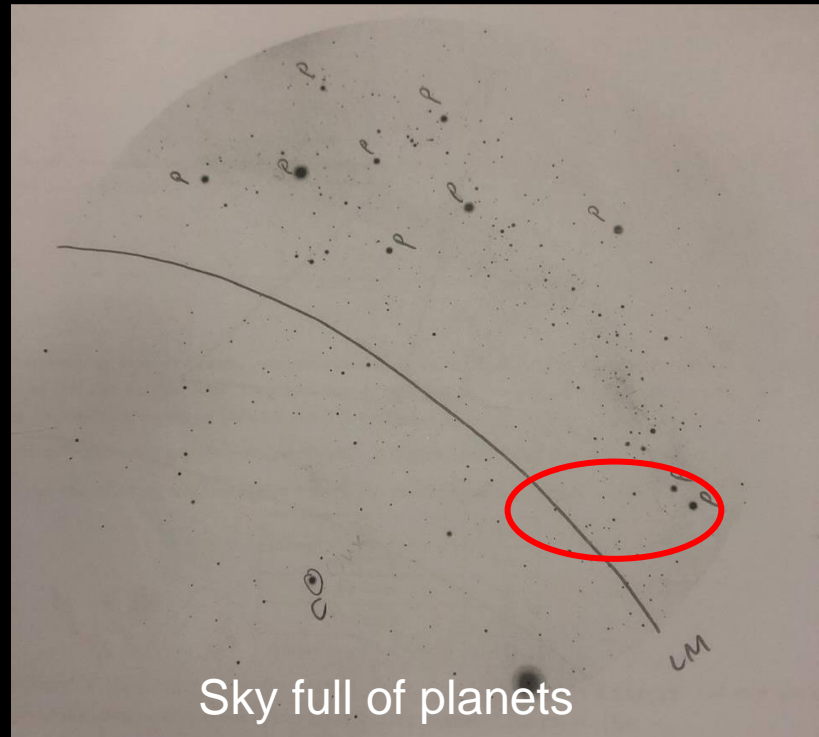
*My parents won't come home.
 Where did they go
 WHERE IS MY FATHER.*

Im sorry :(

Theory Q4 Night Sky

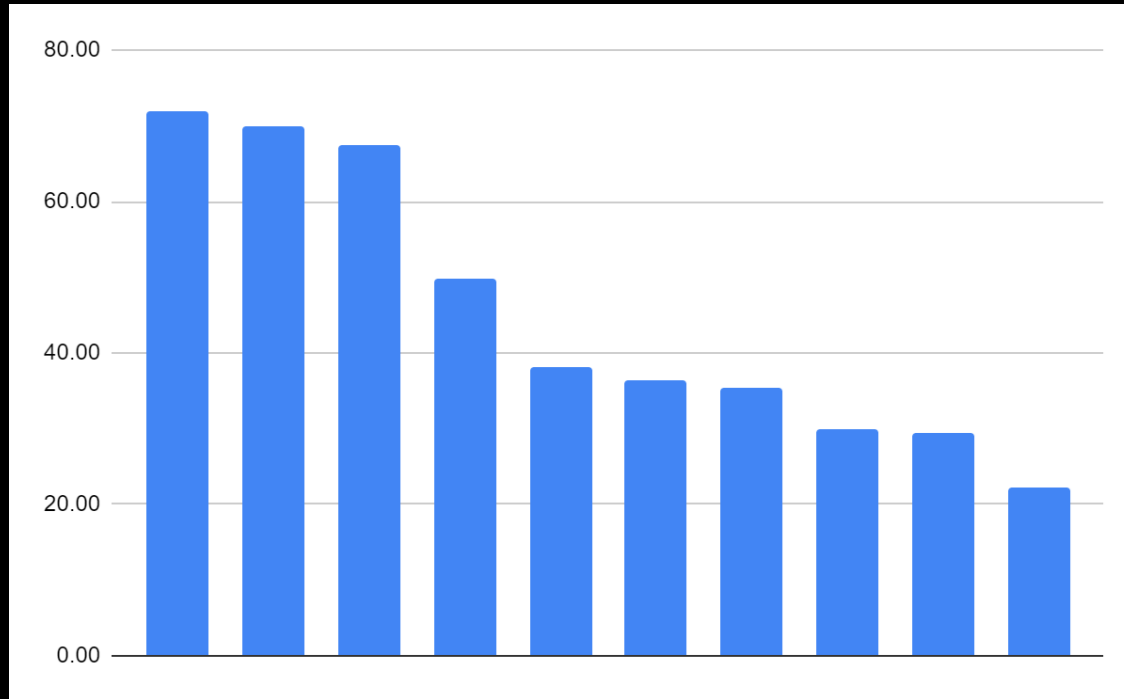


Pretty sure local meridian
is a line

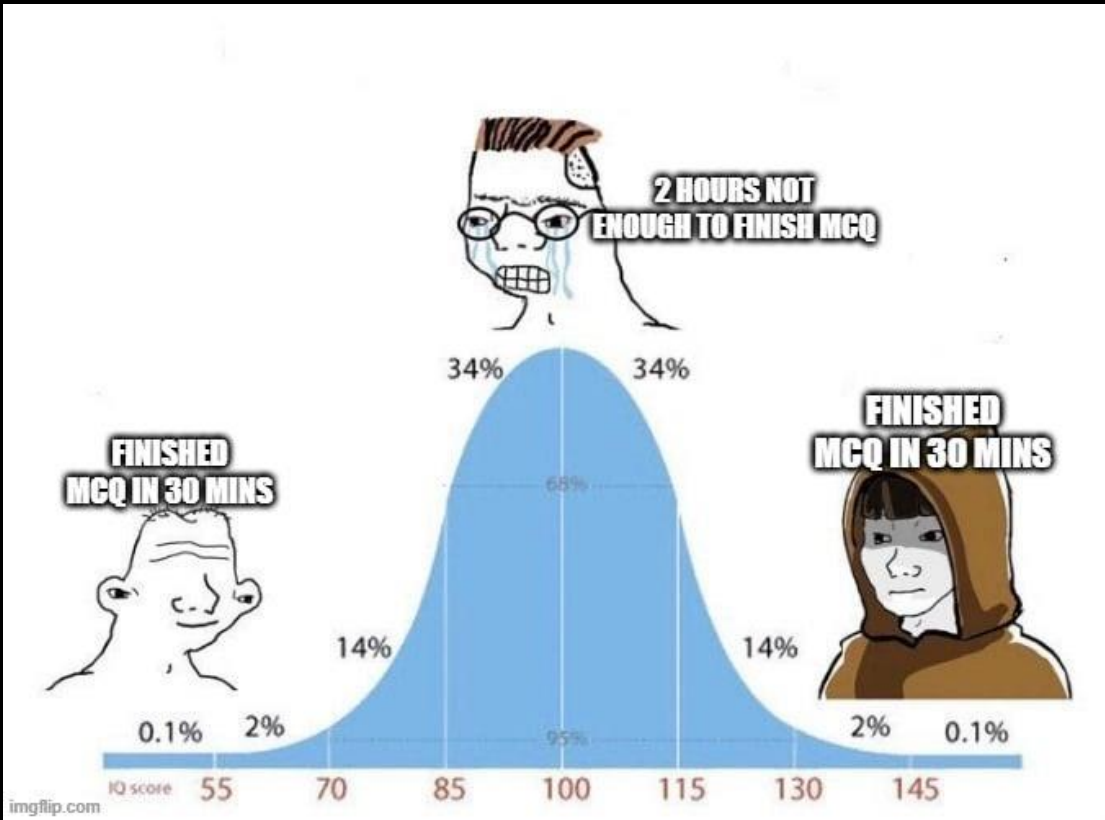


Overall

- Top 3 are very close



4. MCQ Round



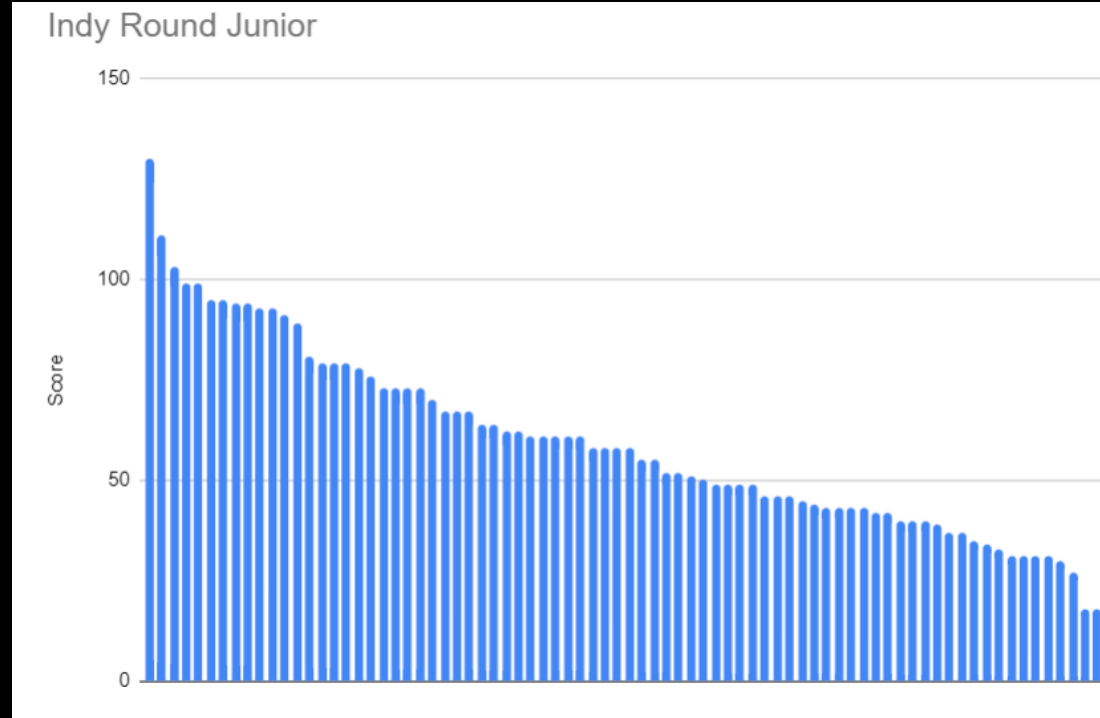
MCQ Junior

Mean: 59.7

Median: 58

Max: 130

Min: 18



MCQ Junior - Confusing??

Most blanks: Q11

11. One tropical year is the time the Sun takes to return to the same solstices or equinoxes, while the sidereal year is the time the Sun to return to the same position relative to distant stars.

Given that a sidereal year is longer than a tropical year, looking from the north ecliptic pole to the south ecliptic pole, which of the following describes the rotation of the **first point of Aries** and the **first point of Libra** on the ecliptic plane compared to distant stars?

- (A) Counter-clockwise, clockwise
- (B) **Clockwise, clockwise**
- (C) Counter-clockwise, counter-clockwise
- (D) Clockwise, counter-clockwise
- (E) Both points do not move compared to distant stars

MCQ Junior - Misled...

Most Incorrects: Q40

40. From the point of view of someone on Mars, which of the following appear to be *incorrect*? The planets are in opposition from an Earth observer.

- (A) Jupiter will appear larger in the night sky than on Earth due to its closer distance
- (B) Earth's apparent size from Mars is larger than Mars' apparent size from Earth
- (C) The Sun will appear brighter to an observer on Mars than on Earth due to Mars having less atmosphere**
- (D) Stars will appear dimmer in general to an observer on Mars
- (E) More than one of the above statements are incorrect

MCQ Junior - Piece of Cake?

Most Corrects: Q28

28. Why does Mars appear red to the naked eye?

- A** The Martian surface is rich in iron oxides, which appear red
- B Mars is a black body and thus emit red light by Wien's Law
- C Widespread volcanic activity in the Tharsis Montes region emits significant amount of red light
- D Raging wildfires on its surface emit red light
- E Mars is not red, it only appears red due to post-processing

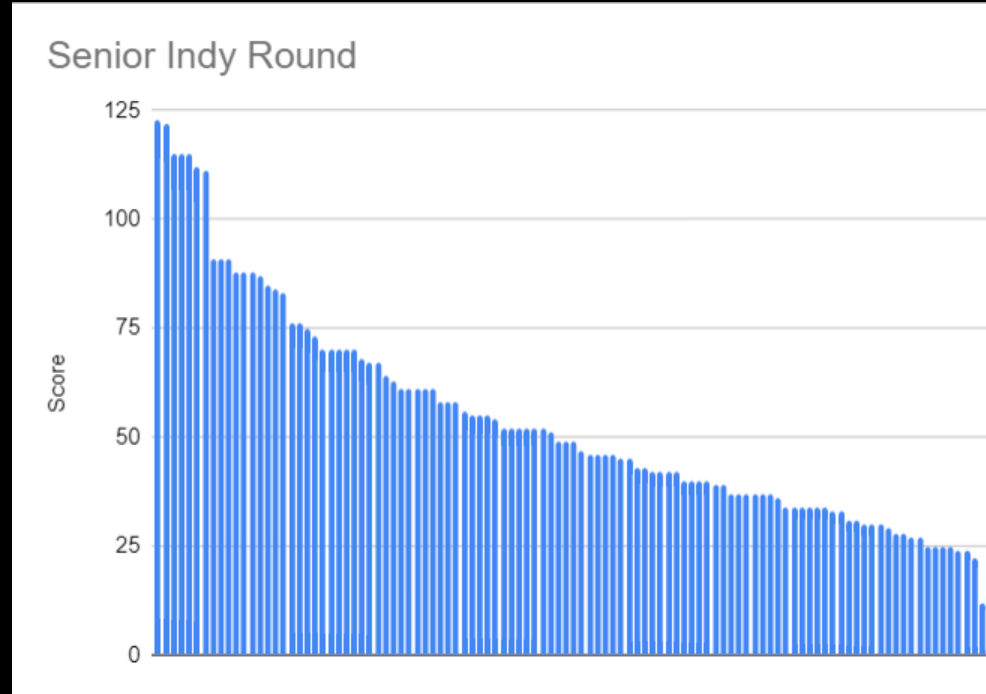
MCQ Senior

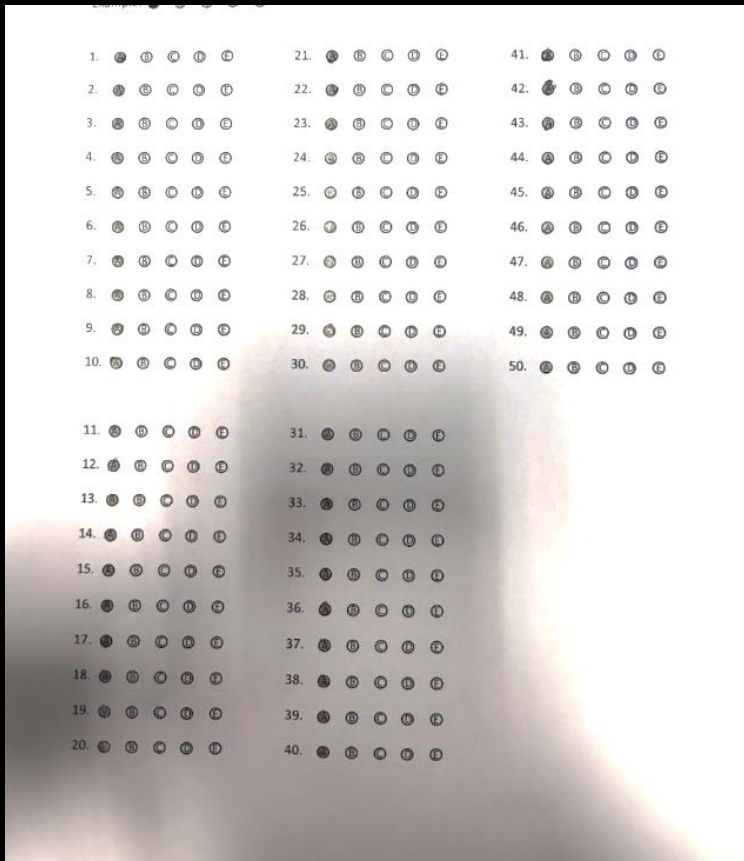
Mean: 54.2

Median: 49

Max: 123

Min: 12





Two of such “straight-As”
sheet are found



Fun Fact: You can beat the individual average by just answering C in Senior round...

MCQ Senior - A Surprise

Most blanks (tied):

Q16 and Q26

26. Given that an eyepiece of 15mm focal length and Apparent Field-of-View (AFOV) of 70° is used on Telescope B. Calculate the True Field-of-View (TFOV) of the setup.

- (A) 0.432°
- (B) 0.827°
- (C) 1.43°
- (D) 2.04°
- (E) 2.89°

MCQ Senior - A Surprise

Most Incorrects: Q1

1. Which of the following are **not** one of the ways astronomers measure the Hubble's constant?
 - (A) Using the merger of two black holes or neutron stars and measuring the subsequent gravitational waves to get their relative speeds to Earth
 - (B) Using the flat rotational curve model and absolute magnitude of Active Galactic Nuclei (AGN) to get their relative speeds to Earth**
 - (C) Using spectroscopic analysis of a distant object of known distance to determine its relative redshift to Earth
 - (D) Use bubbles in the CMBR and the flat universe model to determine the distance of certain Supernovae to determine its relative speed to Earth
 - (E) All of the above methods are valid methods of measuring Hubble's constant

MCQ Senior - A Surprise

Most Corrects: Q6

6. Black holes are regions of space where matter collapsed in on itself, creating a singularity. This collapse is so strong that not even light can escape the black hole's gravity. As a result, black holes are often described as being "invisible" because they do not emit any light or other radiation that we can detect.

What methods do scientists use to measure the mass of "invisible" black holes?

- i Direct modeling of the motions of resolved stars that are in orbit near the black hole
- ii Finding them in binary systems and measuring the motion of the companion object
- iii Measurement of emitted gravitational waves in black hole mergers
- iv Measuring the temperature difference between the black hole's core and event horizon

- A i and ii
- B ii and iii
- C i and iv
- D i, ii, and iii
- E All of the above

Common Pool Questions

Some questions are present in both JNR and SNR. How does the two categories compare?

JNR		
Qn No.	Corrects	Incorrects
26	23%	77%
42	39%	61%
44	27%	73%
45	49%	51%
46	24%	76%
47	48%	52%
48	35%	65%
49	62%	38%
50	33%	67%

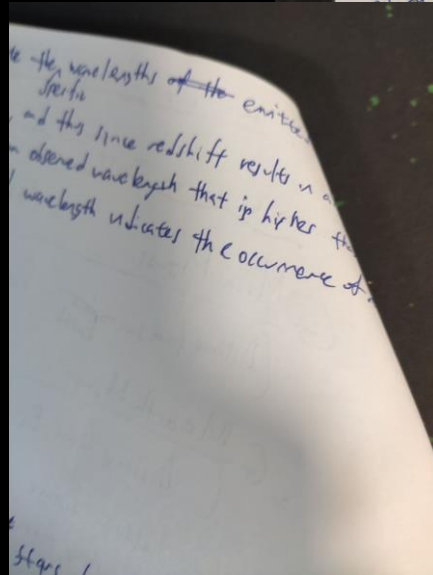
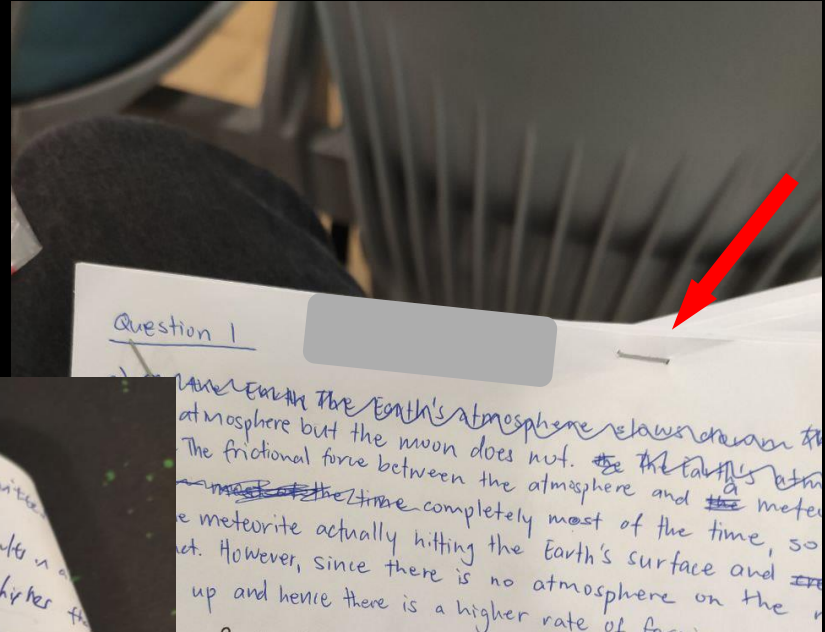
SNR		
Qn No.	Corrects	Incorrects
25	23%	77%
32	55%	45%
34	30%	70%
36	55%	45%
37	23%	77%
38	46%	54%
39	43%	57%
40	53%	47%
41	39%	61%

47. The James Webb Space Telescope is one of the most anticipated space telescopes with an immense budget. Because it is primarily designed for near-infrared astronomy, it must be positioned at the L2
49. Unlike planets like Earth and Uranus, Jupiter does not experience significant seasonal changes. This is primarily because
- (A) Jupiter is tidally locked to the Sun
 - (B) Jupiter moves too slowly along its orbit
 - (C) The axial tilt of Jupiter is negligible**
 - (D) The weather on Jupiter is driven by tidal forces exerted by the Galilean moons
 - (E) The weather on Jupiter is driven by deuterium fusion within its core
-
- (E) None of the above

6. DRQ Round

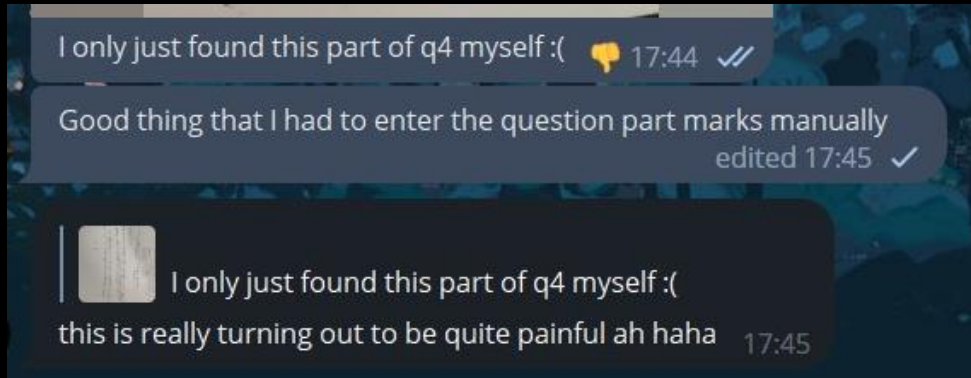
Minor Bugbear

- Annoying stapling practices



Not So Minor Bugbear

- To facilitate the marking, we requested for separate questions to be answered on separate papers...for a good reason...



- The saga continues...

I think you missed a part of the [redacted] script lol 17:53 ✓✓

Brendan and I missed a part each which we only caught just now as well 🦴 17:53 ✓✓

Oh ok 17:58

I thought i checked thru ytd but still missed out 17:58

Their answers all over the place 17:58

Oh btw I think there's a part of the [redacted] paper that you missed 17:28 ✓✓

UGH 17:34

making me play scavenger hunt for their parts ah 17:34

then i should make them play scavenger hunt for their points :< edited 17:35

ok I want to flip table alr, after checking I realised they answered part f twice in different parts of the paper 18:41 ✓✓

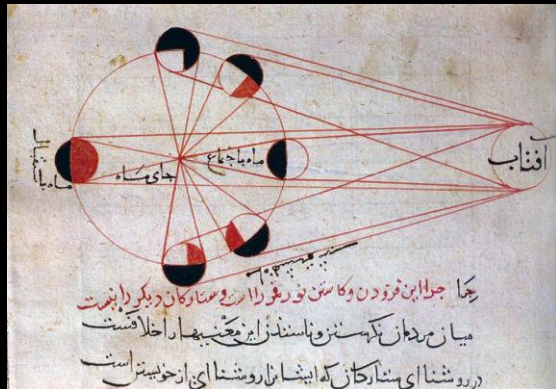


Image: space.com

5.1 Junior DRQ



Image: Kurzgesagt



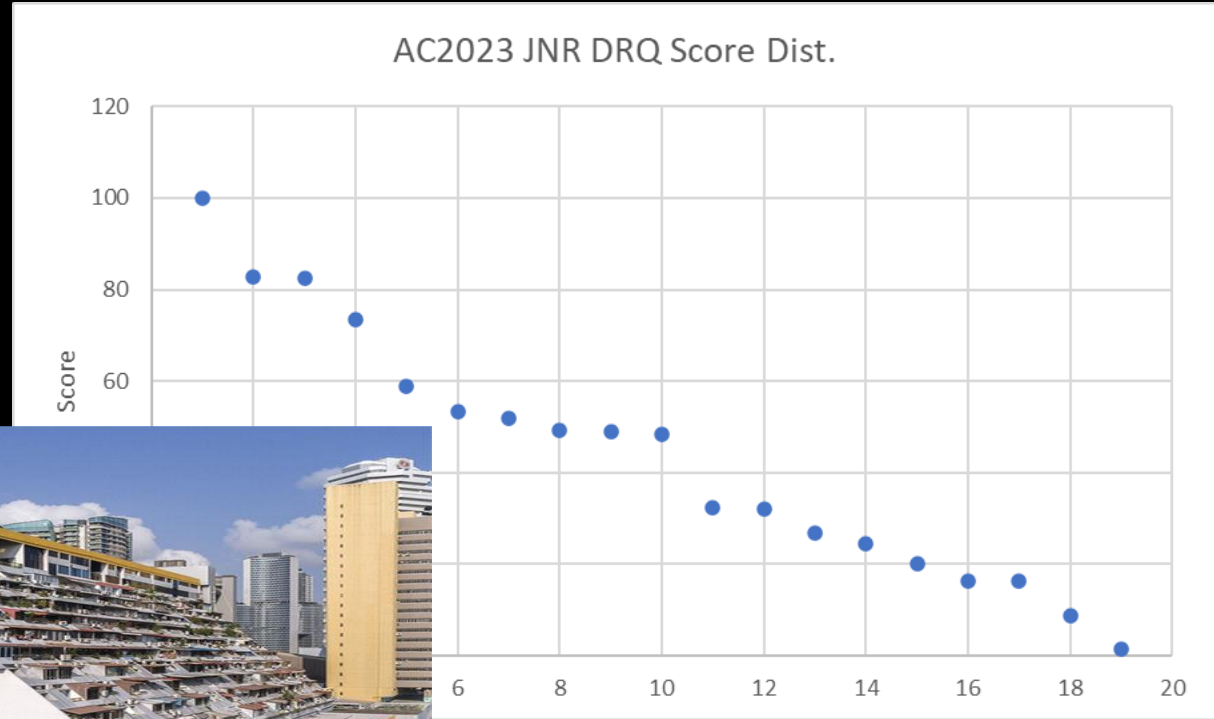
Statistics

After Moderation:

Mean: 43.60

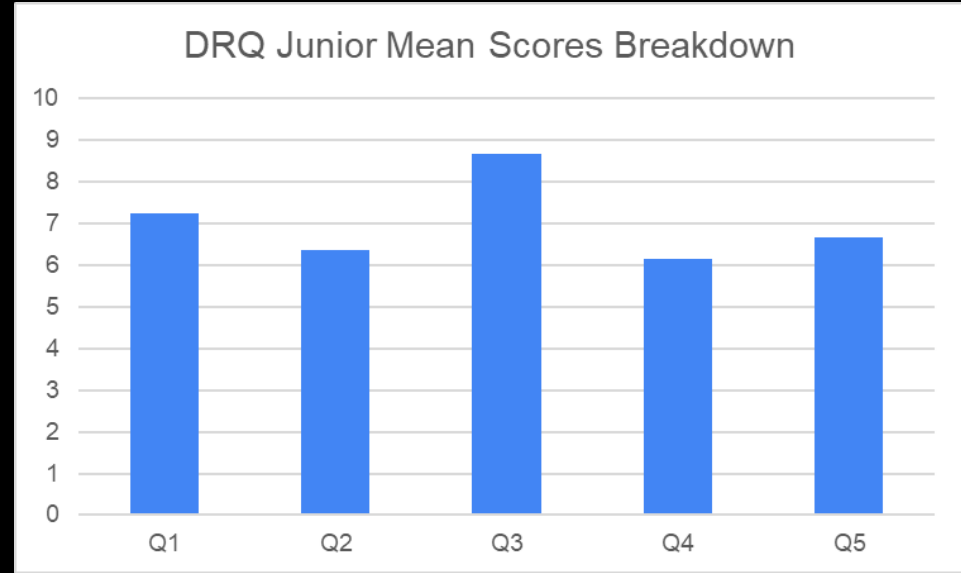
Median: 48.44

HI: 100



Score Breakdown

- Expectation: better scores for Q1 (general astronomy) and Q5 (practical astronomy) than Q2/Q3/Q4
- Reality: most participants can do some math (Q3) but not astronomy :(



Q1

A Job Interview
NPZ



Rationale

- Easy-to-score general astronomy question
- Provide a score buffer for the inevitable slaughter in the later questions

Reality:

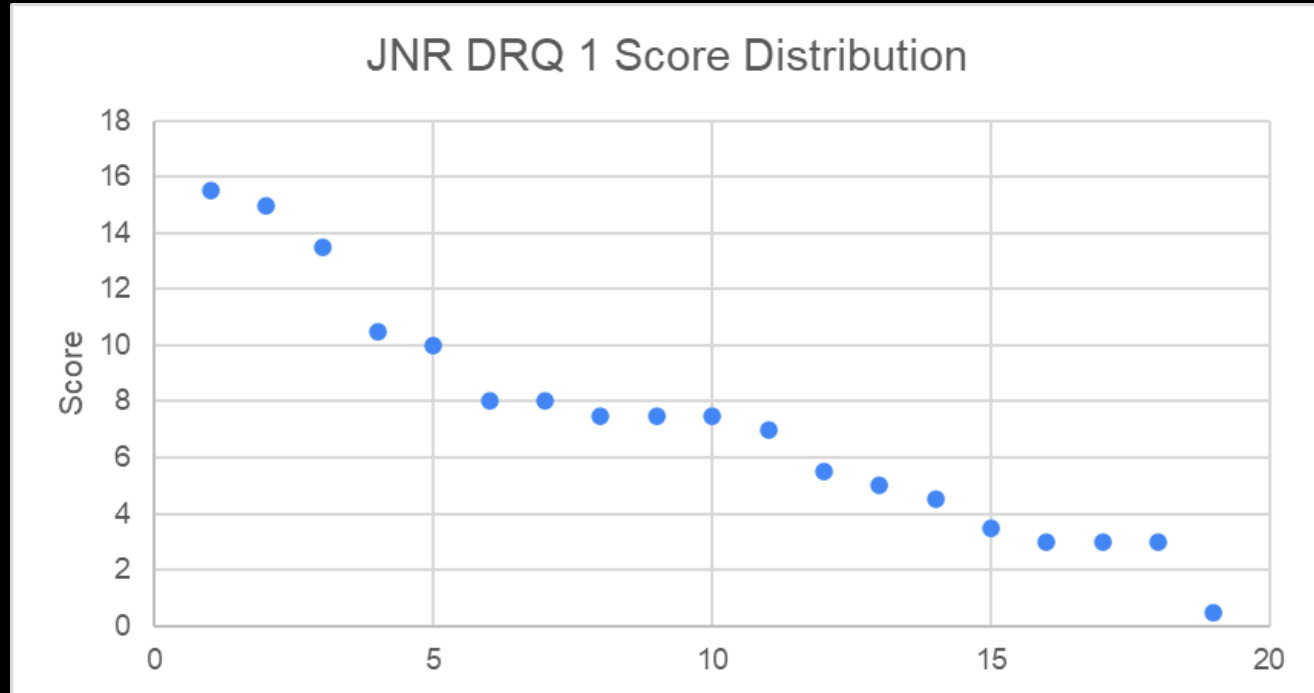
- Participants don't have a strong grasp on general astronomy :(

Statistics

Mean: 7.26

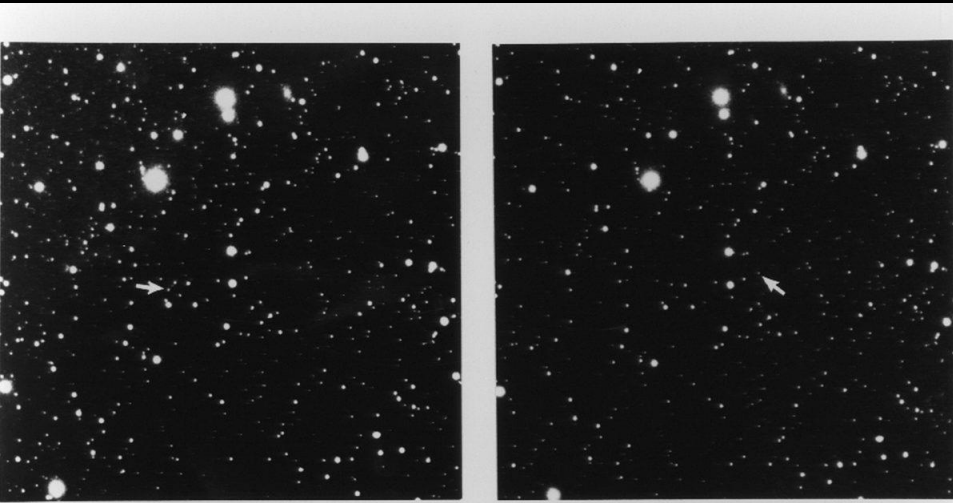
Median: 7.5

Hi: 15.5



An equally valid way to get your free marks

instead of more complex targets. max bar.
II) No. My answers were slipshod at best. (1)



Q2

Asteroid-Centered
Direct Redirection Quest

Brendan

Overall Intent

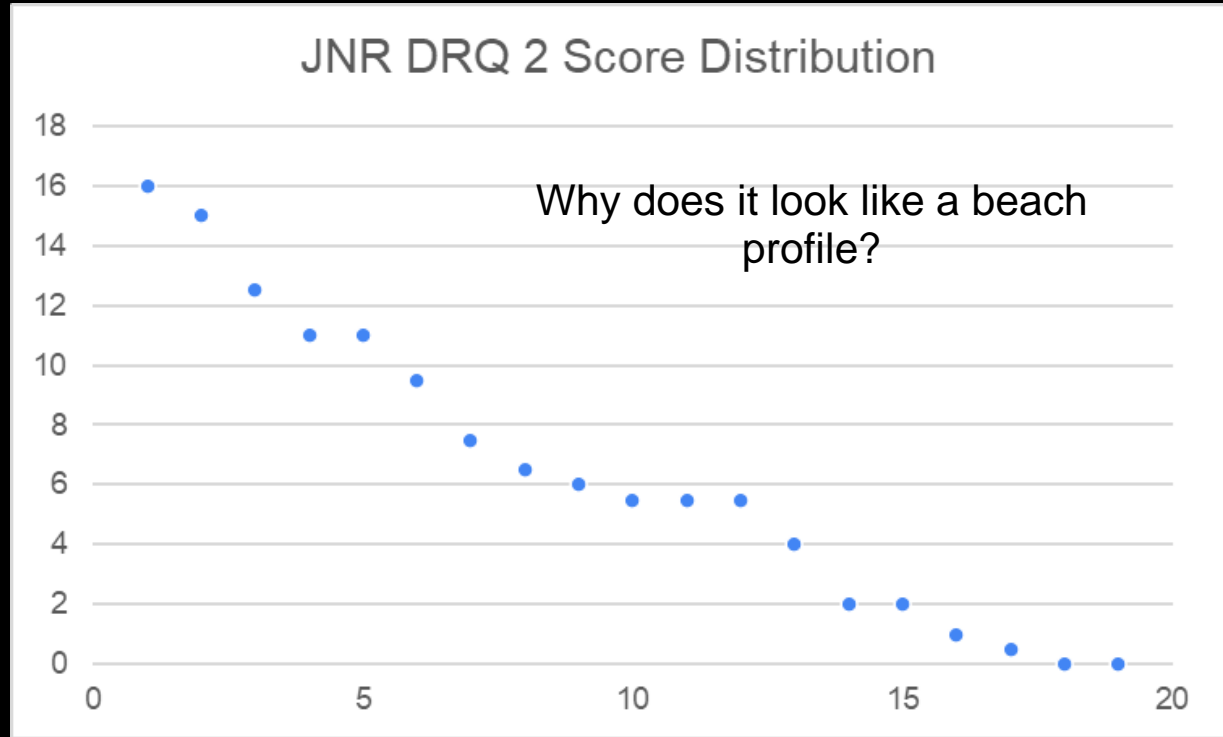
- Introduction to popular Asteroid Redirection techniques
- Spans multiple topics in Astrophysics
 - More heavy on Celestial Mechanics
 - Orbital Transfers
 - Orbital Parameters
 - Momentum Conservation
 - Touches slightly on Stellar Physics
 - Momentum of Light

Statistics

Mean: 6.37

Median: 5.5

Hi: 16



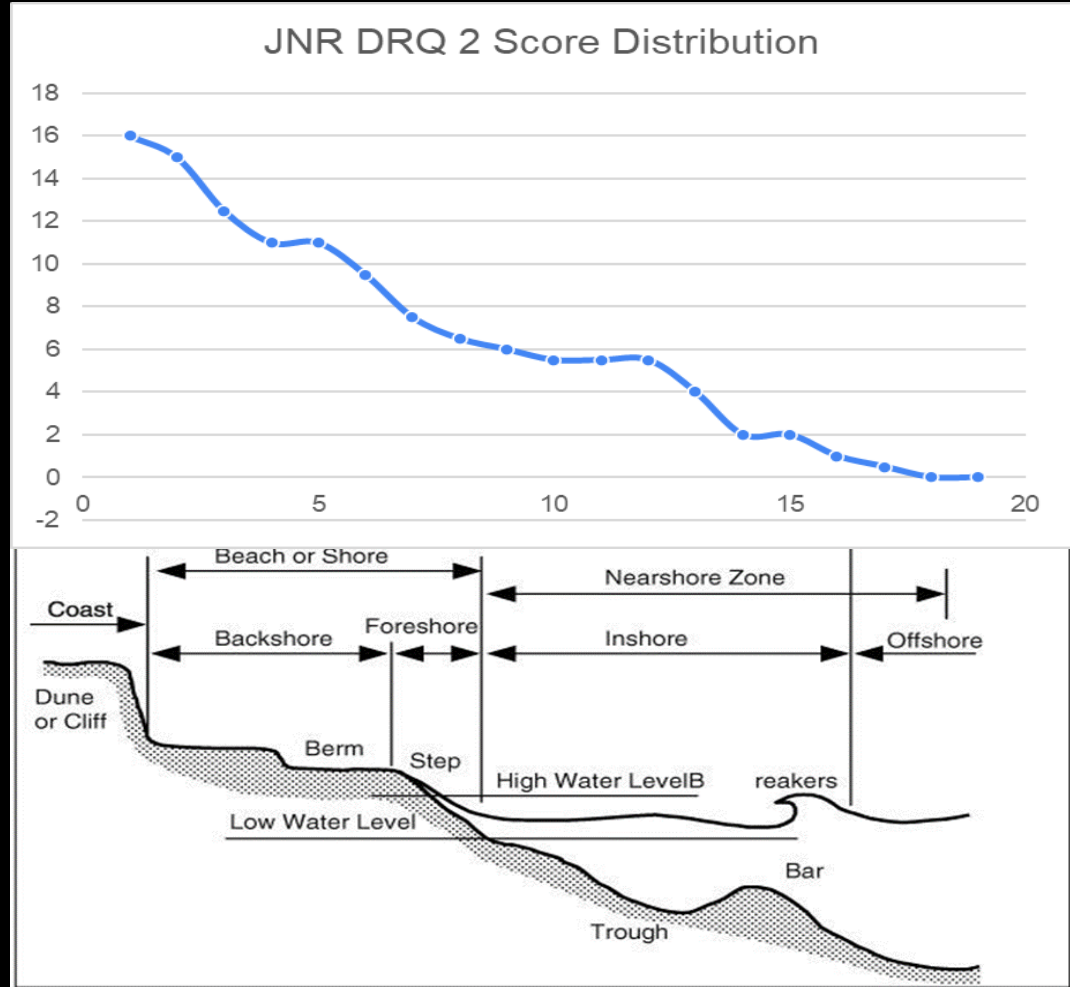
Statistics

Removing NIL Attempts

Mean: 7.12

Median: 6


Hi: 16



Summary

- Most got the “give-away” questions
- Only a few attempted the harder questions
- Most saw the integral and then panicked.




(j)
I know calc. but I can't integrate.  < Me when I see \int .

(k)
I'm too lazy to show.

You don't have to integrate.

$$\Delta p = \int_{-\pi/2}^{\pi/2} \int_{-\pi/2}^{\pi/2} p_{\gamma} (1 + \cos 2\theta \cos 2\psi) d\theta d\psi$$
$$= p_{\gamma} \pi^2$$

(c).
 ∞ I have no idea :(

Next time, just write something.

Not Reading the Question



What was "U"?

$$\Delta V \approx -\frac{2Mu}{M}$$
$$V \approx -\frac{2(1000\text{kg})(u = 1.660539 \times 10^{-27} \text{ kg})}{2 \times 10^{19} \text{ kg}}$$

What?!
;

Atomic mass unit $u = 1.660539 \times 10^{-27} \text{ kg}$

m and M are the masses of the probe and the asteroid respectively, with u being the orbital velocity of the probe with respect to the Sun at the point of impact.

Not Reading the Question



as a single entity. We can then show that the change in the asteroid's velocity is roughly given by:

$$\Delta V \approx -\frac{2mu}{M} \quad (3)$$

What was "U" again?

We ignored the ~~fact that~~ the relative velocity of the satellite with respect to the asteroid. In reality, since we use the relative velocity we used it is almost equal to the orbital velocity of

Clarification

You might be wondering where the negative sign came from.

A sneak peek into
an older draft...

For convention, we will use m and M as the masses of *Messiah* and Alvarez respectively, with u being the orbital velocity of *Messiah* with respect to the Sun at the point of impact.

Then, it is a matter of applying the conservation of angular momentum:

$$m(-u)r + Mur = (M + m)(u + \Delta V)r$$

We can simplify by cancelling like terms and get:

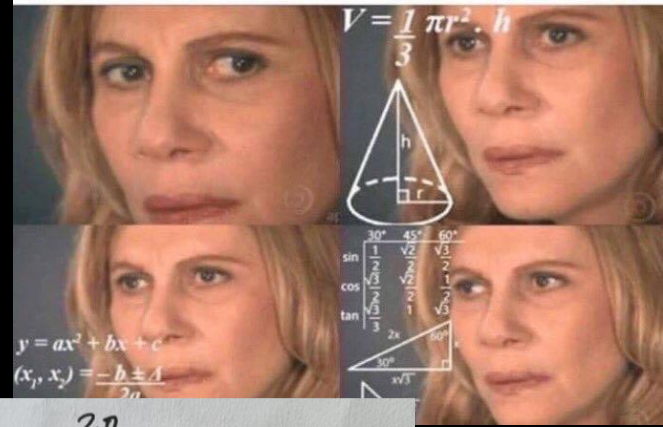
$$-2mu = (M + m)\Delta V$$

from which we get our desired result by taking that $m \ll M$:

$$\Delta V = \frac{-2mu}{M + m} \approx \frac{-2mu}{M}$$

Math Errors

Random Math Errors



$$\begin{aligned} \therefore |U| &= 2.96 \times 10^{19} \text{ kJ} \\ &= 2.96 \times 10^{16} \text{ J} \end{aligned}$$

kilo is $\times 10^3$...

$$\begin{aligned} \text{(b) } \omega_{\text{rot}} &= \frac{2\pi}{T_{\text{rot}}} && \text{Check your math...} \\ &= 0.00000082666 \text{ rad/s} \\ v_0 &= r\omega_0 \\ &= 123669.65 \text{ m/s.} \end{aligned}$$

rip.

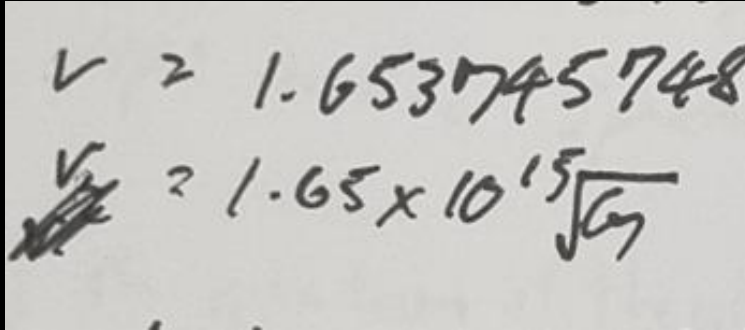
$$\begin{aligned} U &= -\frac{3GM^2}{5R} \\ &= \cancel{2.1667} \cdot 2.966151111 \times 10^{16} \end{aligned}$$

a) ff234le1 tigt years What?!

Orbital Period	ff234le1

Physics Errors

Forgetting what "G" is

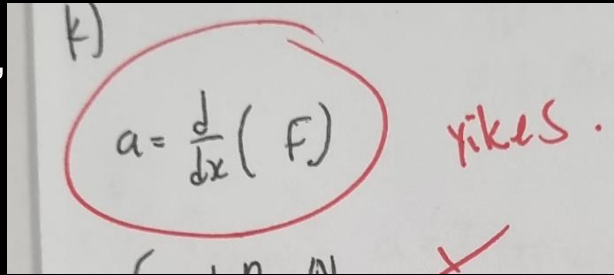


Handwritten notes showing a value for v and a formula for v_r (likely v_{rms}).

$$v = 1.6530745748$$
$$v_r = 1.65 \times 10^{15} \sqrt{G}$$

GG

Putting the NEW in NEWton's
Law



Handwritten notes showing a formula for acceleration a .

$$a = \frac{d}{dx} (F)$$

Units: Nikes

Part (B)

$$v^2 = GM \left(\frac{2}{r} - \frac{1}{a} \right)$$

(1)

(b) Calculate the $|\Delta v|$ needed to change the probe's orbit.

[3]

“Rederiving” the Vis-Viva equation

The image shows a piece of paper with handwritten mathematical derivations. The equations are as follows:

$$= -\frac{GMm}{R} - \left(-\frac{GMm}{1.6R} \right)$$
$$= -GMm \left(\frac{1}{R} - \frac{1}{1.6R} \right)$$

$-\Delta GPE = \Delta KE$ as $GPE_{start} + KE_{start} = GPE_{end} + KE_{end}$

$$GMm \left(\frac{1}{R} - \frac{1}{1.6R} \right) = \frac{1}{2} m v_{end}^2 - \frac{1}{2} m v_{start}^2$$
$$2GM \left(\frac{1}{R} - \frac{1}{1.6R} \right) = v_{end}^2 - v_{start}^2$$

On the right side of the paper, there is a vertical red line and handwritten text in red ink:

Why are you
rederiving the formula
I gave you
~

Part (B)

Using the Vis-Viva Wrongly

$$\begin{aligned}
 a & \approx v^2 \left[GM \left(\frac{2}{r_i} - \frac{1}{a_i} \right) \right] \\
 & = \left[\sqrt{GM \left(\frac{2}{1.4a} - \frac{1}{1.0a} \right)} - \sqrt{GM \left(\frac{2}{1.8} - \frac{1}{1.8} \right)} \right] \\
 & \approx 5140.66 \text{ m/s} \\
 & \approx 5140 \text{ m/s}
 \end{aligned}$$

Need to convert to metres!

$$\left(\frac{2}{1.496 \times 10^{11}} + \frac{1}{1.496 \times 10^{11}} \right)$$

Supposed to be a minus sign

$$\left(\frac{2}{(1.49597870700) \times 10^{11}} + \frac{1}{(1.49597870700) \times 10^{11}} \right)$$

$$\begin{aligned}
 v &= 6.370 \times 10^6 \times \omega \\
 v &= 6.370 \times 10^6 \times 1.99 \times 10^{-7} \\
 v &= 1.26763 \text{ m/s}
 \end{aligned}$$

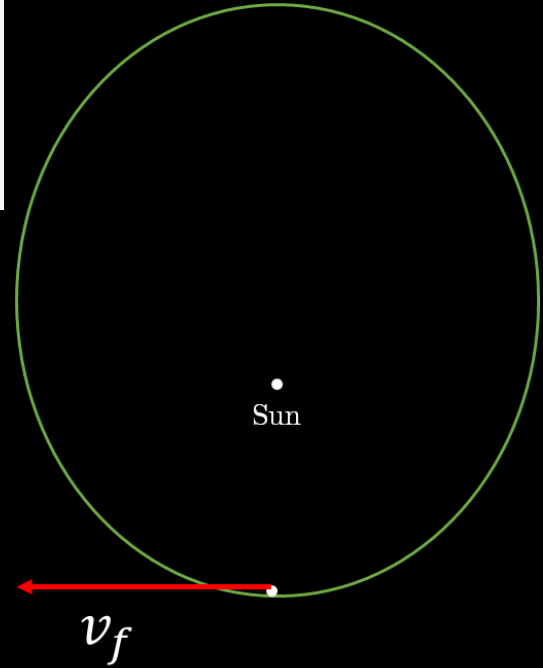
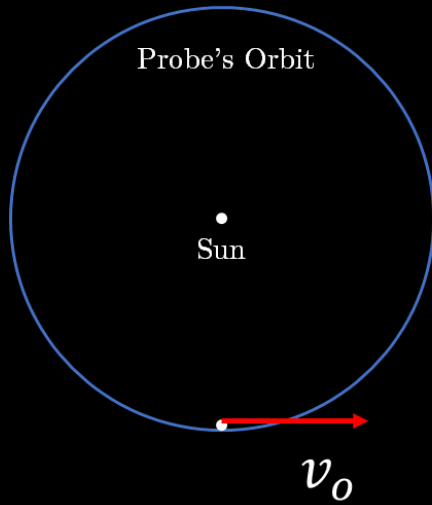
Accidentally used R_{Earth}

$$\begin{aligned}
 v_E^2 &= GM \left(\frac{2}{r} - \frac{1}{a} \right) \\
 &= (6.67384 \times 10^{-11}) (1.989 \times 10^{30}) \left(\frac{2}{6370 \times 10^6} - \frac{1}{1.496 \times 10^{11}} \right) \\
 &= 4.167656247 \times 10^{13}
 \end{aligned}$$

not supposed to be R_{Earth}

Part (B)

What is a Vector?



Part (B)

Forgetting to account for direction.

m/s , making $v_2 \approx 34930 \text{ m/s}$.

So, $|\Delta v| = |v_2 - v_1| \approx 5142 \text{ m/s}$ ~~X~~ Did not account dirⁿ!

$\Delta V = -\frac{2mu}{M}$. By the Vis-Viva

$= 2573553066 \text{ } 29786 \text{ m/s}$ ~~X~~

$\Delta v = 34929 \text{ m/s} - 29786 \text{ m/s} = \underline{5142.5 \text{ m/s}}$ ~~X~~ Forget the direction!

$|\Delta V| = 9087.68 \text{ m/s} - 5141.55 \text{ m/s (2d.p.)}$

$= 4000 \text{ m/s (3s.f.)} - 5140 \text{ m/s (3s.f.)}$ ~~X~~ Forget to account for dirⁿ.

$2mu$

“assumptions

Part (C)

(c) For a medium-sized probe of $m = 1000\text{kg}$ and using the mass of the asteroid as $2 \times 10^{15}\text{kg}$, show that the change in velocity is $\Delta V = 2.07 \times 10^{-8}\text{m/s}$.

[2]

“relationships.”

“Proof by Assertion”

justesru.com

Q2(c) $\Delta V = 2.07 \times 10^{-8}\text{m/s}$ *You cannot just state it pls.*

$$\begin{aligned}
 \text{c) } \Delta v &= \frac{2mu}{M} = \frac{2 \times 1000 \times \sqrt{GM_{\text{ast}} \left(\frac{2}{1.90519 \text{AU}} - \frac{1}{1.6 \text{AU}} \right)}}{2 \times 10^{15}} = 8.026 \times 10^{-3}! \\
 &= 0.000002069 \\
 &\approx 2.06944 \times 10^{-8} \\
 &\approx 2.07 \times 10^{-8} \text{ m/s}
 \end{aligned}$$

Please don't assert!

“Proof by Working Backwards”

$$\begin{aligned}
 \text{(c) } \Delta V &= -\frac{2mu}{M} \\
 &= \frac{-2 \times 1000 \times 2069.29}{2 \times 10^{15}} \quad \text{Wow!} \\
 &= -0.0000002069 \text{ m/s} \quad \text{Y'all worked backwards didn't you...} \\
 &= 2.069 \times 10^{-8} \text{ m/s} \\
 &\approx 2.07 \times 10^{-8} \text{ m/s}
 \end{aligned}$$

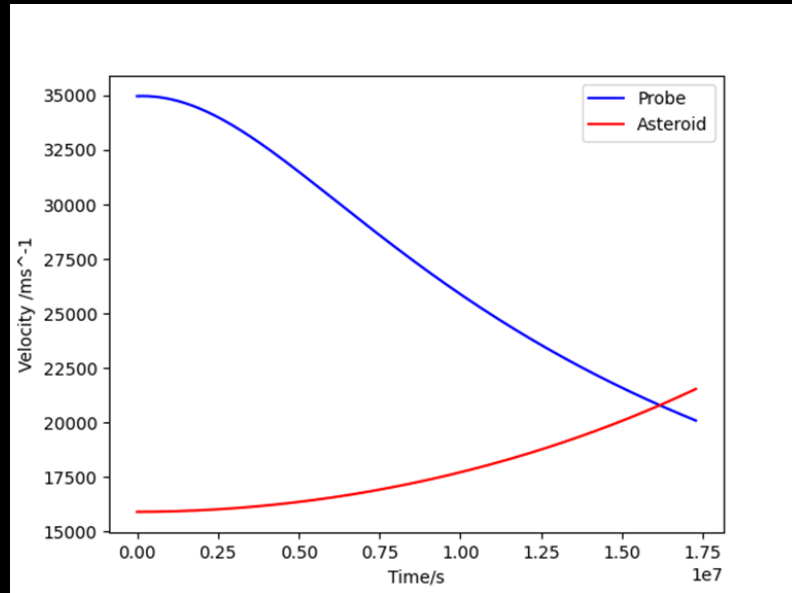
Part (D)

(d) Which assumption did we make in our analysis that caused such a underestimation in our theoretical prediction?

[2]

Some argued that gravitational effects will increase the impact

So if we were to account for it and simulate it:



```
while t < fraction*T:
```

```
xdotA = vA[i][0]
```

```
# Get the difference positional vector
dx = xP - xA
dy = yP - yA
thetaD = math.atan2(dy, dx)

# Get the respective forces
FA = -attraction(M_Alvarez, M_SUN, norm(xA, yA))
FP = -attraction(M_Probe, M_SUN, norm(xP, yP))
FCross = attraction(M_Alvarez, M_Probe, norm(dx, dy))
```

$$v_f = 20787 \text{ ms}^{-1}$$

This constitutes a 0.5% increase in velocity.

Part (F)

(f) Given the worlds' current nuclear stockpile, is it enough to gravitationally unbind the asteroid in one singular (spectacular) blast?

[2]

How many nukes do we have?

We have a lot of nuclear weapons in the world. As of early-2023, the world has around 13000 nukes[?].

(f).
100-kilotons = $4.184 \times 10^{12} \times 10^2$
= $4.184 \times 10^{14} \text{ J}$ ✓ this is for only one nuke!

Following this, $10^4 \text{ J} \times 10^4 = 10^8 \text{ J}$. This is not enough.

Part (G)

If you had been paying close attention...

(g) List two other possible (physical) pitfalls with this plan of using nukes, or other high-yield explosives, in saving the Earth from the asteroid impact.

- BLOW IT UP



Creates
more
asteroids

← You'd have seen this

- Make it shiny

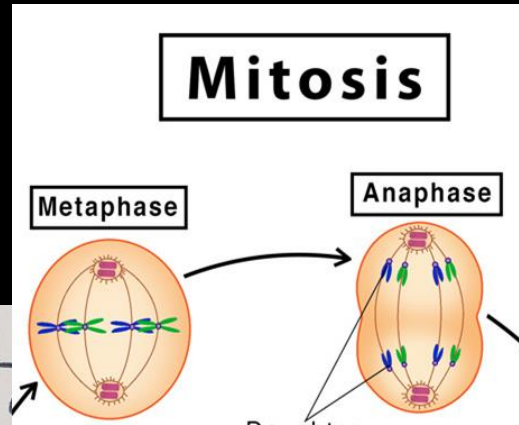
...and this line v

To blow it up, we need to add energy into the asteroid to overcome the gravitational forces holding it together. Well, technically, we also need to break the rock by overcoming the rock's elastic properties but they would have to live on another planet or in another system. So let's just consider the gravitational

Free 2 marks! Average was 0.895...

Part (G)

Still...



hobby to relax for him. ??

2 The asteroid would multiply ??

Q (g) They can simply blow up the asteroid into many ?? extremely small

atmosphere they ~~can~~ simply be dissolved ?? in the atmosphere.

receive the impact. They would have some nuclei

Solubility Rules

Mnemonic Tricks

Always Soluble
NAG SAG

Nitrates (NO_3^-)
Acetates ($\text{C}_2\text{H}_3\text{O}_2^-$)
Group 1 (Li^+ , Na^+ ; etc.)

Sulfates (SO_4^{2-})
Ammonium (NH_4^+)
Group 17 (F^- , Cl^- ; etc.)

Exceptions

PMS and Castro Bear

P (Pb^{2+} , lead)
M (mercury, Hg^{2+})
S (silver, Ag^+)

Ca²⁺
Sr²⁺
Ba²⁺

Q3

Exoplanets and Exo-Life

Choon Hean

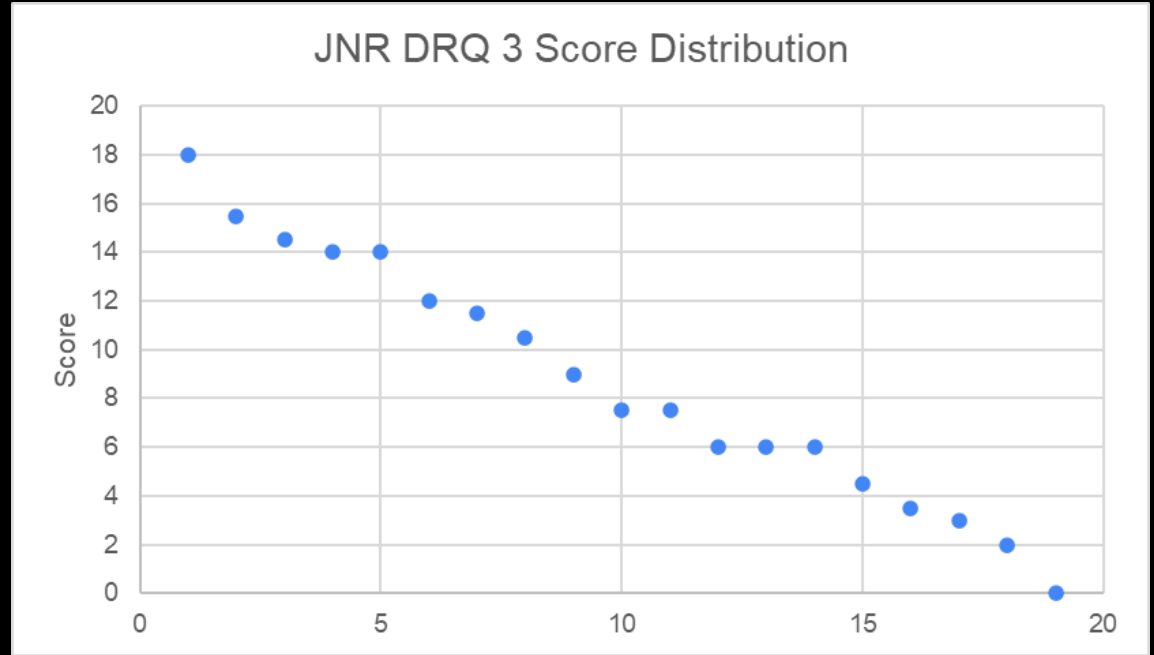


Statistics

Mean: 8.68

Median: 7.5

Hi: 18



Summary

- Test some concepts in exoplanet discovery/spectroscopy
- Some calculations with given formulae

- Relatively well-done overall (compared to the rest of the questions)
- Some careless mistakes in calculations :(ul>- Remember to check your work!

When you give up

At albedo is this stupid thing we have in Genshin Impact, and having a higher albedo made god very angry, so he blasts the planet with las





Q4

Red Spiral Galaxies at High Noon

Janani, Frederik, Ken Rui

Rationale

Astrophysics > Astrophysics of Galaxies

[Submitted on 30 Jul 2022 (v1), last revised 8 Dec 2022 (this version, v2)]

Red Spiral Galaxies in the Cosmic Noon Unveiled in the First JWST Image

Yoshinobu Fudamoto, Akio K. Inoue, Yuma Sugahara

In the first image of the James Webb Space Telescope (JWST) of SMACS J0723.3-7327, one of the most outstanding features is the emergence of a large number fraction among nearby spiral galaxies. While these apparently red galaxies were already detected with the Spitzer Space Telescope, their spiral morphology is revealed for the first time. Within the red spiral galaxies, we focus on the three most highly red galaxies that are very faint in the $z < 3$ galaxies are likely to be in the Cosmic Noon (i.e., $1 < z < 3$) and could be consistent with passive (i.e., \sim zero star-formation rates) galaxies. We discuss a potentially new population of galaxies, as we start to see their detailed morphology using JWST, for the first time. Finally, we note that the spurious galaxies contaminate to $z > 10$ galaxy samples, especially when they were faint and small.

- Introduce a recent JWST research paper result
- Guide participants through understanding the methods of the paper, the results, and its implications
- Test conceptual understanding of star formation, galaxies, and spectroscopy

- As a result, question has long background explanatory text
 - Surely people know how to read, right?

QM Postmortem (Errata)

- JWST orbits at L2 (true fact)
- But diagram shows L2 between Earth and the Sun
- What does this mean?

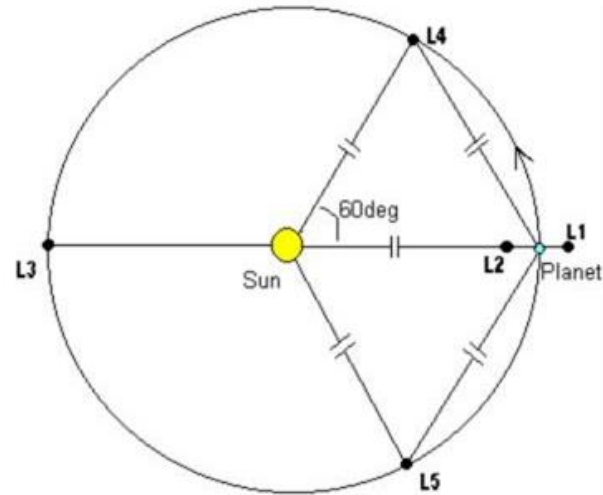
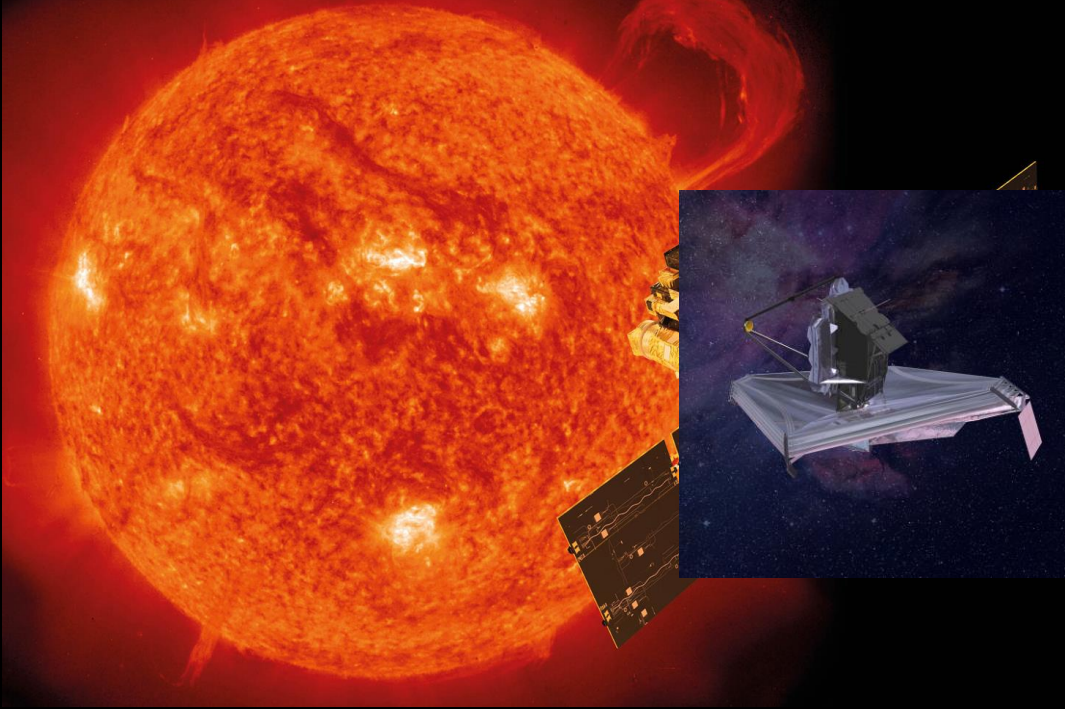


Figure 14: A diagram showing the position of the lagrange points in the Earth-Sun frame of reference

JWST, SOHO's successor



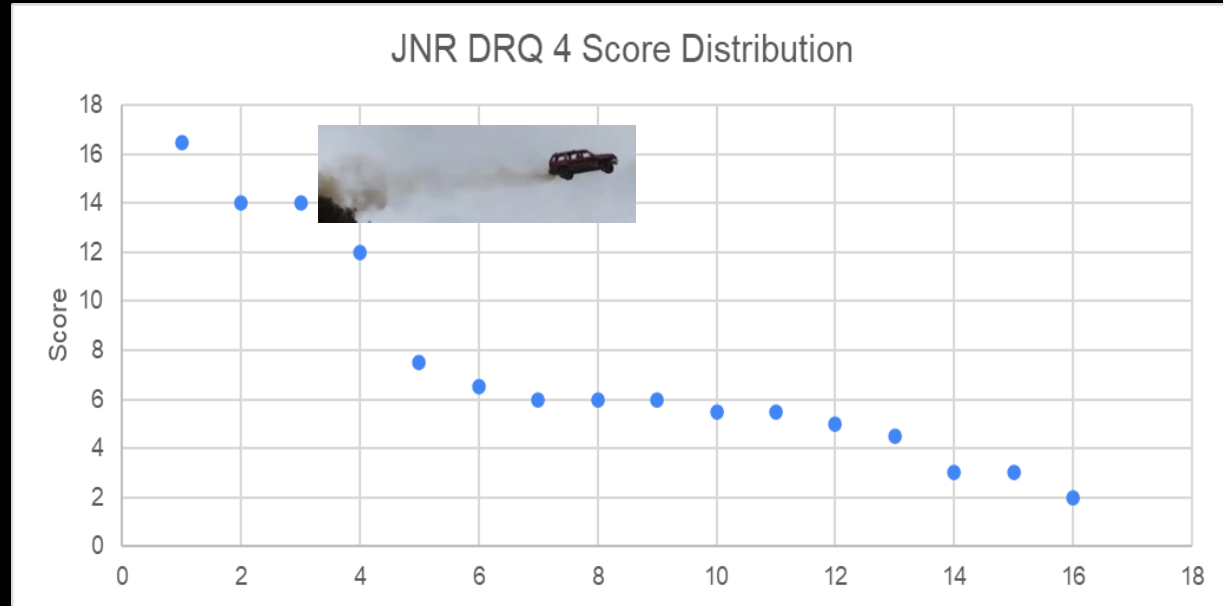
- Nobody raised this up during the DRQ btw
- Full marks given for calculations based on diagram instead of the actual L2 point
- Lesson Learnt: Don't trust everything you find on google

Statistics

Mean: 6.16

Median: 5.5

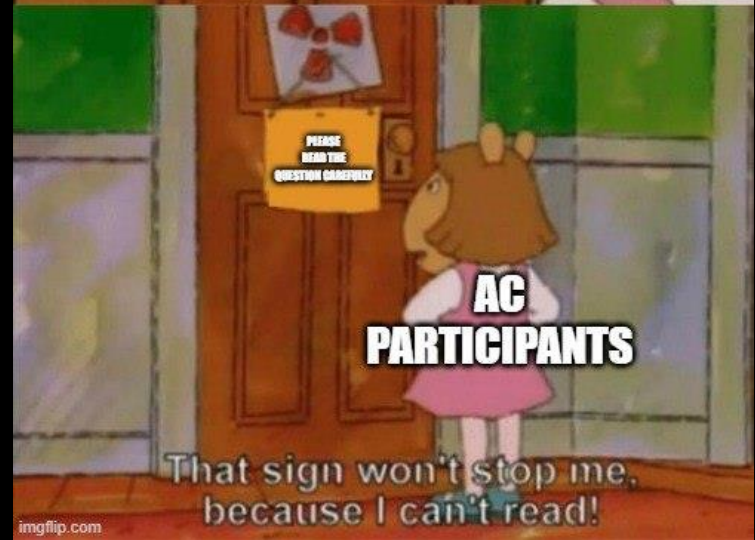
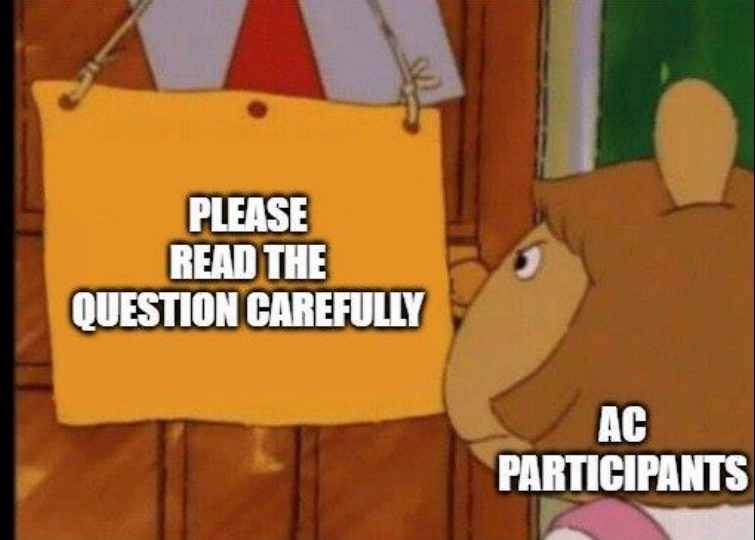
Hi: 16.5



Summary

1. Many appear shocked by the amount of graphs when checking the paper
 - a. Some realised afterwards that it is actually mostly conceptual questions (graphs are your friend!)
1. I get the impression that you are skipping all the explanatory text the QMs spent hours writing ;_;

Seems to be a persistent theme throughout the DRQ round



Surely people will read the text before the question?

When we observe the spectra of elliptical galaxies such as in Figure 16, we find that they tend to not exhibit strong emission lines like in most spiral galaxies. Instead, we mostly see the 'reverse'; strong characteristic dips corresponding to known elements which can also be used to measure redshift. To understand this, it might be helpful to recall how the spectrum of a star looks like (Figure 17).

(d) Explain how are the absorption lines of a galactic spectra mainly produced.

[1]

Starlight has distinct absorption lines!! ->

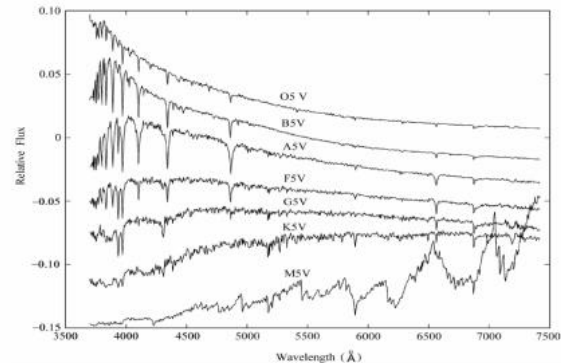


Figure 17: Examples of typical stellar spectra labeled by their Harvard spectral classification.

An unfortunately common answer

c) Clouds of dust and gas that obscure starlight in galaxies.

d) Gas in the galaxy, ~~with~~ contains elements that "correspond" to the absorption lines, i.e. light from within galaxy is absorbed by the gas, causing the absorption lines.

(d) The interstellar medium absorbs light ^{uniformly} from ~~the galaxies~~ ^{from the galaxies}. It absorbs the same wavelengths ~~from the same~~. Thus, the absorption lines ~~from~~ are from the interstellar medium.

It is called "speed of light" for a reason...

Q 4(b) Infrared is ^{the} fastest form of light NO!

Another casualty of poor reading comprehension...

- (i) Based on what was discussed thus far, state the 3 factors that could plausibly explain the red appearance of the JWST galaxies. These factors need to be accounted for or be included as parameters in the model fitting process.

[3]

Solution:

1) Redshift 2) Presence of dust 3) Old stellar population

All of these factors were painstakingly introduced and explained as you progress throughout this question!

(a) Given the information above, derive an equation on how we can find the distance between Earth and JWST. You do not need to make numerical calculations nor provide a neat RHS equation (i.e., $r = f(x,y,z)$) [2]

Exemplary Answer

Correct binomial expansion and approximation for L2 distance in terms of m , M and R_{earth}

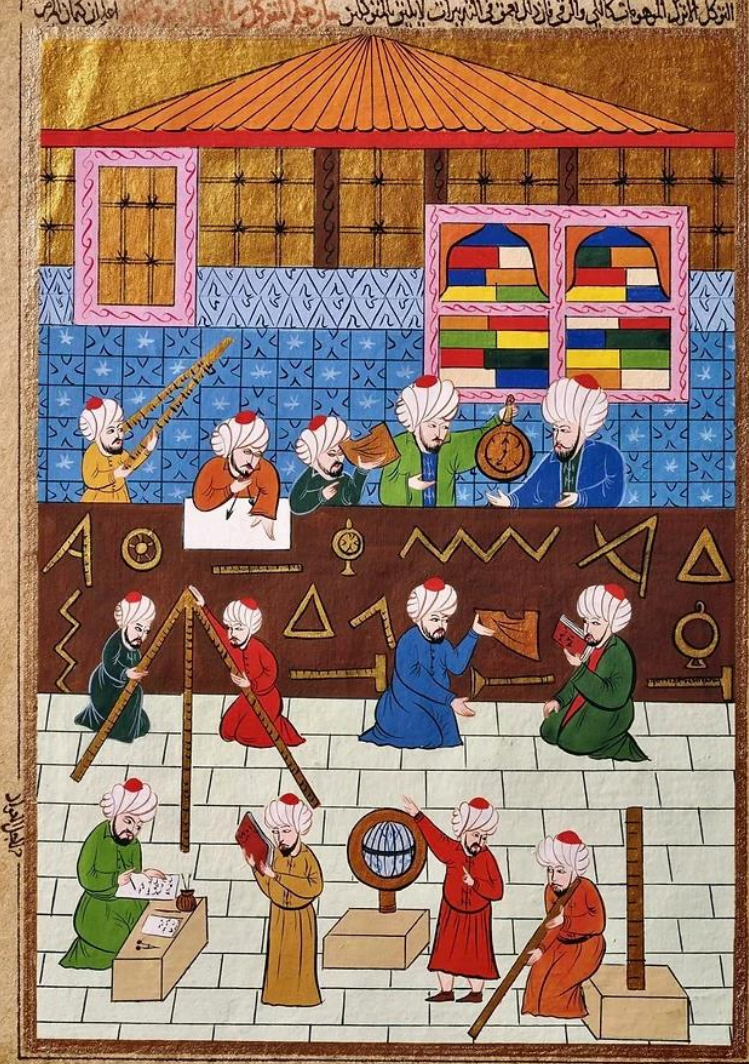
No extra credit though :(

This is actually why we only require you to write the correct equality without solving

$(R-x)^{-2} = \frac{1}{(R-x)^2} = \frac{1}{R^2} + \frac{2x}{R^3} + \dots$
 $\frac{GM}{(R-x)^2} - \frac{Gm}{x^2} = (R-x)\omega^2$
 $x \ll R, \frac{1}{(R-x)^2} \approx \frac{1}{R^2} + \frac{2x}{R^3}$

$\frac{GM}{(R-x)^2} - \frac{Gm}{x^2} = (R-x)\omega^2$
 $G \left(\frac{M}{R^2} + \frac{2xM}{R^3} - \frac{m}{x^2} \right) = (R-x)\omega^2$
 $\frac{GM\omega^2}{R^2} = mR\omega^2$
 $\omega^2 = \frac{GM}{R^3}$
 $G \left(\frac{M}{R^2} + \frac{2xM}{R^3} - \frac{m}{x^2} \right) = (R-x) \frac{GM}{R^3}$
 $\frac{M}{R^2} + \frac{2xM}{R^3} - \frac{m}{x^2} = \frac{(R-x)M}{R^3}$
 $Mx + 2Mx - \frac{mR^3}{x^2} = MR - Mx$
 $2Mx = \frac{mR^3}{x^2} - Mx$
 $3Mx = \frac{mR^3}{x^2}$
 $x = \sqrt[3]{\frac{mR^3}{3M}}$ nice.

The question actually only needs you to write up until your 2nd line, but good job on the expansion approximation!



Q5

Arabic Astronomy

Kia Yee

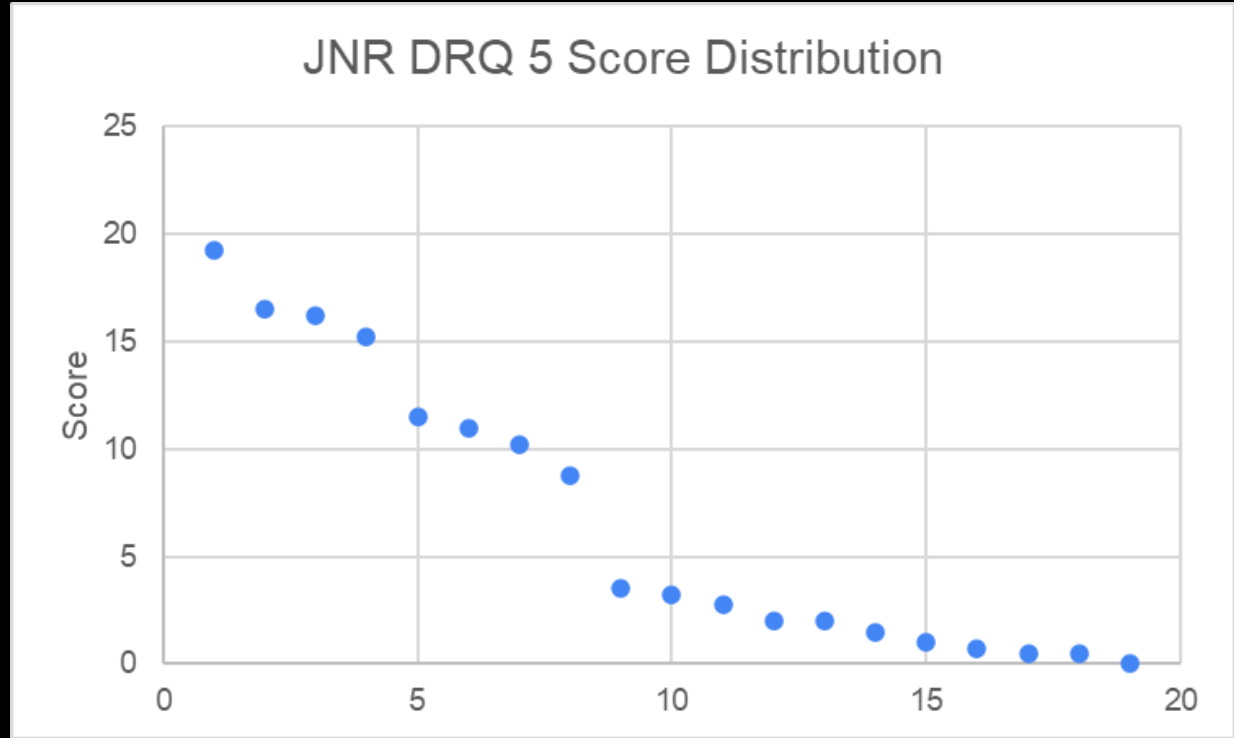
Statistics

Removing NIL Attempts

Mean: 6.66

Median: 3.25

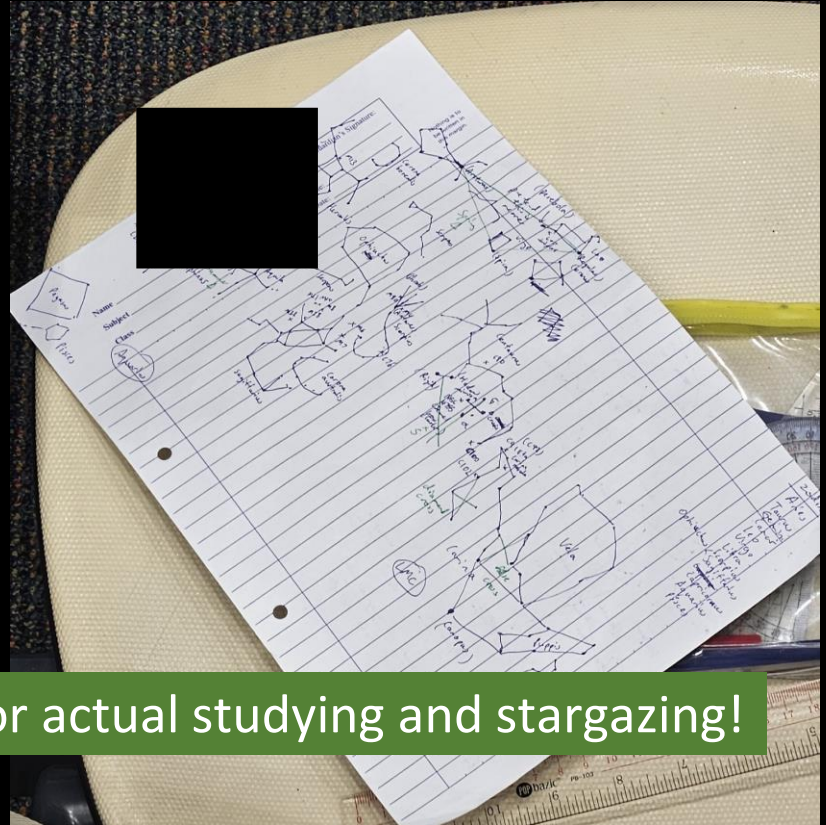
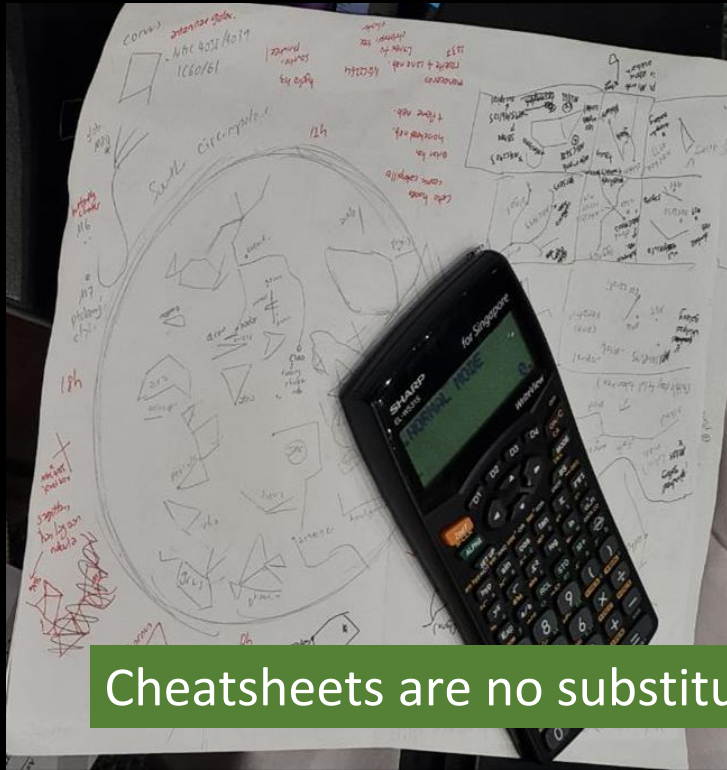
Hi: 19.25



Overall comments

- Performance for this question was highly varied
 - Average score for this question was 6.66 marks, which lies in the middle of the Junior Team round Questions
 - However, this question had a median of only 3.25 marks, which is the lowest median among all Junior Team Round Questions.
- My guess is that many teams were shocked by all the Arabic names and unfamiliar constellations that appeared...
 - Many of our modern star names however are transliterations of these Arabic names, so reading those names out aloud would probably have clued you in to the answer.

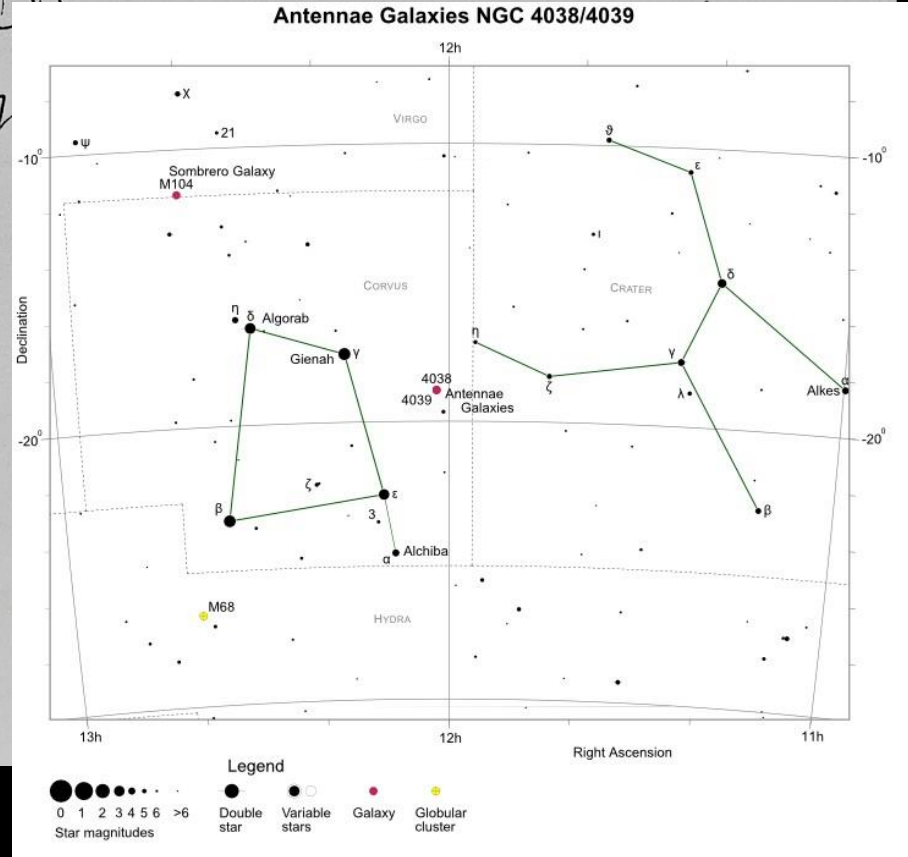
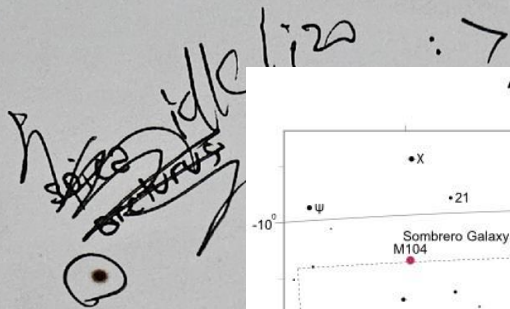
The best scoring teams came well prepared...



Cheatsheets are no substitute for actual studying and stargazing!

Case in point

- Out of this team's perfect star chart analysis was this errant marking.
- I thought this couldn't possibly be correct so I went to check it up.
- Thank you NYGH1 for educating me about the Antennae Galaxies!



Some interesting attempts

Thank you for trying :D

What “camels” could Aldebaran be herding?

- Idea of the question: what objects could stargazers in the 8th Century observe?



f) Omicron retula. ??

f) Pillars of creation ??

Please read instructions

- Part VI states that you were supposed to attempt it on the next page

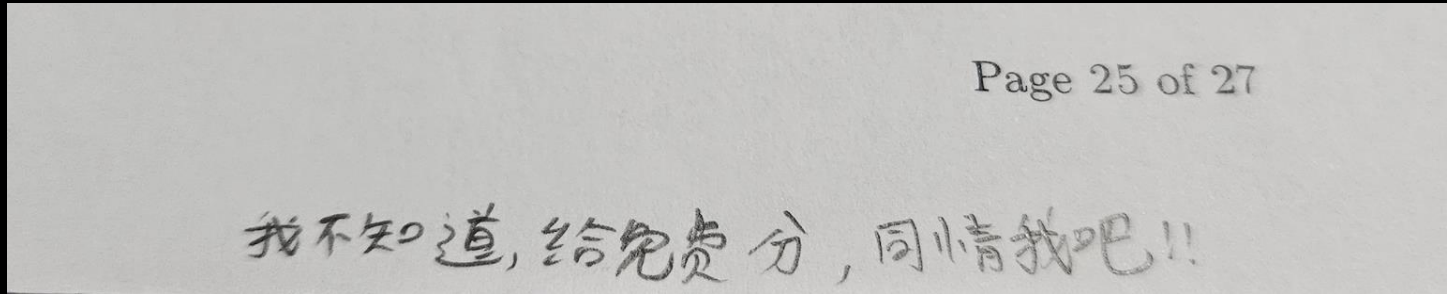
Part VI Star Chart Analysis

A 1-page sized replica of Figure 23 is attached on the next page. You are to mark your answers on the image directly. Remember to detach the page and staple it to your answer script as part of your submission.

- A team however decided to attempt it on the wrong page...

Please read instructions

- Clearly the team realized their mistake at the last moment, because someone wrote this...



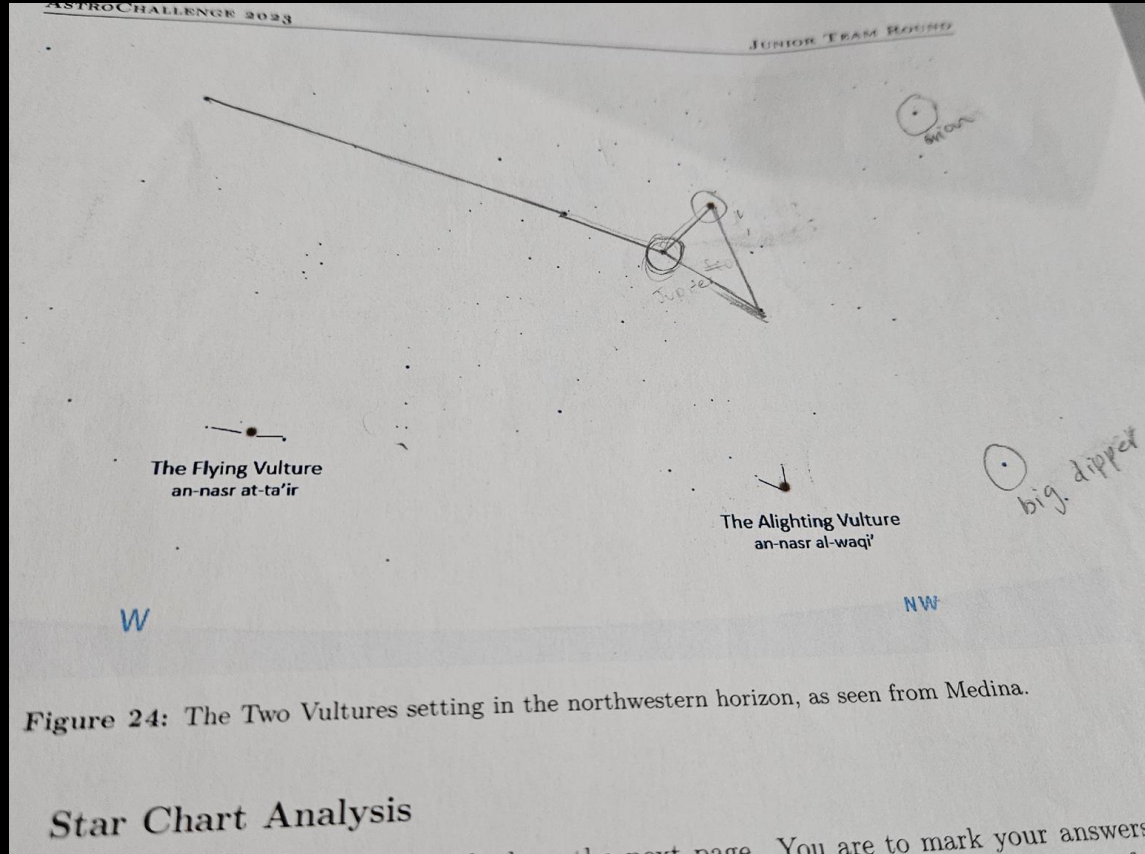
Translation: I didn't know, please give me free marks and pity me!!

- Marker's first thought : Saya tak tahu cina?!?

Translation: I don't know Chinese?!?

Please read instructions

- Out of kindness, the marker did try to see if any marks could be awarded
- Thank you for the attempt at drawing a Big Dipper



Moral of the story

世界上没有免费的东西...

Translation: There are no free things in this world...

More seriously:
do read instructions!

Thanks for trying, and I hope you learnt something from this question!

5.2 Senior DRQ

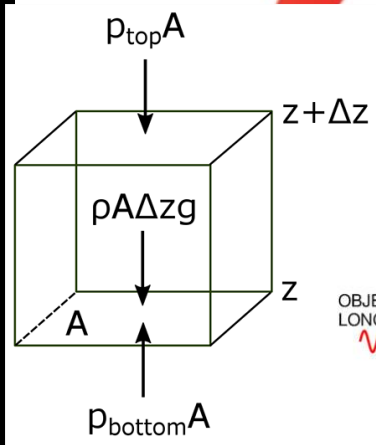


~~5.2 Senior DRQ~~

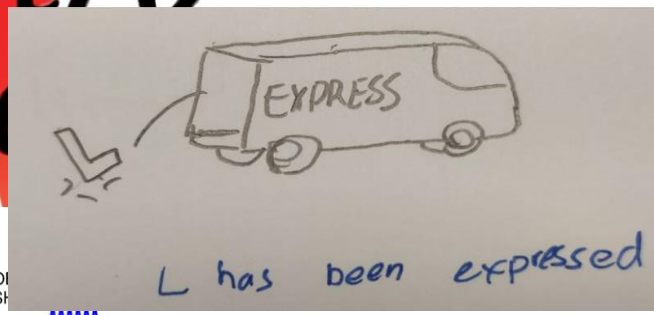
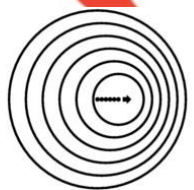
AC Trauma Support Network



Astro



OBJECT RECEDING:
LONG RED WAVES



LIVE TUCKER REACTION



How to fumble the bag 101

1. See unfamiliar* topics
2. mfw not written on your cheat sheet
3. TRY NOT TO PANIC!
4. ...
5. Start laughing like a maniac in the middle of the LT



*Note: unfamiliar doesn't always mean difficult!

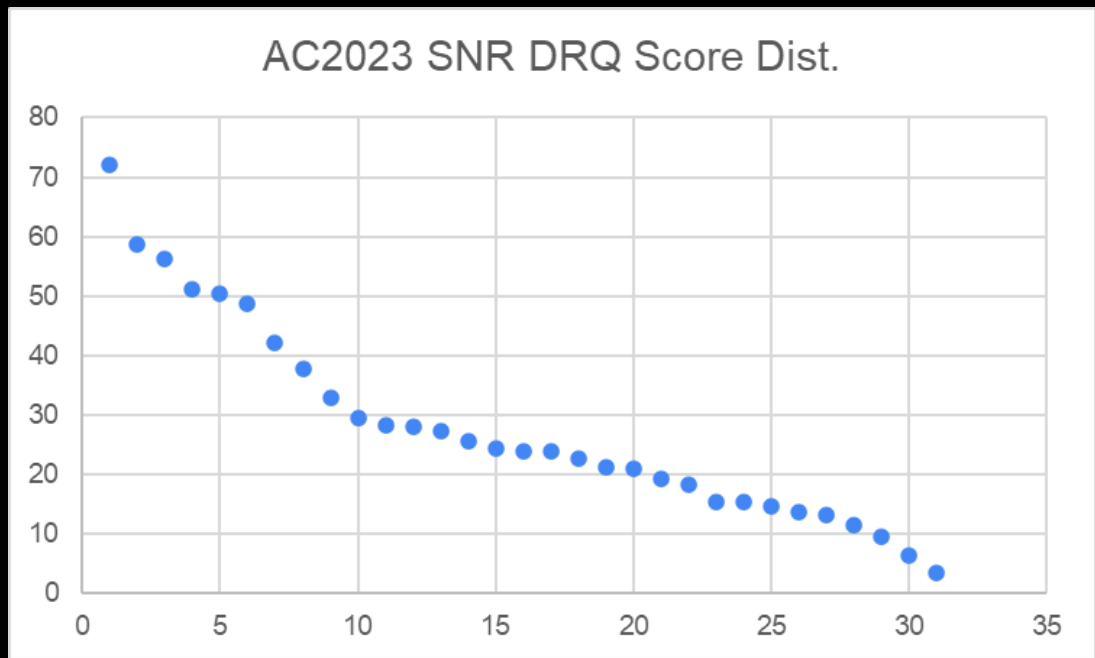
Statistics

Raw Scores

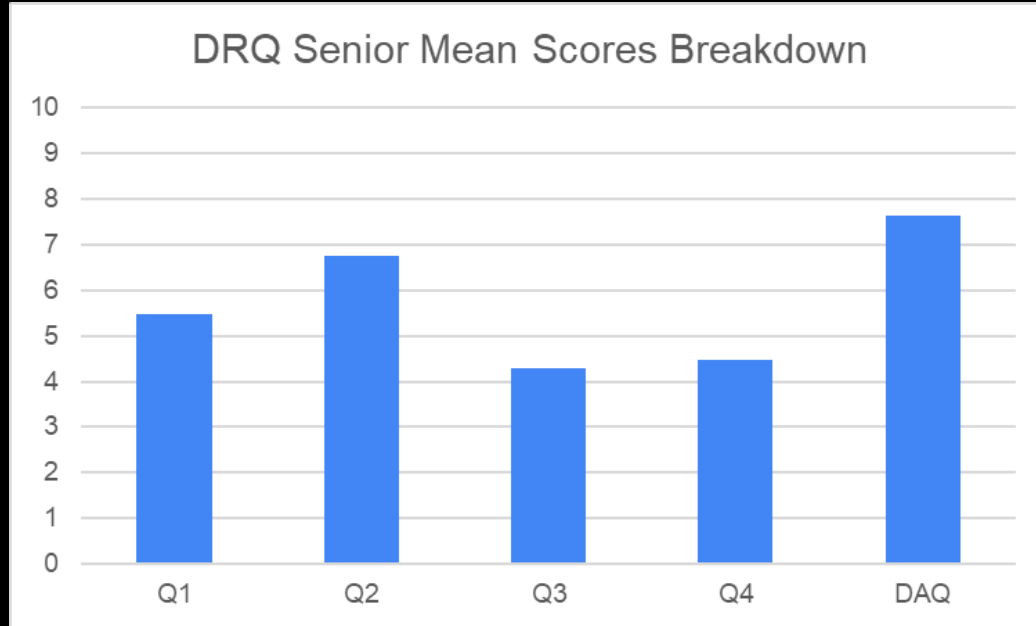
Mean: 28

Median: 24

HI: 72



Score Breakdown





Q1

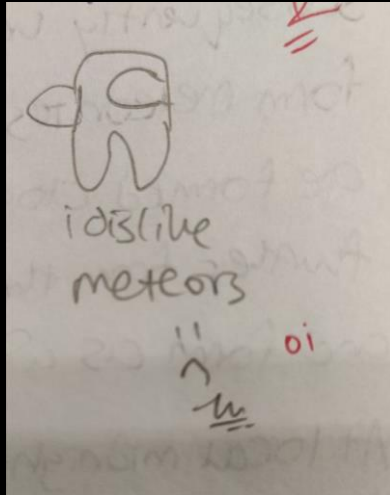
Wishing Upon a Star

Kaiwen

Summary

- Expectation: Friendly conceptual stargazing + solar system question to ease people in.
 - Fun fact: this question was originally meant for the juniors

- Reality:



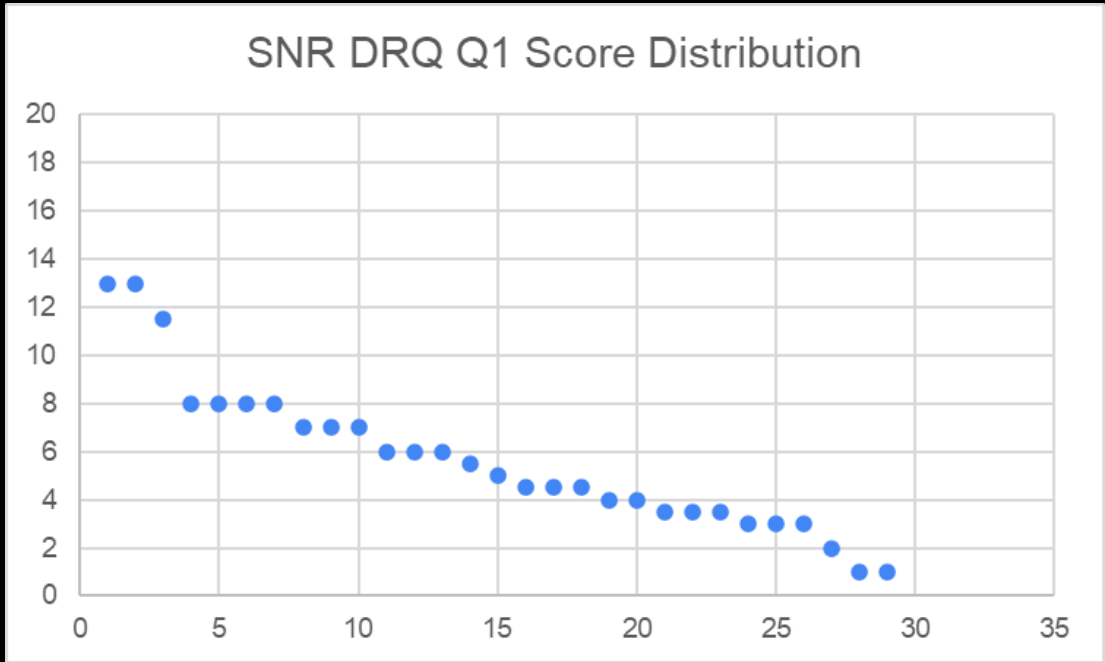
Statistics

Removing NIL Attempts

Mean: 5.3

Median: 4.5

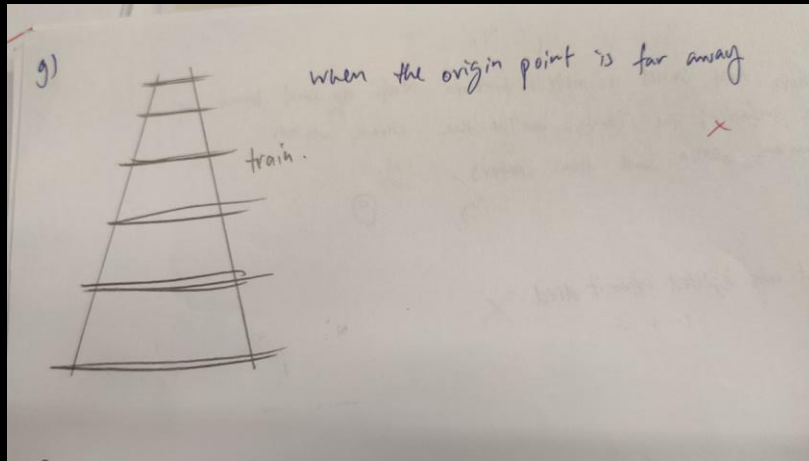
Hi: 13



(g) Why do meteor showers originate from a radiant point? (Hint: Think about train tracks)

[2]

- Expectation: surely people understand how train tracks work?



brightness might not always translate to its good visibility. X

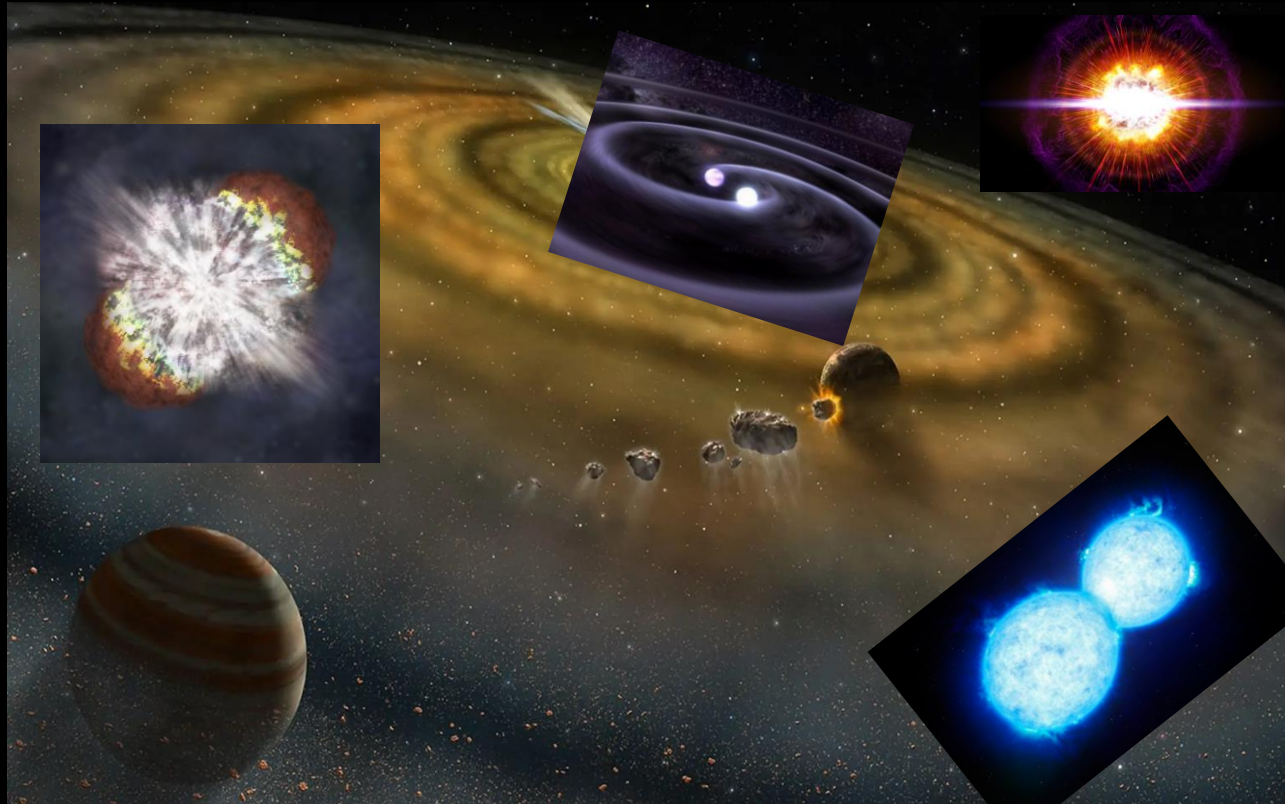
All the visible meteors seem to be coming from a single point due to how this is the point where, taking the viewer's position on Earth into consideration, the Earth's orbit around the sun intersects with the comet's orbit littered with meteoroids. From that point it seems to diverge due to the deviation of the meteoroid paths from each other as they enter the Earth's atmosphere. X

(b) Most meteorites are believed to originate from the early solar system. Given their origins, explain how the three types of meteorites might be formed during the early solar system.

- Expectation: surely people know the history of the solar system?

cb) | Stony meteorites: are formed ~~when~~ from the collision of stars
Iron meteorites: are formed from when major stars become supernova.

The early solar system must be a hectic place...



When you give up - 2nd season 1st cour

j) Every 33 years, Saitama sensei travels to $\frac{1}{4}$ the Leonids ~~and~~ and causes a supernova at one of the comets, releasing a galaxy-level explosion, causing a spike in ZHR. X



When you give up - 2nd season 2nd cour

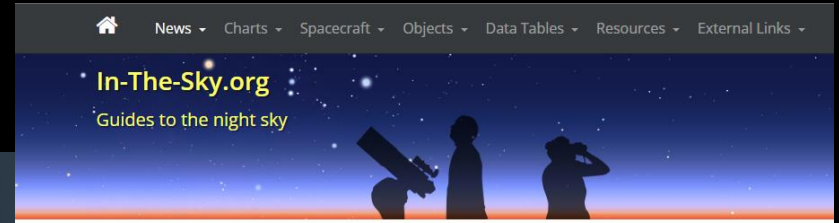
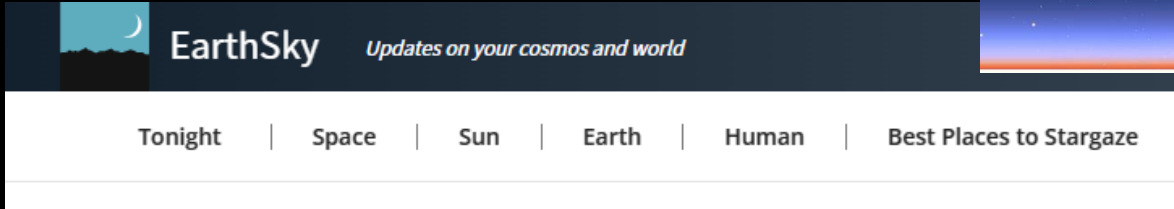


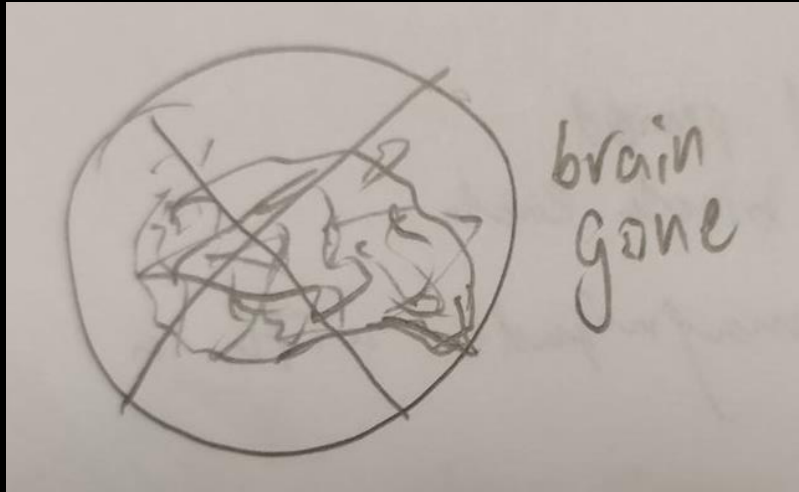
o.o

Given that every 23 years, the universe momentarily stops, this results in a momentarily surge in acceleration of these Leonids in 2HR, hence they will be concentrated and therefore a large spike, thus a meteor storm. ✗

Remedy

- Read popular astronomy/stargazing articles!





Q2

Twinkle Twinkle Little Star
in the Great Nebula

Jerry

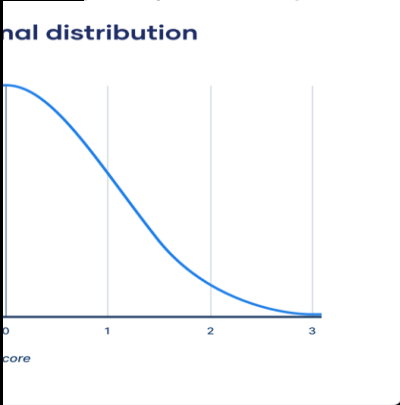
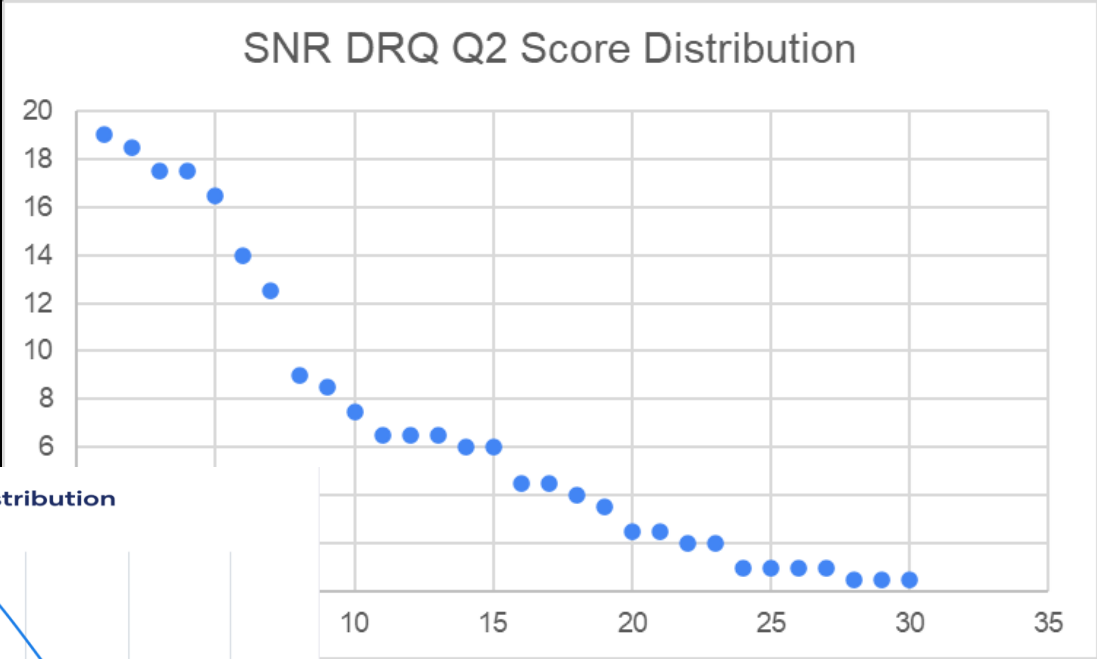
Statistics

Removing NIL Attempts

Mean: 6.5

Median: 4.5

Hi: 19



Summary

- (Surprisingly) Most well-done question
- Many saw through the first integral as a bluff (it's just the Stefan-Boltzmann Law!)
 - The second integral was not a bluff though, so most people died

(g) Write down the integral for the total time τ for a sound wave to travel the diameter of a star, solve it and show that the period of oscillation is given by:

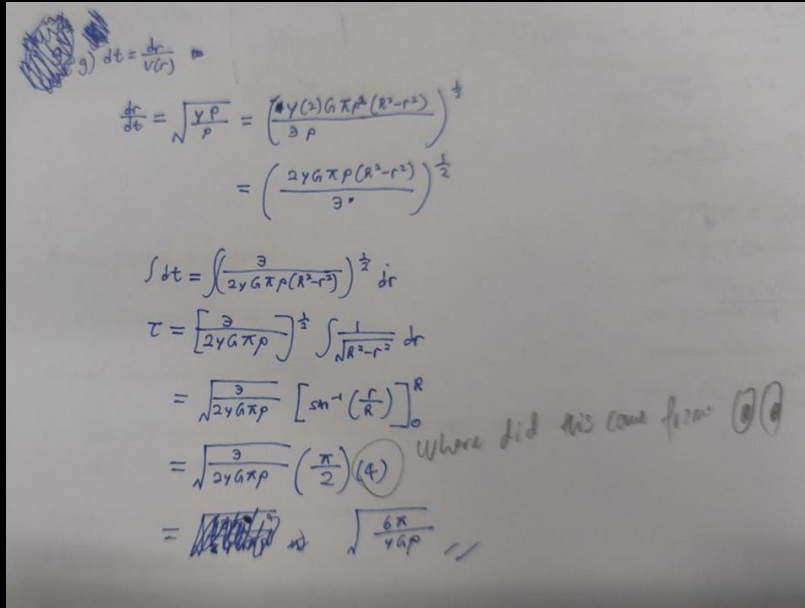
$$\tau = \sqrt{\frac{6\pi}{\gamma G \rho}}$$

This will come in handy:

$$\int \frac{1}{\sqrt{R^2 - r^2}} dr = \sin^{-1} \left(\frac{r}{R} \right) + c.$$

- Takeaway(?): Most SNR participants are still more comfortable with math than astronomy :(

Quick Note: Don't underestimate your marker



Handwritten derivation showing the steps to find the Schwarzschild radius. The derivation starts with the equation $dt = \frac{dr}{v(r)}$ and proceeds through several steps, including the use of the Schwarzschild metric and the definition of the Schwarzschild radius R . The final result is $R = \frac{2GM}{c^2}$.

$$g) dt = \frac{dr}{v(r)}$$
$$\frac{dr}{dt} = \sqrt{\frac{v(r)}{p}} = \left(\frac{2\gamma G \pi \rho (R^2 - r^2)}{3\rho} \right)^{\frac{1}{2}}$$
$$= \left(\frac{2\gamma G \pi \rho (R^2 - r^2)}{3\rho} \right)^{\frac{1}{2}}$$
$$\int dt = \left(\frac{3}{2\gamma G \pi \rho} \right)^{\frac{1}{2}} \int \frac{1}{\sqrt{R^2 - r^2}} dr$$
$$\tau = \left[\frac{3}{2\gamma G \pi \rho} \right]^{\frac{1}{2}} \int \frac{1}{\sqrt{R^2 - r^2}} dr$$
$$= \frac{\sqrt{3}}{\sqrt{2\gamma G \pi \rho}} \left[\sin^{-1} \left(\frac{r}{R} \right) \right]_0^R$$
$$= \frac{\sqrt{3}}{\sqrt{2\gamma G \pi \rho}} \left(\frac{\pi}{2} \right) (4)$$

Where did this come from? (4)

$$= \frac{\sqrt{3}}{\sqrt{2\gamma G \pi \rho}} \cdot \frac{\pi}{2} \cdot 4 = \sqrt{\frac{6\pi}{\gamma G \rho}}$$

- One team tried to sneak in a random factor of 4 so that their final derivation matches the answer.

When you give up - OVA

(e) $p(r)$ is smaller the larger $m(r)$ is. X

(d) $\frac{dp(r)}{dr}$ = Good question. Good answer.

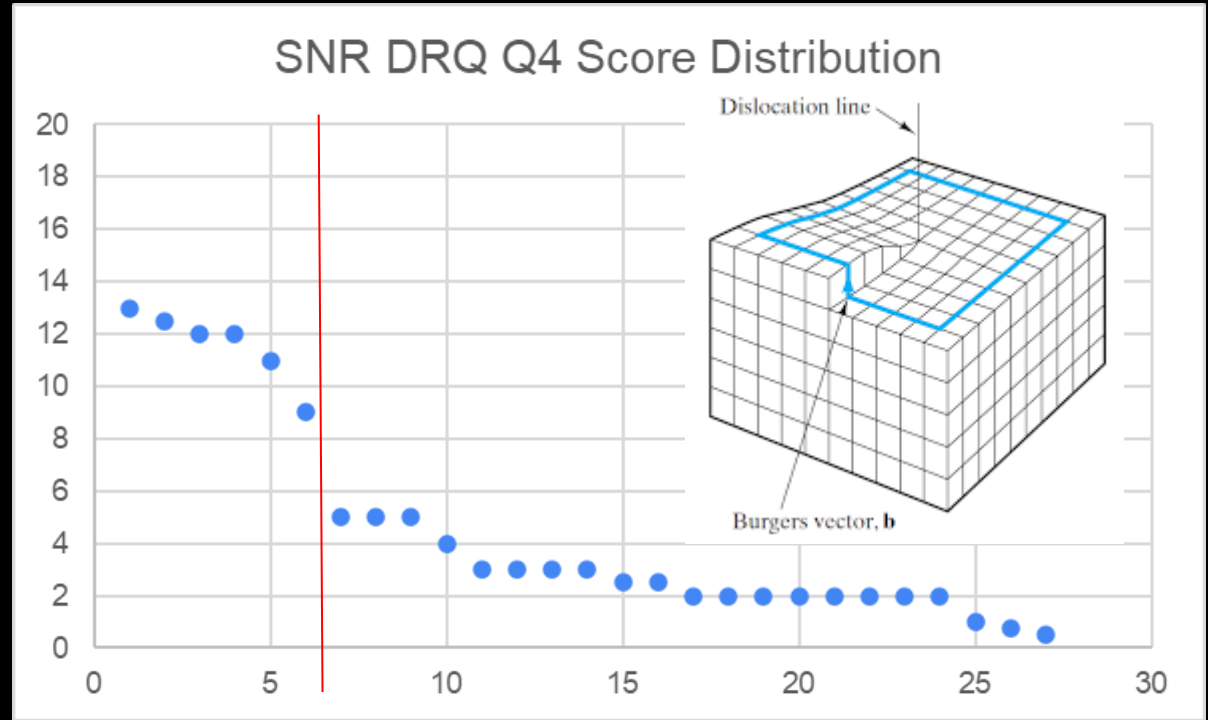
Statistics

Removing NIL Attempts

Mean: 4.1

Median: 2.5

Hi: 13



Live replay of AC senior participants reactions

(a) Given the above simplifying assumptions, calculate the orbital velocities of both Jupiter and Earth. Express your answers in km s^{-1} .

[1]

(b) How long will it take before Saitama is able to see Jupiter at opposition again?

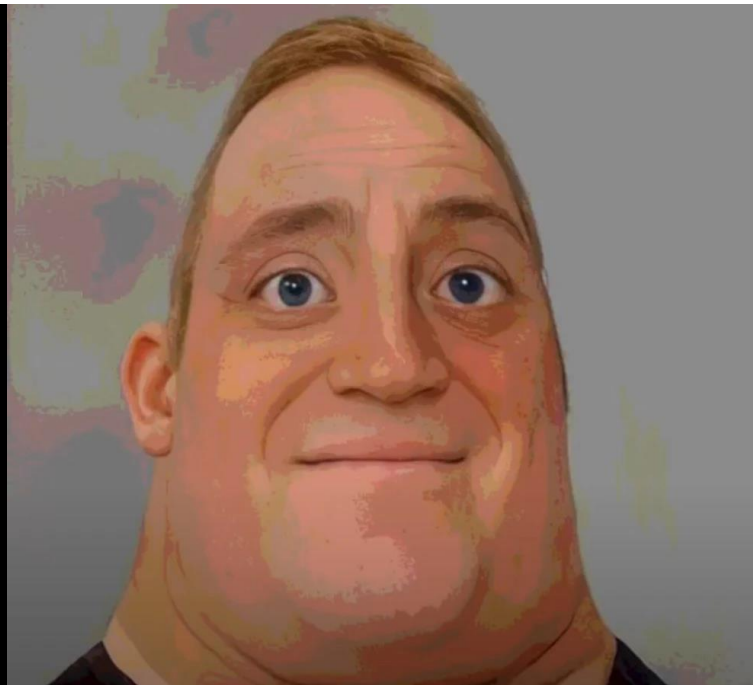
[2]



(c) By considering energy and momentum conservation, show that $V_{E_f} \approx 2V_J + V_E$.

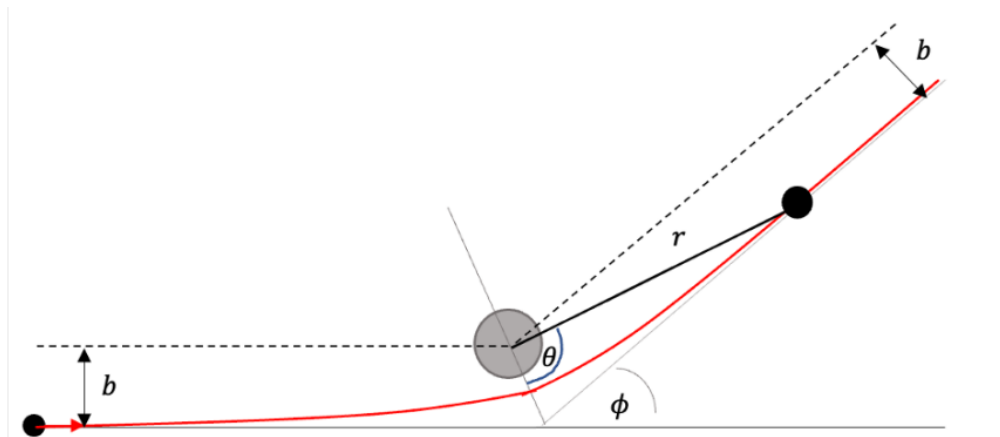
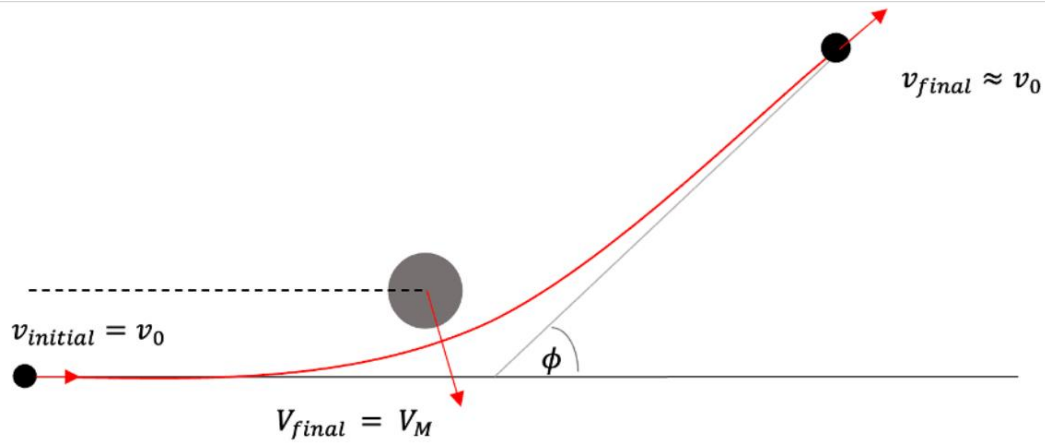
(d) Given that $V_{E_f} \approx 2V_J + V_E$ in the one-dimensional case, derive the expression for V_{E_f} for the two-dimensional case in terms of θ , M_J and M_E .

[3]



This relatively simple derivation should give us some intuition about the boost from slingshotting around Jupiter. However, notice that the specified angle at which the earth approaches Jupiter, θ , this does not describe the earth (imagine displacing the earth while leaving its velocity unchanged) result in a different trajectory, but our derivations do not take the symmetry requirement, we have already made a particular assumption to describe the trajectory of Earth, we need a few more ingredients





(e) Express the angular momentum L and total energy E of the small mass m in terms of the initial speed of the small body v_0 and the impact parameter b . [2]

(f) Thus, express the constant C and eccentricity e as given by (6) in terms of the mass of the large body M , v_0 and b . [1]

(g) From equations (5) and (6), derive the expression for r_m , the closest distance of mass m and mass M as mass m moves along its trajectory, in terms of M , v_0

$$\phi = 2\theta_{max} - \pi$$

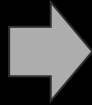
(h) Thus, derive the expression for the deflection angle ϕ in terms of v_0 , b , and M .



Important PSA

- This is frankly a very difficult question
 - Don't be disheartened if you couldn't do it...it is not really an astronomy question either

Lvl 1: Plug in formulae
and press calculator



Lvl 2: COM/COE
(A lvl Physics)



Lvl 3: Parametrizing the
trajectory of an object
(Uni Phys/Eng)

Derivations can be challenging

i) $v_m = v_0 \frac{m}{M} \sqrt{2(1 - \cos \phi)}$ prove this



→ $v_m =$ loss of ~~mass~~ momentum of
mass big

$$= v_0 \frac{m}{M} \sqrt{2(1 - \cos \phi)}$$

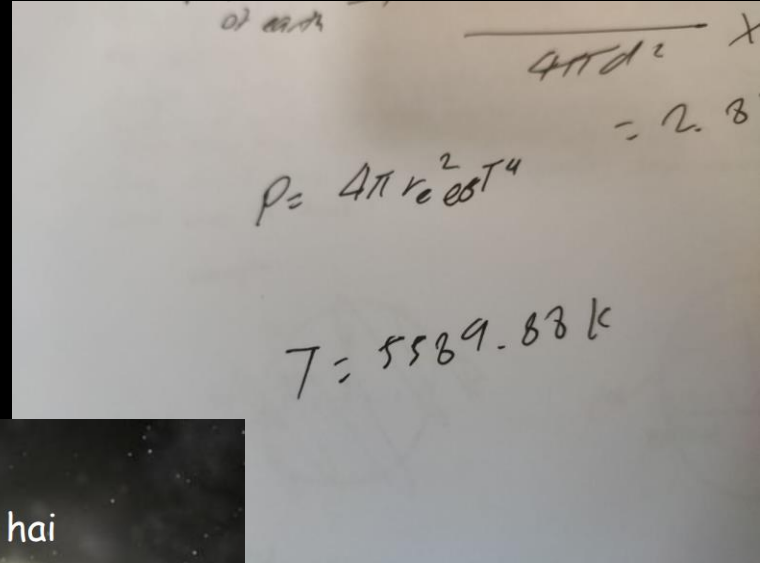
Most rigorous physics derivation

How to spot calculation mistakes

- Develop physical intuition (takes time)
- Check order of magnitudes
 - (there is an estimation round in finals for a reason!)

How hot can a planet be?

- $T = 5389.83 \text{ K}$ (too many s.f.!!)
- Surface of the Sun: 5772 K



Handwritten mathematical derivation on a piece of paper. At the top, there is a faint "of earth" and a fraction $\frac{4\pi r_e^2}{4\pi r_s^2}$ with an "x" to its right. Below this, the equation $\rho = 4\pi r_e^2 \epsilon \sigma T^4$ is written. To the right of this equation, there is a note "= 2.8". At the bottom, the result $T = 5589.83 \text{ K}$ is written.



How hot can a planet be? #2

- $T = 215935 \text{ K}$ (40 times hotter than the surface of the sun!)
- The culprit: Orbital radius calculated to be 4×10^5 metres
- Radius of the Sun: 7×10^5 kilometres

b) $\frac{GM}{r^2} = \frac{v^2}{r}$

$v = \sqrt{\frac{GM}{r}}$

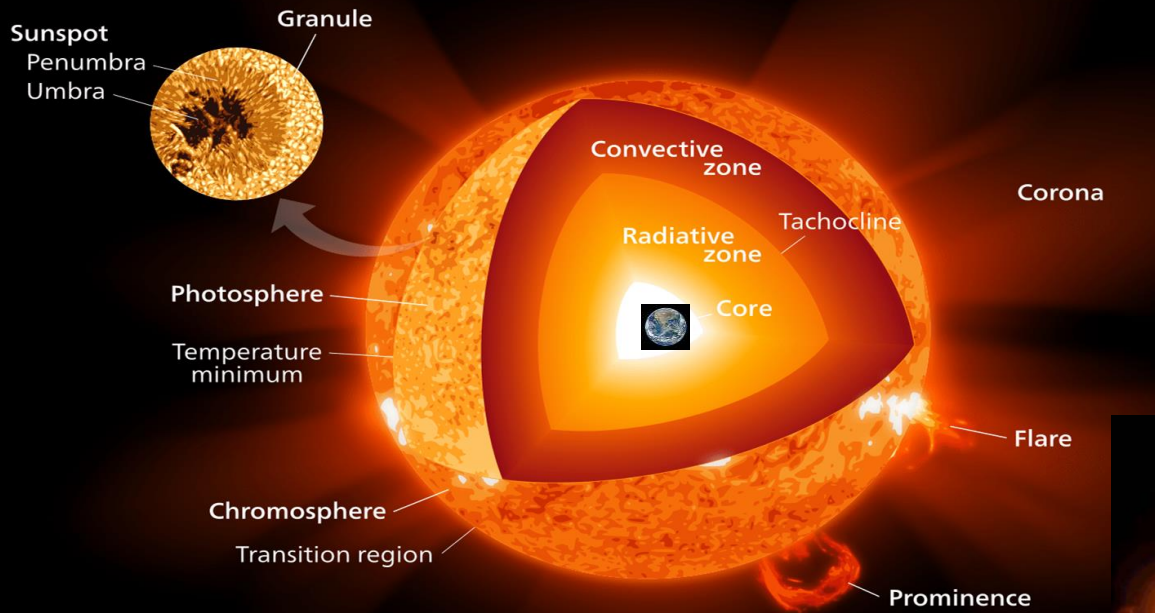
$= \sqrt{\frac{6.67 \times 10^{-11} \times 1.5 \times 1.989 \times 10^{30}}{(80 \text{ m})^2}}$

$= 470222 \text{ m}$

$T = \left(\frac{(80 \times 1.2)^4 \times (1.3 \times 696340 \times 10^3)^2}{4(470222)^2} \right)^{1/4}$

$= \cancel{216 \times 10^4} \cdot 215935 \text{ K}$

No. It's too ~~high~~ high.



Turns out the estimate of 215935K is a tad low...



Contestants from the Junior DRQ

~~radiated by sun~~
Intensity of sun = $4\pi (6.963 \times 10^8)^2 \times 5.67 \times 10^{-8} \times 5770^4$

Temperature of Earth = $\sqrt{\frac{\sigma_{sun}(1 - 0.3)}{16 \times 5.67 \times 10^{-8} \times \pi \times 3.843 \times 10^8}}$

= 703340.9874k X

Earth's temperature is 700000K? Are you sure
cited surface Temperature is lower since there is the presence
of human activity that has resulted in global warming and a
increase in greenhouse gas emission

Is this our highest bidder?

- 1×10^{12} Kelvins

= 1 million X



$$(i) \quad v_m = v_0 \frac{m}{m'} \sqrt{2(1-\cos\theta)} \quad \# \quad (5h)$$

Part IV: Habitable Zone



$$(5) \quad 1000000000000000000^\circ \text{C} \quad \#$$

$$(14) \quad 50^\circ \text{C} \quad \# \quad \text{Yes it does.}$$

Throwback Time! (see AC2016 PM)

ULTIMATE PLANET



A new foe has appeared!

CHALLENGER APPROACHING



Our grand winning bid:

Handwritten calculations on a piece of paper:

$$P = \pi (6.96340 \times 10^8)^2 \times 1 \times (5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4})^4$$
$$= 9.995629375 \times 10^{25}$$

equilibrium $T = 9.995629375 \times 10^{25} \times (365.24 \times 24 \times 60 \times 60)$

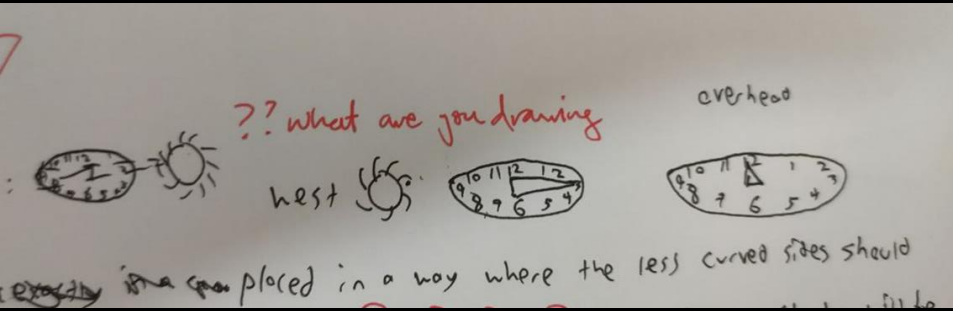
$$\approx 2.996509116 \times 10^{33} \text{ J}$$

- Temperature is 10^{33} Joules?
 - This actually makes sense in plasma physics for electron temperature!
- Let's do a conversion:
- 1 eV = 11605 Kelvin
- 1 J = 6.2×10^{18} eV
- 10^{33} J = 1.1×10^{55} Kelvin

How hot is 10^{55} Kelvin?

- Temperature at the start of the big bang: 10^{10} Kelvin
- = 10^{45} big bangs
- Lesson: Units matter!
(a lot)





Q4

An Afternoon at the Sundial Garden

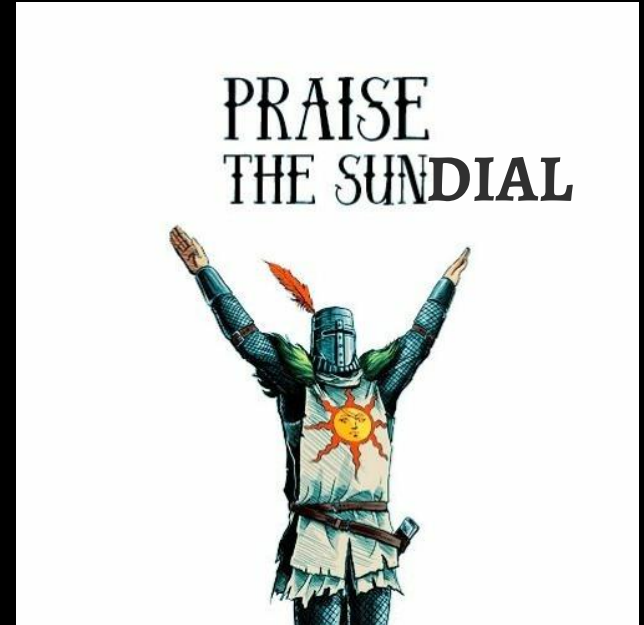
Ken Rui

Rationale

- Historical role of astronomy in timekeeping
- Focus on concepts rather than math
- Filter those who can do physics but not astronomy

Reality:

- Everyone got filtered



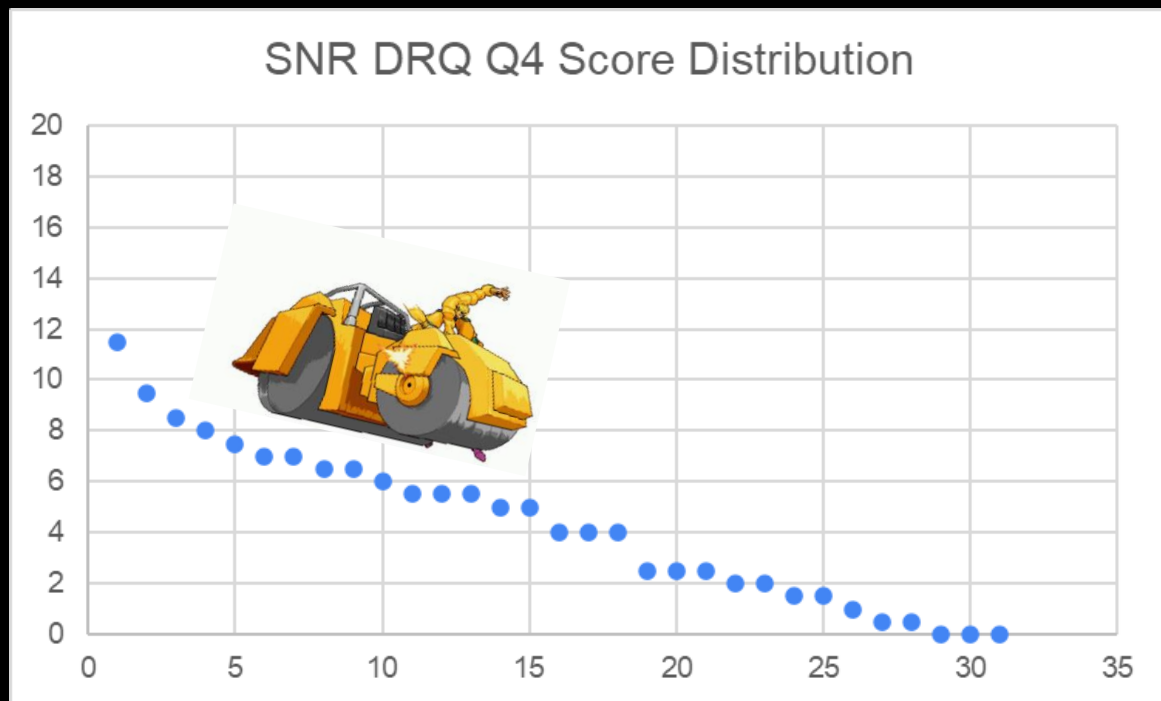
Statistics

Removing NIL Attempts

Mean: 4.32

Median: 4

Hi: 11.5



Killer Question (most zeros)

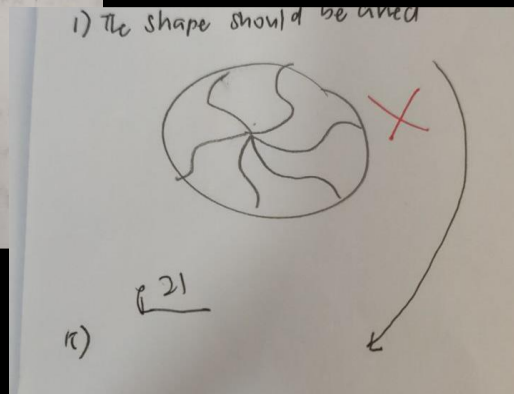
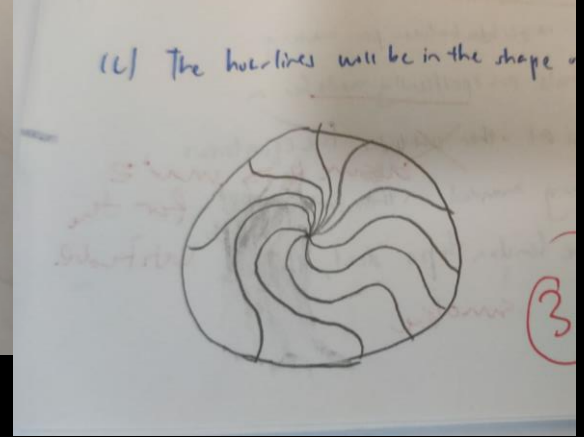
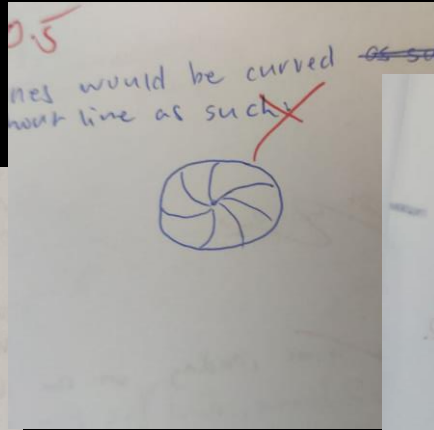
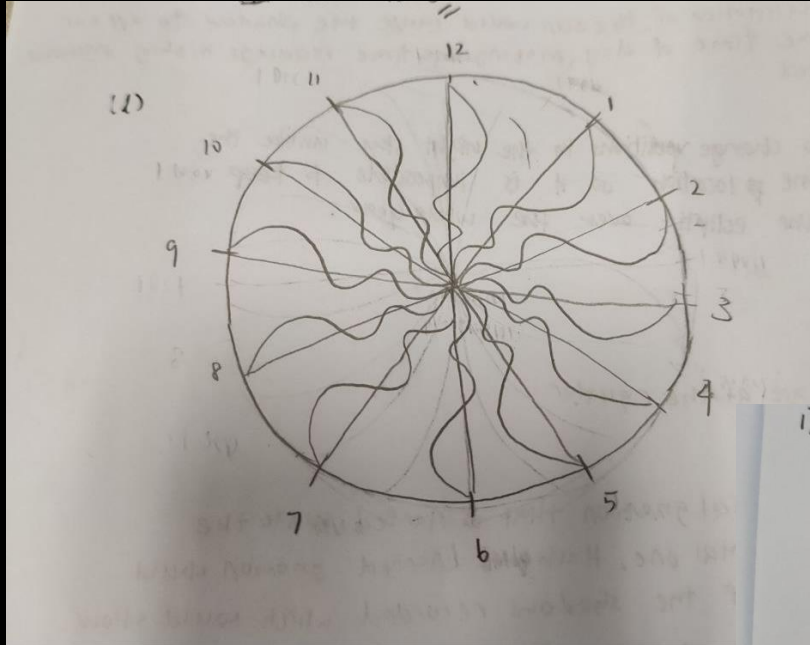
It should be possible to construct the hour lines on a nodus-based sundial such that it automatically compensates for the equation of time. This is done with a curved hour line that is ahead or behind the original straight hour line at points corresponding to different solar declinations, with the time difference given by the equation of time.

- (1) Describe the shape of the hour lines if such a correction was to be applied. You may supplement your description with a sketch if needed.

[2]

*Don't worry, this was meant to be difficult

Tasty Dumplings



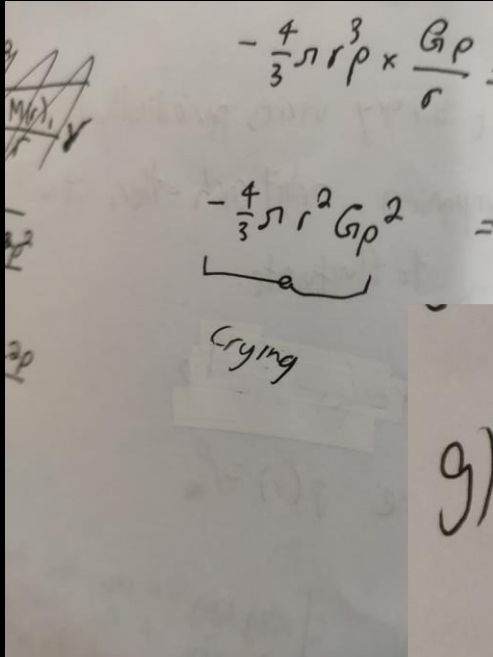
Your logic:

1. Sundial hour lines are like clock faces
2. Equation of time is curvy
3. Make hour lines curvy

You're on the right track, but the whole point of the question is to debunk premise 1!



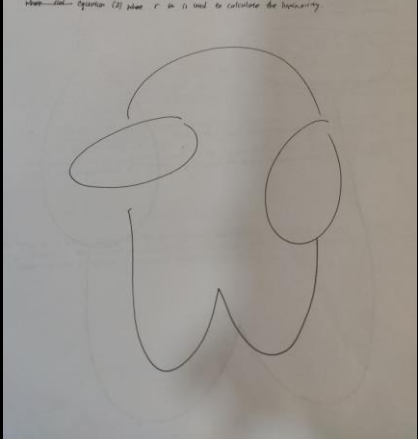
When you give up - Final Season



Handwritten notes on a piece of paper. At the top left is a diagram of a triangle with a smaller triangle inside it, and some lines extending from the vertices. To the right of the diagram is the equation $-\frac{4}{3}\pi r^3 \times \frac{G\rho}{r}$. Below this is another equation $-\frac{4}{3}\pi r^2 G\rho^2$ with a bracket underneath it. At the bottom, the word "Crying" is written.

i) my pen is running out of ink.
see.

g) It is just as it is, no reason.
Power of nature.
yes.



(iv) A ✓

(i) Unname. ~~I love you~~ Super Mario Bros Movie.

Peaches, peaches, peaches, peaches, peaches x2

I love youuuuu.

Peach, understand, I'mma love you to the very end.

A hopeless romantic all my life.

Surrounded by couples all the time.

I guess I ^{it} should take ~~that~~ a sign.

OoWaa OoWaa OoWaa OoWaa ^{wish I'd}

I'm feeling lonely, Oh I [^] ~~W~~ find a lover
that could hold me.

Now I'm crying in my room.

So skeptical of love, (say what you ^{want} ~~say~~ [^] still)

But still I want it more, more, more.

I gave a second chance to cupid

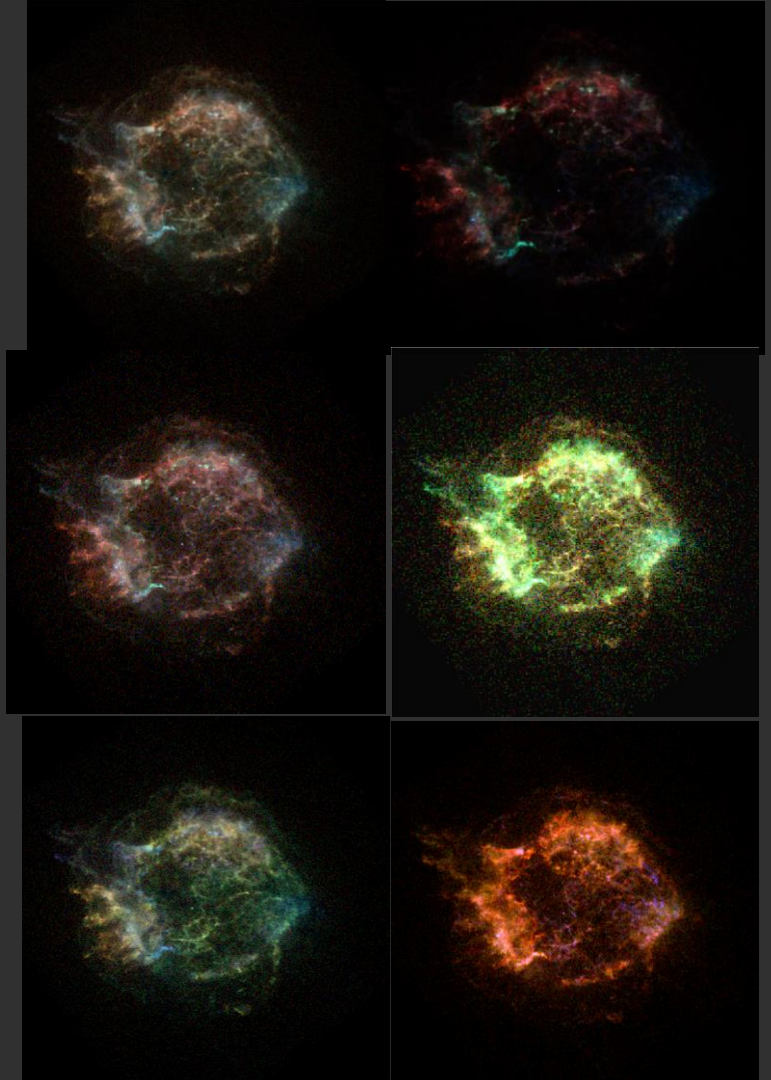
Least insane Princess
Peach simp



DAQ (Senior)

Data Analysis Question

Benjamin



Rationale

- Introduction to a few tools and the data analysis process of Astrophysics-related research.
 - Observation → Data Collection and Processing → Data Analysis → Data Visualization → Inference Making

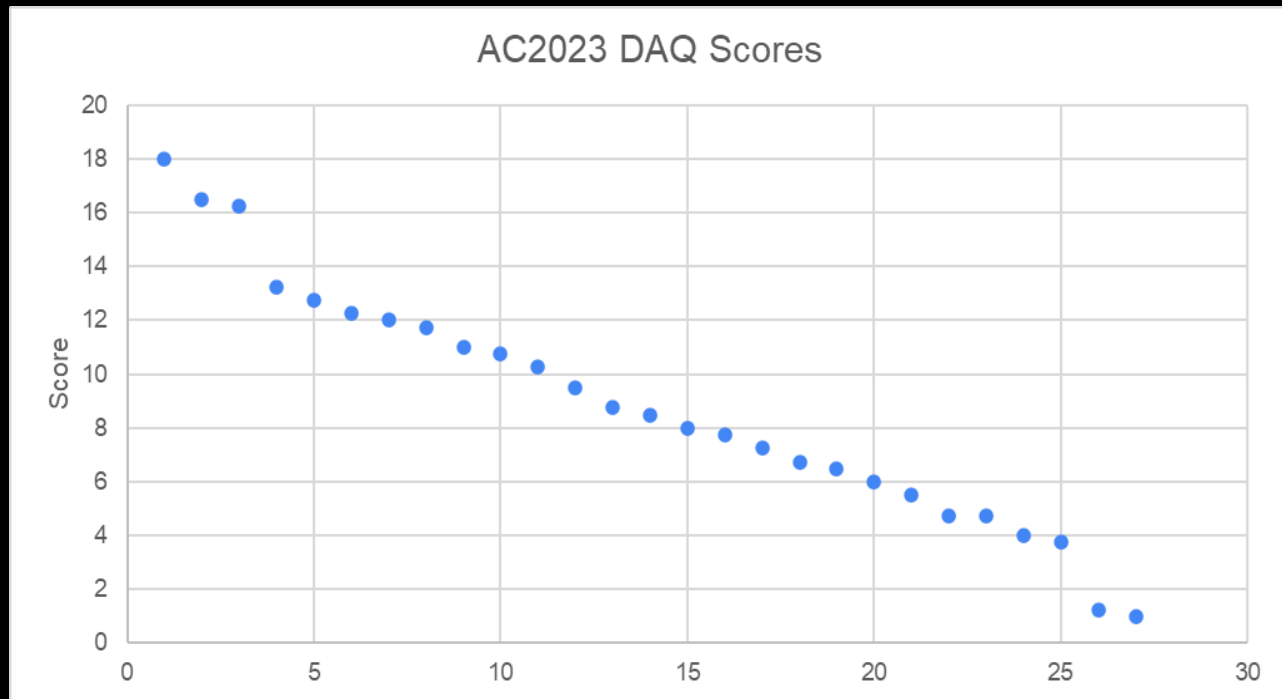
Statistics

Removing NIL Attempts

Mean: 8.84

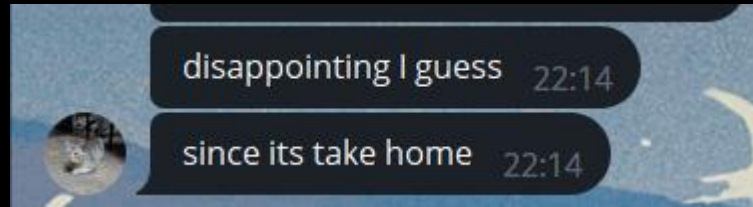
Median: 8.5

Hi: 18



Killer Questions were 1a and 2e

A word from your marker when we asked him how were the submissions...



Teams that spent time and put in effort did significantly better!

General Complaints

- Some did not follow instructions clearly...
 - Did not save .fits file as rgb image
- Shallow research done. Evident in responses
 - Referencing with no evidence provided is not substantial.
 - Those that did research performed vastly better overall.
- Answers were long-winded and missed the mark
- Random math taking place due to panic.
 - There's no time limit!

Exemplary Case

- Excellent Research showcase



slots for the lower image values than the higher image values (C. Patterson, 2011) This highlights low luminosity features in the image that may not be noticeable with a linear scale. It helps to accentuate faint maxima, where there is a bright source in the field.

(SAO, n.d.)

1.5

good

1. “Explore LAT Data”- SLAC Stanford University (Published by Chuck Patterson-03/02/2011)[link]<http://vizier.u-strasbg.fr/doc/man/saoimage.scale.htx>
2. “Scaling from image pixel value to displayed colours in SAOimage”- Smithsonian Astrophysical Observatory (SAO) [link] <http://tdc-www.harvard.edu/software/saoimage/saoimage.scale.html>

- Good citations but wrong use case

Cen-X3 mass = 1.21 Solar Masses

Companion star mass = 20.5 Solar Masses

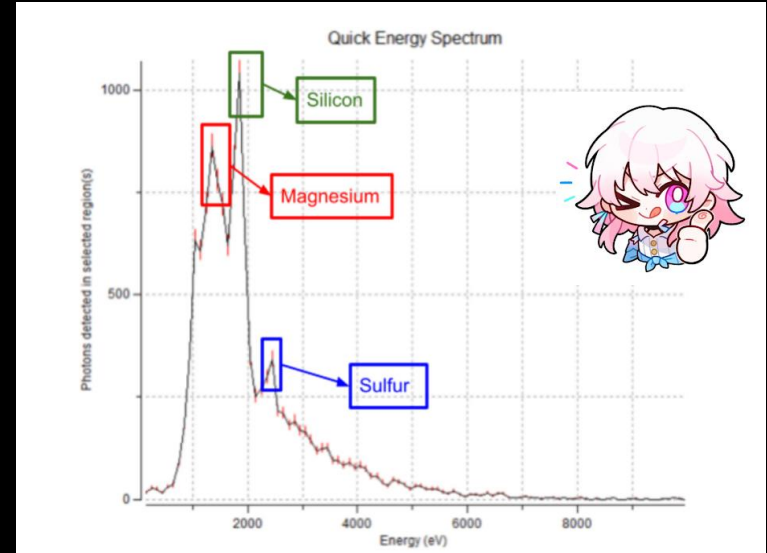
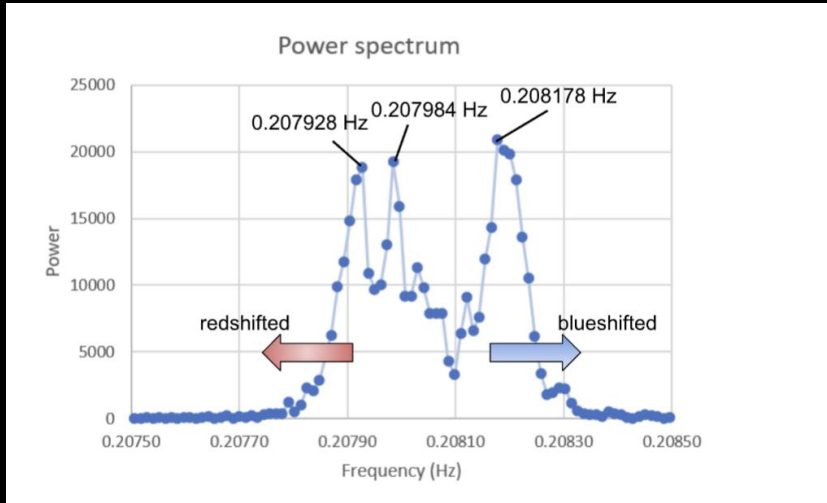
(Ref. Naik, Sachindra; Paul, Biswajit; Ali, Zulfikar (August 2011))

(Sorry, we could not figure the last 3 out despite our best efforts 😞)

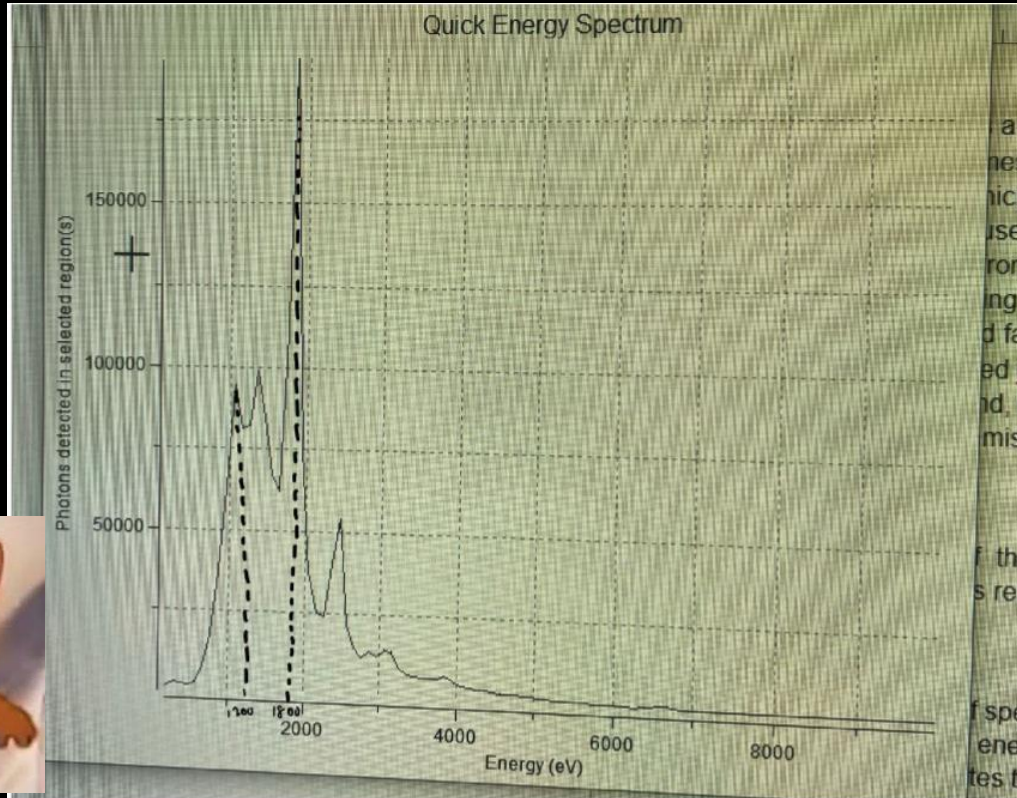
its ok

Exemplary Case

- Well-labeled Diagrams



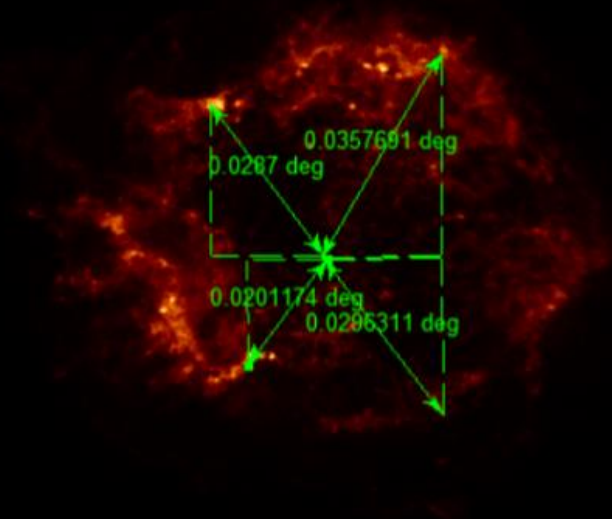
Negative Example...



Surely AC participants are young enough to know how to export image files??

Exemplary Case

- Using multiple points to improve accuracy (thinking like a scientist!)



Random fails



Random Calculations

$$M1+M2=a^3/p^2$$

Mass of binary system= $a^3+p^2=0.079277797^3+0.005561644^2=5.29190388 \times 10^{-4}$ AU

$$MP^2 = a^3$$

Mass= $a^3 \cdot p^{-2}=0.079277797^3 \times 0.005561644^{-2}=16.10824949$ AU [1] ???

where did you get this number?

$$365.25 \times \underline{86400km} = 631152000km$$

Not Calculating, just Googling

10 light years (Google gives the radius of Cassiopeia A to be 5 light years)

(h) What is the mass of the Cen-X3 and its companion star respectively?

(Wiktionary: <https://academic.oup.com/mnras/article/307/2/357/1104307?login=false>)

Mass of Cen-X3: $1.21 \pm 0.21 M_{\odot}$

Mass of companion star: $20.5 \pm 0.7 M_{\odot}$

lol

Forgetting Relativity

Thus, Maximum radial velocity of Cen-X3,

$$V_r = c \times \frac{\lambda_{\max} - \lambda_{\text{rest}}}{\lambda_{\text{rest}}}, \text{ where } c \text{ is the speed of light and } \lambda = \frac{c}{f}$$
$$= 2.738209 \times 10^{12} \text{ ms}^{-1} = 2.74 \times 10^{12} \text{ ms}^{-1} \text{ (3s. f)}$$

These are 9150c!

$$\begin{aligned} \text{Maximum radial velocity} &= c \cdot \frac{\Delta\lambda}{\lambda_{\text{rest}}} \\ &= c \cdot \frac{\lambda_{\max} - \lambda_{\text{rest}}}{\lambda_{\text{rest}}} \\ &= c \cdot \frac{\left(\frac{c}{f_{\min}}\right) - \left(\frac{c}{f_{\text{rest}}}\right)}{\left(\frac{c}{f_{\text{rest}}}\right)} \\ &= 3.00(10^8) \left(\frac{\frac{3.00(10^8)}{2.276(10^{-5})} - \frac{3.00(10^8)}{0.20817784}}{\frac{3.00(10^8)}{0.20817784}} \right) \\ &= 2.7437 (10^{12}) \text{ ms}^{-1} \end{aligned}$$



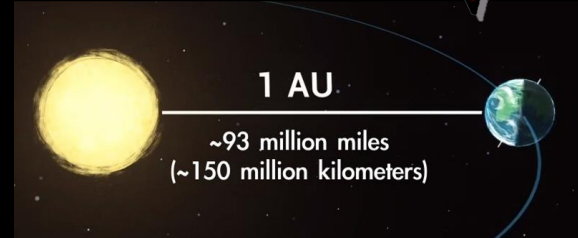
Juniors: Watch this

$$v_{\oplus} = 29788.20164 \text{ m/s} \checkmark$$
$$v_A = \left[1.989 \times 10^{30} \right] \left(6.67384 \times 10^{-11} \right)$$

forgot sqrt!

$$= 1,206,328,961 \text{ m/s BRUH}$$
$$\Delta v = (1,206,328,961 - 887,336)$$

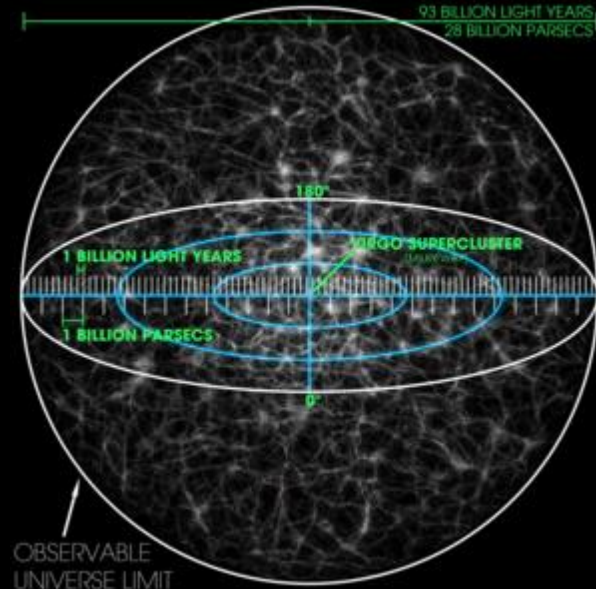
75% off



2 minutes
Up: 8 minutes

Seniors: ok but hold on

$$= \sqrt{\frac{Gm_{\text{earth}}}{r^2}}$$
$$\text{Orbital } v_{\text{earth}} = \sqrt{\left(\frac{Gm_{\text{earth}}}{r^2}\right)}$$
$$= (1.496 \times 10^{11}) \sqrt{\left(\frac{6.67384 \times 10^{-11} (5.972 \times 10^{24})}{(1.496 \times 10^{11})^2}\right)}$$
$$= 2.819143415 \times 10^{22} \text{ m/s}$$
$$\text{Orbital } v_{\text{supitar}} = \sqrt{\left(\frac{Gm_{\text{supitar}}}{r^2}\right)}$$
$$= (7.785 \times 10^{11}) \sqrt{\left(\frac{6.67384 \times 10^{-11} (1.899 \times 10^{27})}{(7.785 \times 10^{11})^2}\right)}$$
$$= 5.011041964 \times 10^{23} \text{ m/s}$$



30 mins drive

To quote the 2017 postmortem...

OBSERVABLE UNIVERSE



If you get answers
like this, the universe
is screaming at you to
check your work.

That's all folks!

- AC2023 QMs

