AC2020 SNR Post Mortem

Project Round

Project Round General Comments

- Do not squeeze too much text into the poster!
  - Balance content versus readability!
  - Good aesthetic design can help in this, but only up to a point

- For a poster, choice of graphics is important
  - Does it help in understanding the content?

- Also: **please credit the source of your images!**

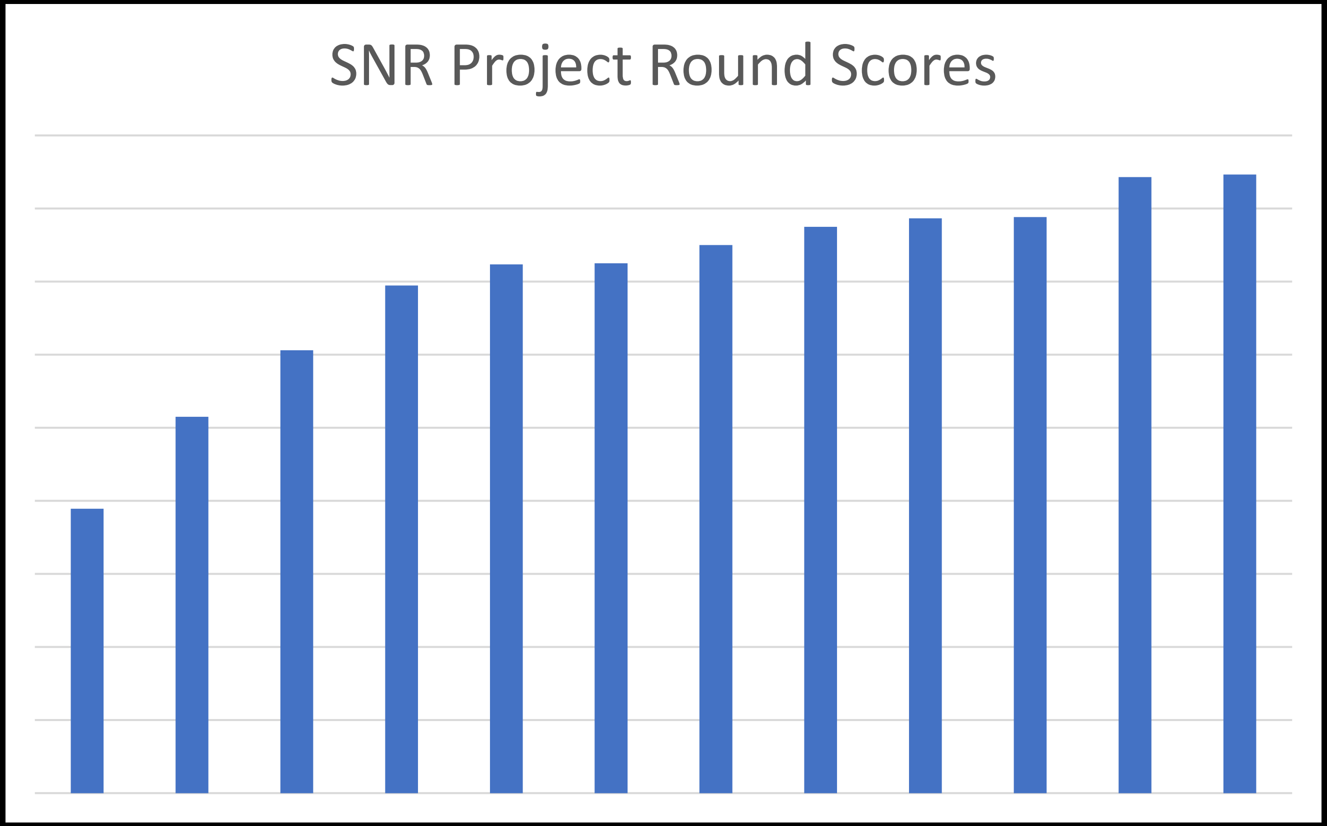
Most Attempted Question

- Q3
  - Choose a planet in the Solar System. Tell us more about this planet and its moons (if any), and what do we still not know about it?

- Teams that attempted this question generally did above average.
  - A few minor factual errors, but otherwise OK
  - Graphic design could be improved for some teams
  - Please contextualize the large astronomical values that you throw around!
    - For instance, how big is 4.5 billion km?
    - You should help members of the public understand the scale of the Solar System!

Project Round Overall Statistics

- Mean: 70.4
- Median: 73.75
- Std. Deviation: 13.1



Individual Round

This year’s “100%” question

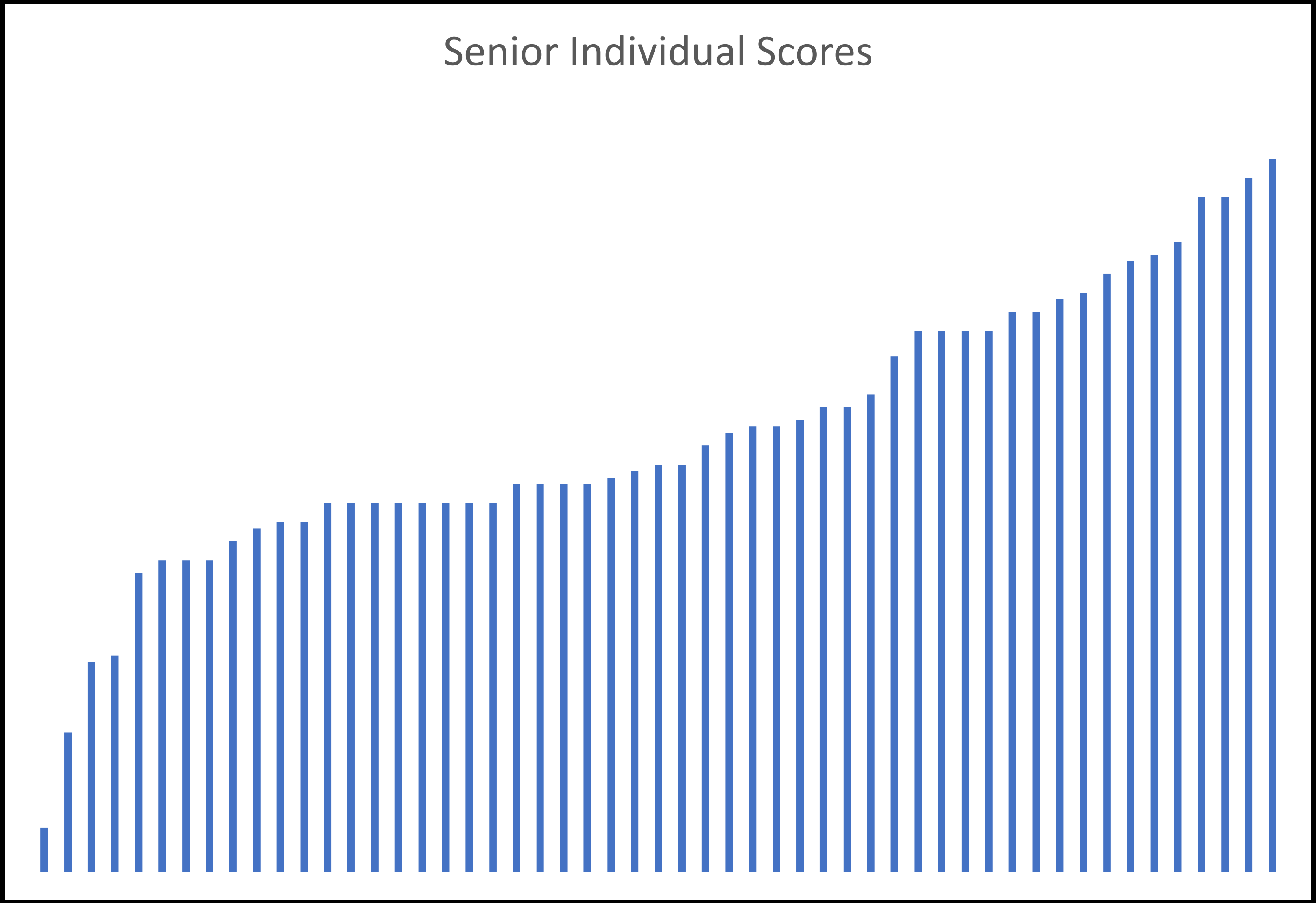
- Q25:
  - I want to take a color image of the Great Dark Spot (6600km across), using individual 10s exposures in 3 different wavelengths….
  - Only 42.8% of Seniors got this correct
    - In comparison, 46.9% got this correct in the Junior Category!
- Key to this question: aperture is NOT the only factor you need to consider when trying to resolve an object!

Individual Round Question Statistics

- Easiest Question: Q3
  - 80.8% correct
- Least Correct: Q33
  - Suppose the September 2020 equinox is occurring right now. Which of the following events will be occurring then?
  - 8.7% correct
  - Most people fell for the misconception that equinox implies day and night are of equal length
- Most blanks: Q11
- Please consult the answer scheme for solutions and explanations!

Individual Round Overall Statistics

- Mean: 68.5
- Median: 64
- Std. Deviation: 21.6



Team Round

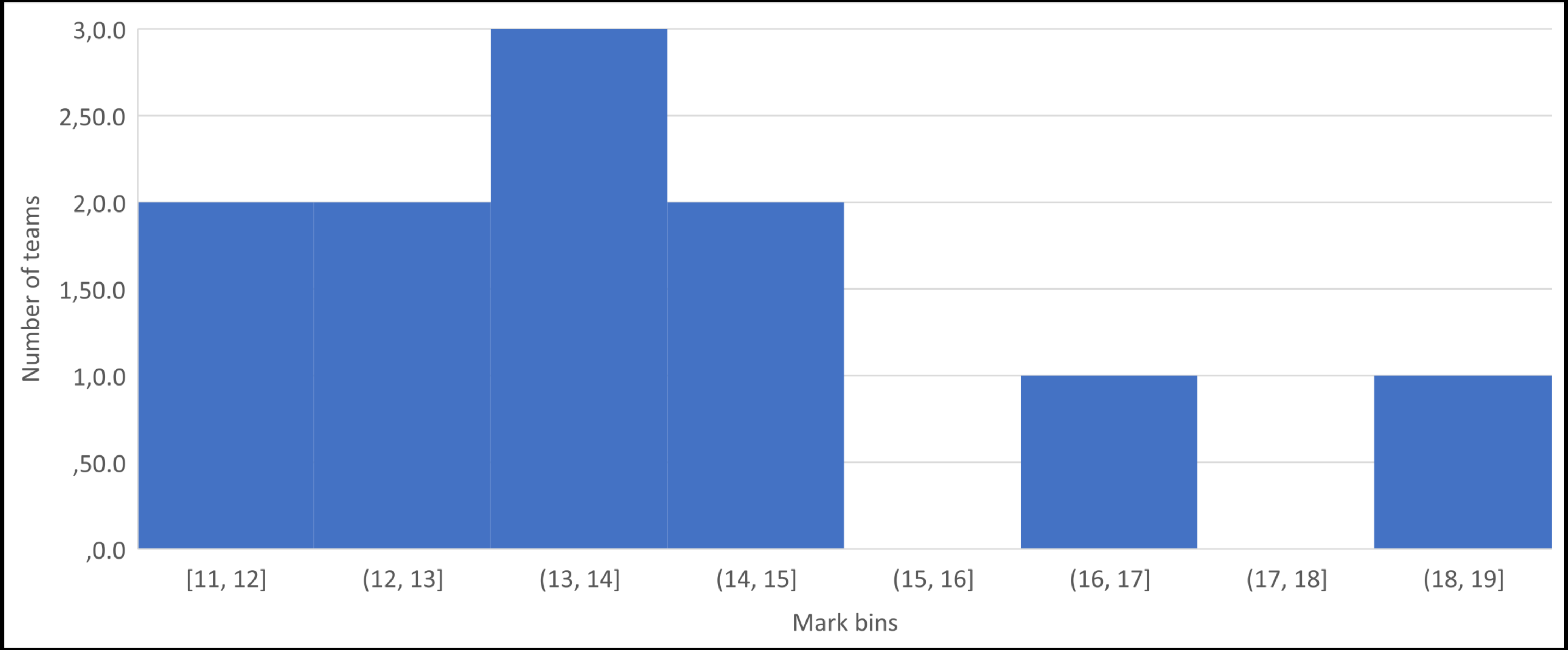
Data Analysis Question

Sharadh Rajaraman
NUS Astronomical Society

Overall Comments

- Data analysis is a new subsection of AC (under the banner of Team Round)
- Marking was relatively lenient, and question itself was a semi-Team Round question with many prose sections
- Huge, *actively-updated* data set (~4000 exoplanets when this question was first drafted; today, 4300 and counting)
- Most teams put in genuine effort to produce a good-quality report, and it shows
- Possibly the best-scoring Team Round section ever: no marks below 11
- Unfortunately marred by cases of intra-school plagiarism
  - Rules and regulations will be clarified and updated next year
- Markers hope that students have learnt about data analysis techniques and exoplanetary science as a whole

Mark spread


3,0.0
2,50.0
2,0.0
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Number of teams
[11, 12]
(12, 13]
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(16, 17]
(17, 18]
(18, 19]
Mark bins

Question 1

- Easiest 2 marks possibly *ever* in the history of AC
  - Follow every single line of instructions in the DAQ problem sheet
  - Submit 2 .csv files, one raw, one trimmed, appropriately named
- Some teams managed to swap the file names (half marks given)
- Some teams submitted the same file for both questions (???)
- FREE MARKS, PEOPLE

Question 2(a)

Categorise the exoplanets in your data set into the following categories, and present an appropriate diagram.

- Many used bar and pie charts
- One team used a treemap chart
- We expect numbers for each category, otherwise teams are penalised

Give reasons for the differences in the number of planets in each category.

- **Six** categories: **one** reason for each for full marks, with keywords
  - Transit
    - bulk of exoplanets discovered using this method also discovered using *Kepler* observatory, purpose-built for this method
    - Relatively low sensitivity needed to detect the dip in brightness of parent star
  - Radial velocity
    - low sensitivity needed due to merely needing to detect periodic Doppler shift variations
    - Both transit and radial v. may be performed with existing equipment
  - Direct imaging
    - Rare: require extremely powerful (space-based) scope, proximity to exoplanet, and a dim parent star
  - Transit timing variations
    - Require multiple exoplanetary system
    - Precise timing difficult to obtain, given orbital periods may be long
  - Grav μ-lensing
    - Planet needs to be in-line with parent star and background star and massive enough to lens background star
    - Rare occurrence
  - Eclipse timing variations:
    - Require exoplanets around binary stars: also rare.

Question 2(b)(i)

Explain what the sin(i) refers to, and why despite a multiplication of this factor, both M_{pl} and $M_{pl}\sin(i)$ may coexist in the same data column.

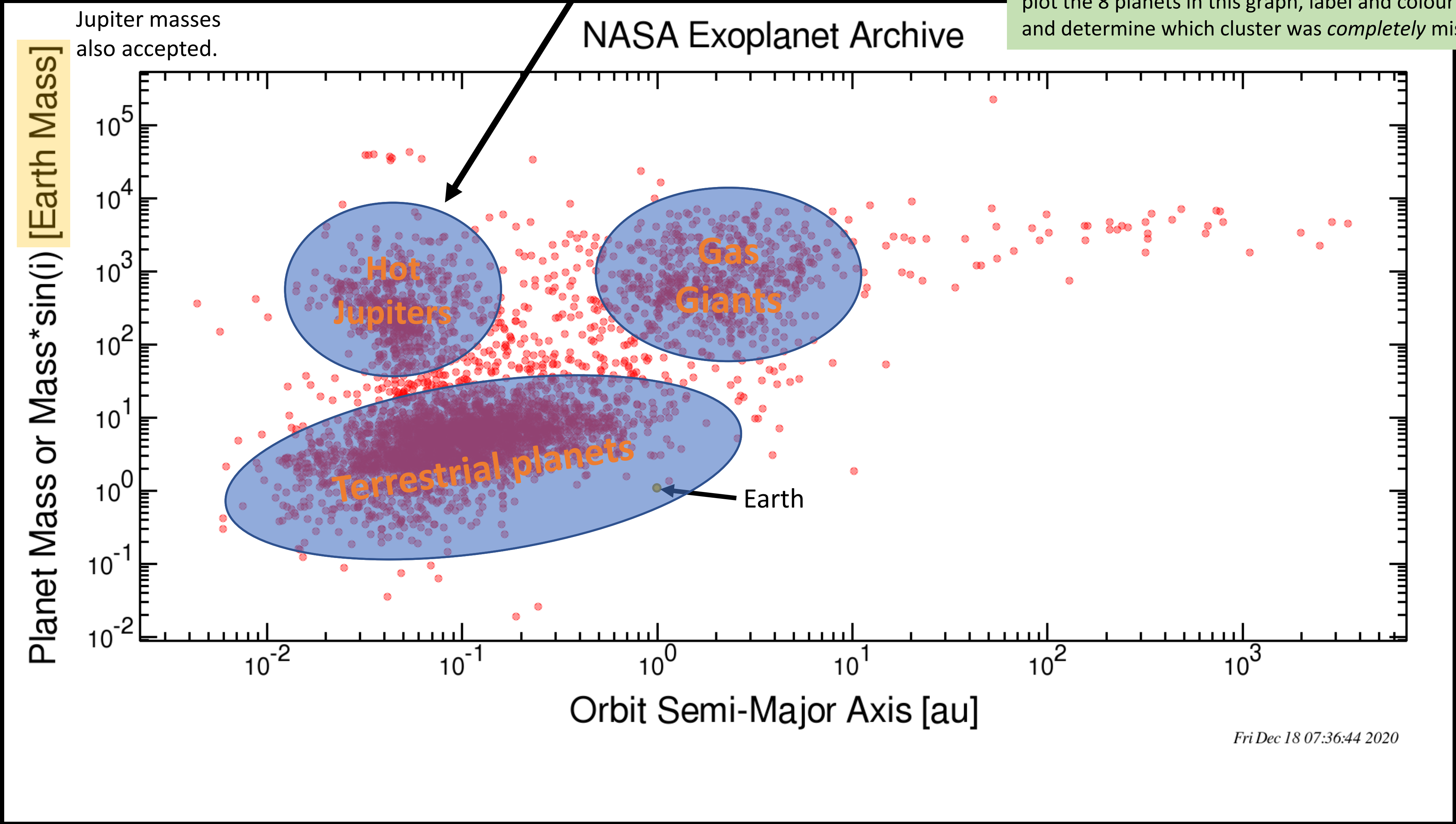
- ***Three*** points needed: what is I (and hence sin(i)), why it is multiplied, and why both M_{pl} and $M_{pl}\sin(i)$ can coexist
- Nearly all teams got this correct
- Many teams presented very nice diagrams to explain their answers
- Others resorted to long paragraphs of prose, but still managed to get the point across

Question 2(b)(ii)

Our solar system contains no hot Jupiters. It was hoped that the large masses of these planets and tight orbits would be a telltale sign, but many teams named the bottom-left cluster as 'super Earths' and pointed to this instead. Marks were still awarded, however.

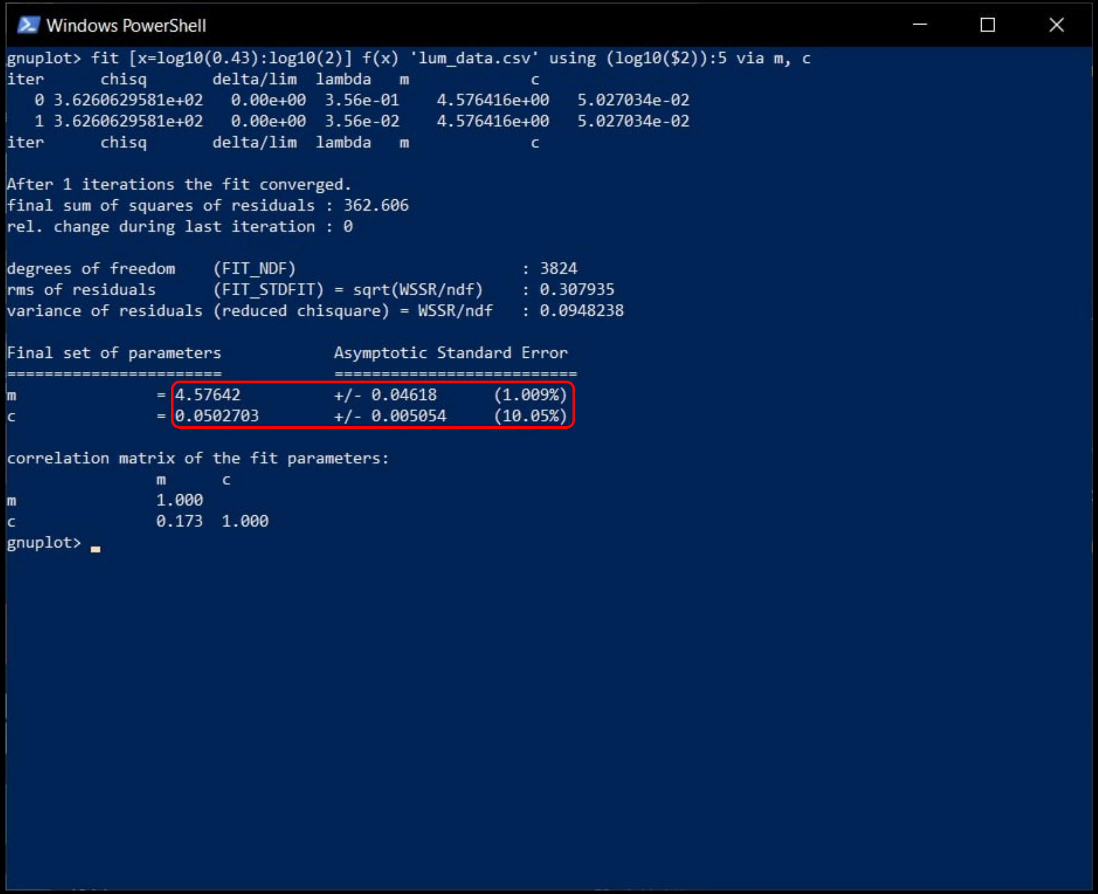
Best way to answer this question would have been to *actually* plot the 8 planets in this graph, label and colour them differently, and determine which cluster was *completely* missing a planet.

Jupiter masses also accepted.



Question 3

- Use Excel function LINEST to obtain regression parameters: make sure to set **const = TRUE** so y-intercept is calculated
- Expected value of **α = 4.57** (depends on your dataset size), with uncertainty **δ_α = 0.046** (some leeway is given here)
  - 3 sig fig expected; some teams only gave to 1 sig fig
- One team used Python to attempt a plot; code was good, but values were waay off
- Another team was aware of the theory, and attempted to massage data to fit theory: **BIG NO NO**.
  - *Explain* discrepancies: why your value diverges from the expected value, and **STOP** there. Do **NOT** proceed to massage out a value that is closer to the expected value. This is bad experimental technique.



Question 4(a)

List some planetary parameters that might be missing in the ESI, and explain their significance.

- Most teams provided good answers:
  - Magnetosphere presence/strength
  - Planetary orbital/rotational parameters (sm axis, eccentricity, etc)
  - Atmospheric parameters (surface pressure/density, composition)
- Presence of liquid water on surface was notably absent
- Look at the very next subpart for hints: the two questions are related!
- List and explain **2 points** for full marks (some teams gave 3 or more)

Question 4(b)

Refer to Figure 1 above. Explain why the plotted points do not all fall on the line y = x. In other words, explain why a given planet's PHI may not equal its ESI value, or vice versa.

- ESI and PHI are fundamentally **unrelated** quantities, with very different input parameters and normalising functions
  - Absolutely no reason why they should fall on the y = x line
  - Red herring sort of question
  - Many teams explained themselves into a ditch; only a handful caught the idea that there is nothing mandating a relationship between ESI and PHI
- Some teams gave great examples by singling out points (Titan, Venus) from the image itself: unfortunately this time there was no avenue for bonuses, which the markers really wanted to give ☺

Question 5

Give some sources of errors and biases in the data that you have downloaded in question 1(b). Explain why you think these sources are significant in their error/bias contribution.

- 3 marks: 1 error, 2 biases or 2 errors, 1 bias for full marks
- Bias: star systems limited to near-solar-mass stars
- Bias: sample size itself is tiny compared to population size (look at DAQ preamble for a hint)
- Errors: point out any possible errors in the imaging sequence itself
    - Transit errors and false +ves/-ves (usually resolved over multiple observations)
- Any other valid biases/errors are generally accepted

SNR DRQ 1

Dubious Statements

Keven

Grading Scheme I

- Each sub-part (statement) is graded out of 5 points
- Final score (out of 20) = sum of all sub-parts / 2

- Only the first three sentences are graded
- This excludes sentences only addressing the T/F, e.g. “True.” or “False.” are not counted

Summary

Grading Scheme II

- Some statements have definite True/False answers
- For these, a wrong answer scores 0 points
- Otherwise, a correct answer with an attempt at justification (even if incorrect) scores at least 1 point

- Some statements allow both True/False responses
- For these, the score depends only on the justification

- 0 points awarded if T/F response contradicts justification provided

Summary

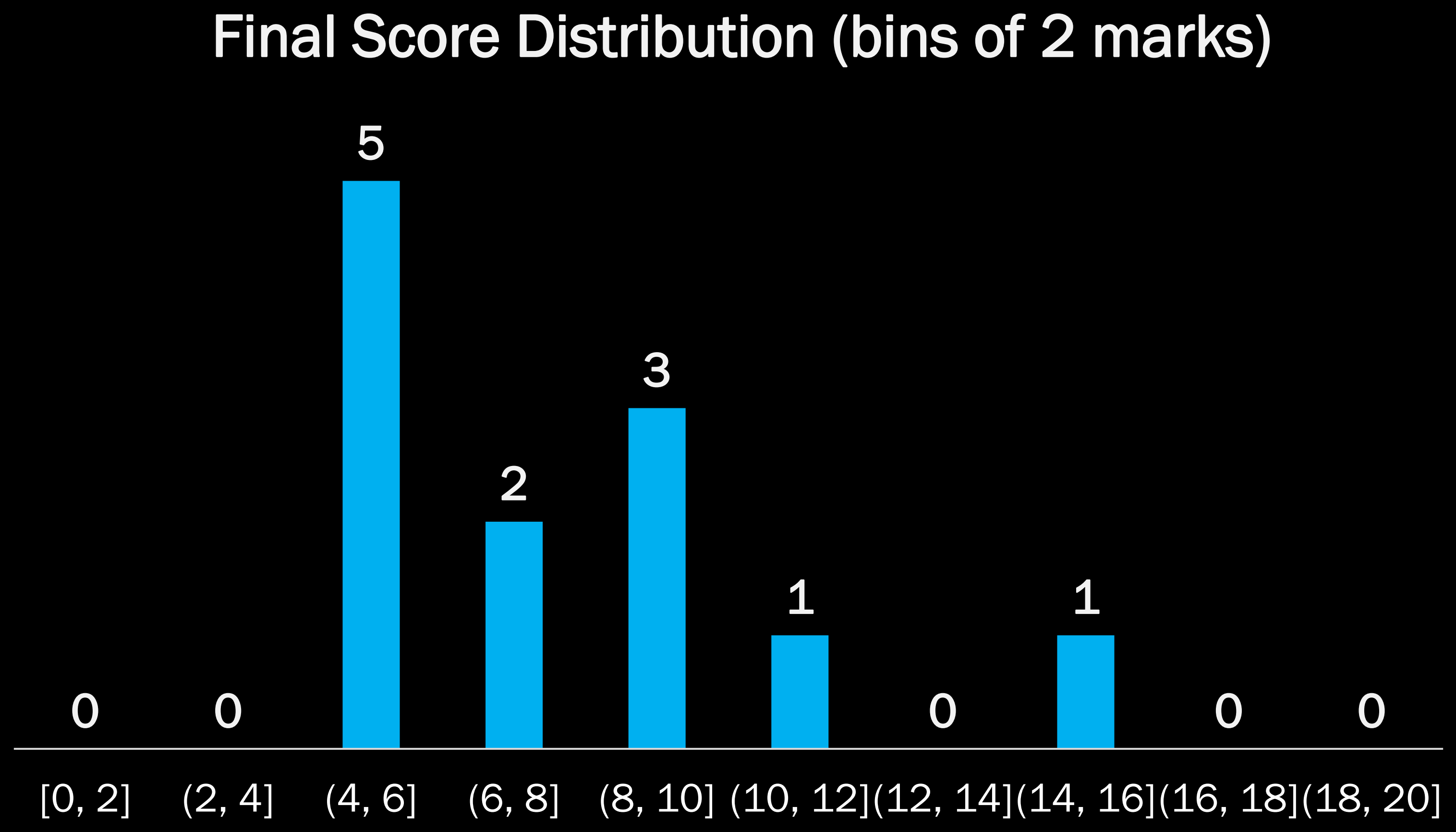
Grading Scheme III

- Scores for responses are awarded as follows:
  - 5 points: Complete explanation of physical/astronomical processes involved with no minor errors
  - 4 points: Near-complete explanation with 1 minor error
  - 3 points: Explanation has 1 major error (factual error, omission or missing assumption) or 2 minor errors
  - 2 points: Explanation has 1 major error and 1 minor error
  - 1 point: Incorrect or largely incomplete explanation
  - 0 points: Incorrect T/F answer, or correct T/F answer with no justification

- Each relevant diagram may score up to 1 point

Summary

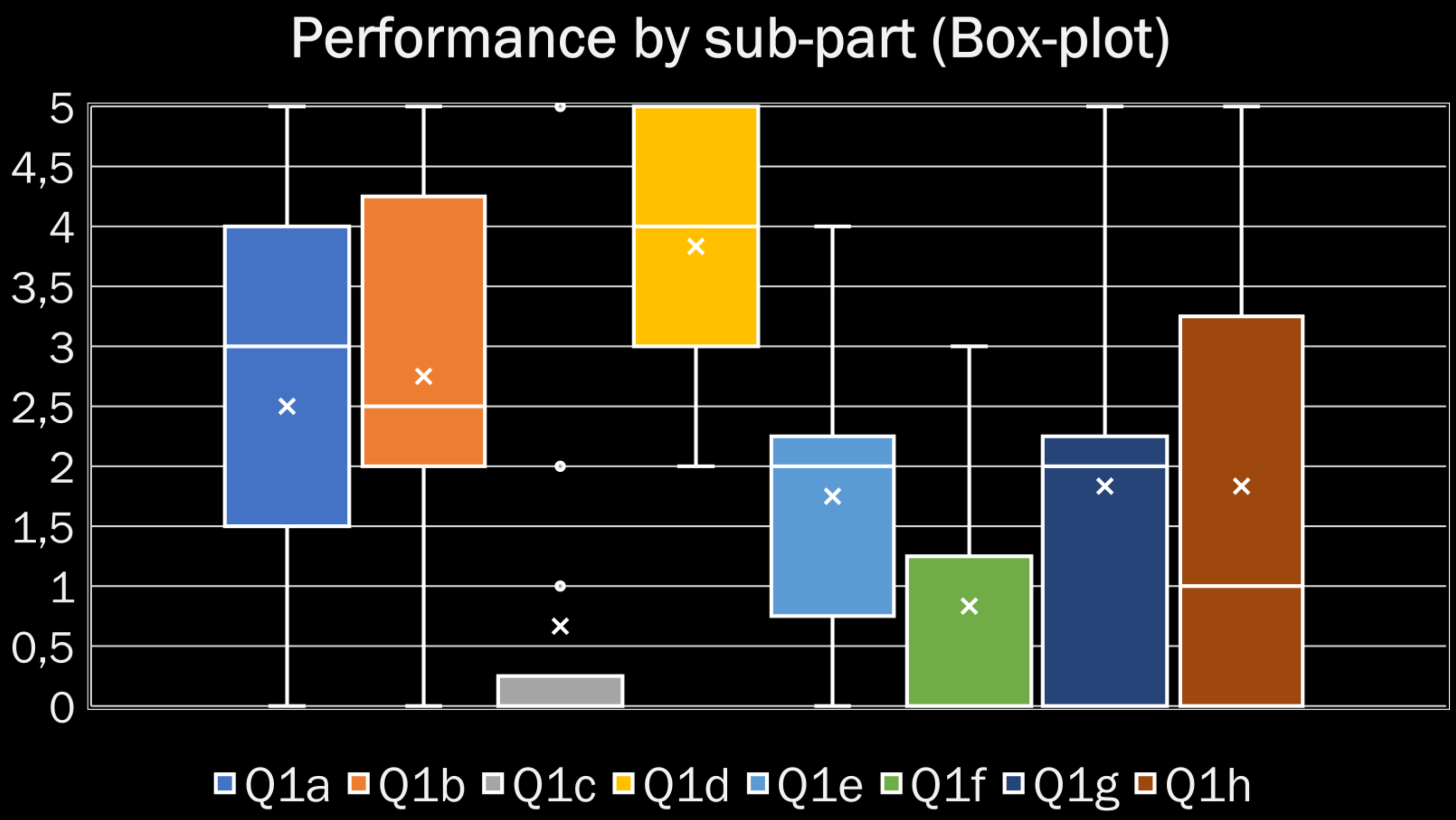
Statistics



Median: 6.50 **Mean:** 6.965 **Mode:** 5.5, 8.5

Summary

Sub-part Statistics



Median: Horizontal line

Mean: Cross

25th, 75th percentile: Box

Outliers (>1.5 IQR): Dots

Comments

Overall Comments

- Please read instructions carefully!
  - Some teams just guessed T/F with no justification - spend the time elsewhere, this is worth ZERO credit!
  - Some teams wrote more than three sentences - this only wastes your time; a good response is possible in 2!
  - A few teams did not clearly label their responses - please label your responses CLEARLY otherwise they may be missed during grading/incorrectly graded!

Comments

Overall Comments

- Question was initially set for a closed-book setting
  - Fewer than half of the responses correctly identified the related phenomena/processes involved
  - Many responses explained the phenomena/processes at a very surface level, and failed to link it to the statement
  - Perusing definitions or statements off the Internet is OK, but many brought in irrelevant statements (e.g. for Q1c, explaining the …triple-alpha process?)
  - Others did not explain significance of these statements…
- Please GOOGLE if you are unsure of your response; the performance was disappointing for open-book

Comments

Overall Comments

- The act of self-sabotage
  - A few teams wrote contradictory justifications to their T/F response (e.g. True for Q1h but then explaining how contrast is …reduced?) - check your work!
  - Unsupported claims, e.g. "gravitationally bound systems have generally reached dynamic equilibrium" - why?
  - Irrelevant incorrect details, e.g. for Q1d, "stars that are forming are called T Tauri stars and emit high-energy UV radiation" - did you Google what a T Tauri star is?
  - Ambiguous language, e.g. "stray light enters the mirror thus image becomes brighter and contrast decreases" - ??
  - Tautologies, e.g. "total eclipses occur at poles when the Moon, Earth and Sun are aligned in a straight line" - so?

Solutions

Q1 (a)

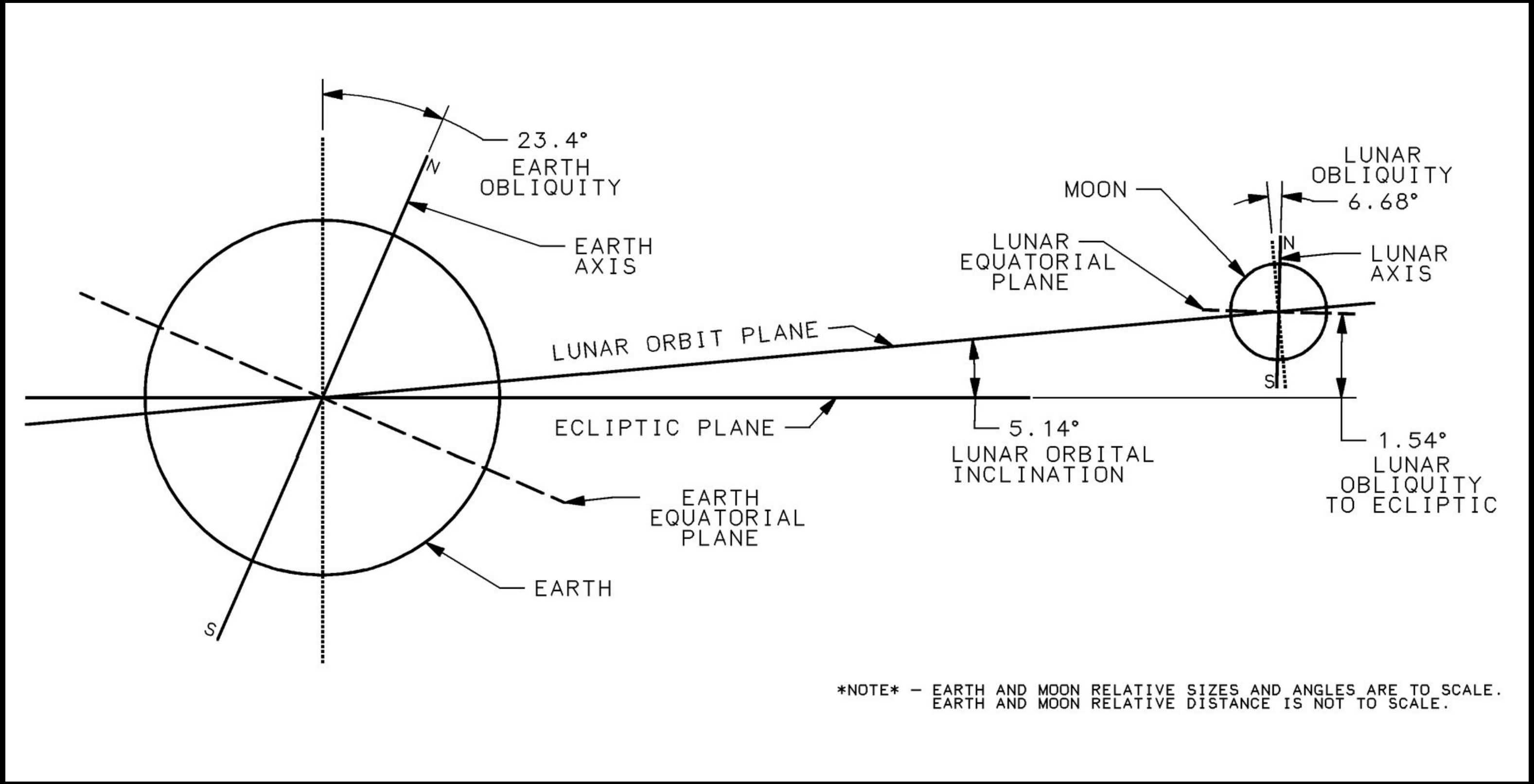
- Total solar eclipses cannot be observed from either of the Earth's geographic poles.

- **Answer: False**
- Since the Moon's orbit is inclined at 5° relative to the ecliptic plane, total eclipses are observed at the poles only near the ascending and descending nodes and when the Sun is above the local horizon.
- A total eclipse has occurred at the North pole on 19 March 2015, and will occur at the South pole on 16 January 2094.

Solutions

Q1 (a)

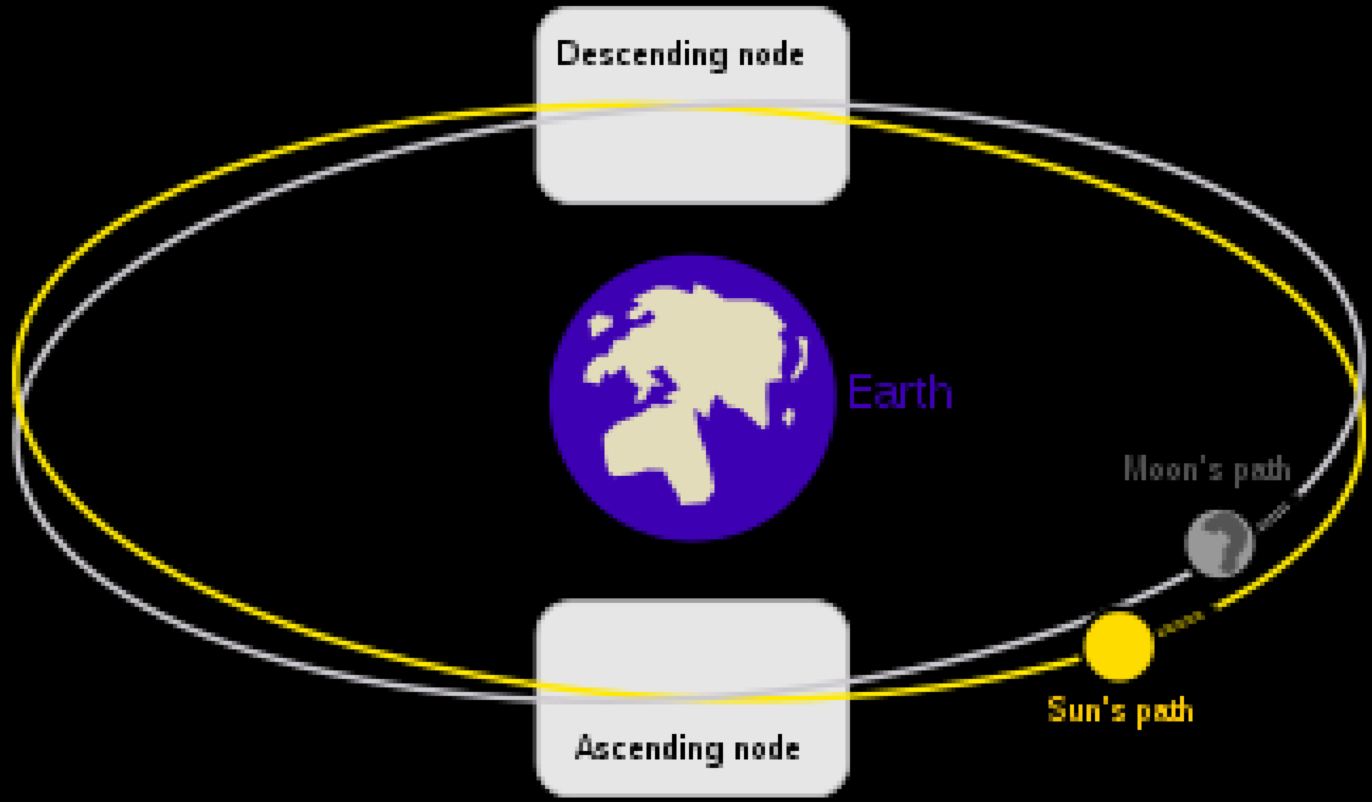
- A relevant diagram (Earth-Moon orbital system w.r.t ecliptic plane)



Solutions

Q1 (a)

- A relevant diagram (ascending and descending nodes of Moon’s orbit w.r.t ecliptic plane)



Solutions

Q1 (b)

- It is possible for the dust and ion tails of a comet entering the inner Solar System to be oriented orthogonally in space.

- Answer: True/False
- The ion tail of a comet points directly away from the Sun as the ions follows the outward direction of the magnetic field of the plasma in the solar wind.

- (Continued next slide - justification depends on extent effect of radiation pressure is considered.)

Solutions

Q1 (b)

- Answer: True
- The dust tail generally follows the comet's orbital trajectory (discounting radiation pressure) and thus the (start of the) tails are orthogonal at perihelion.

- OR

- The dust tail comprises dust particles which are affected by solar radiation pressure, and thus may curve towards the orbital trajectory near the semi-latus rectum, making it orthogonal to the ion tail.

Solutions

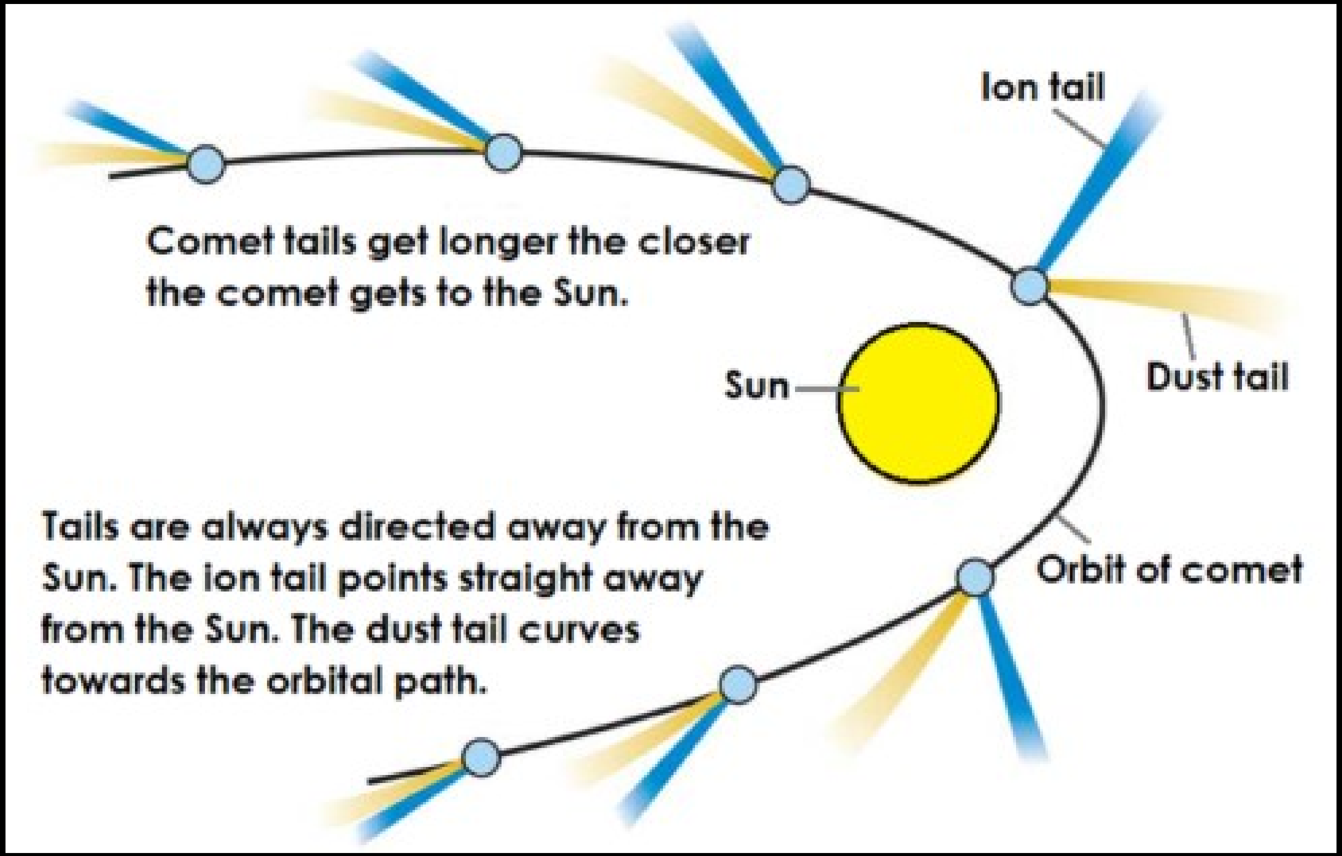
Q1 (b)

- Answer: False
- The dust tail generally points away from the Sun as the dust particles are affected by solar radiation pressure, hence the two tails cannot be orthogonally oriented.

Solutions

Q1 (b)

- A relevant diagram (position of ion and dust tails)



Solutions

Q1 (c)

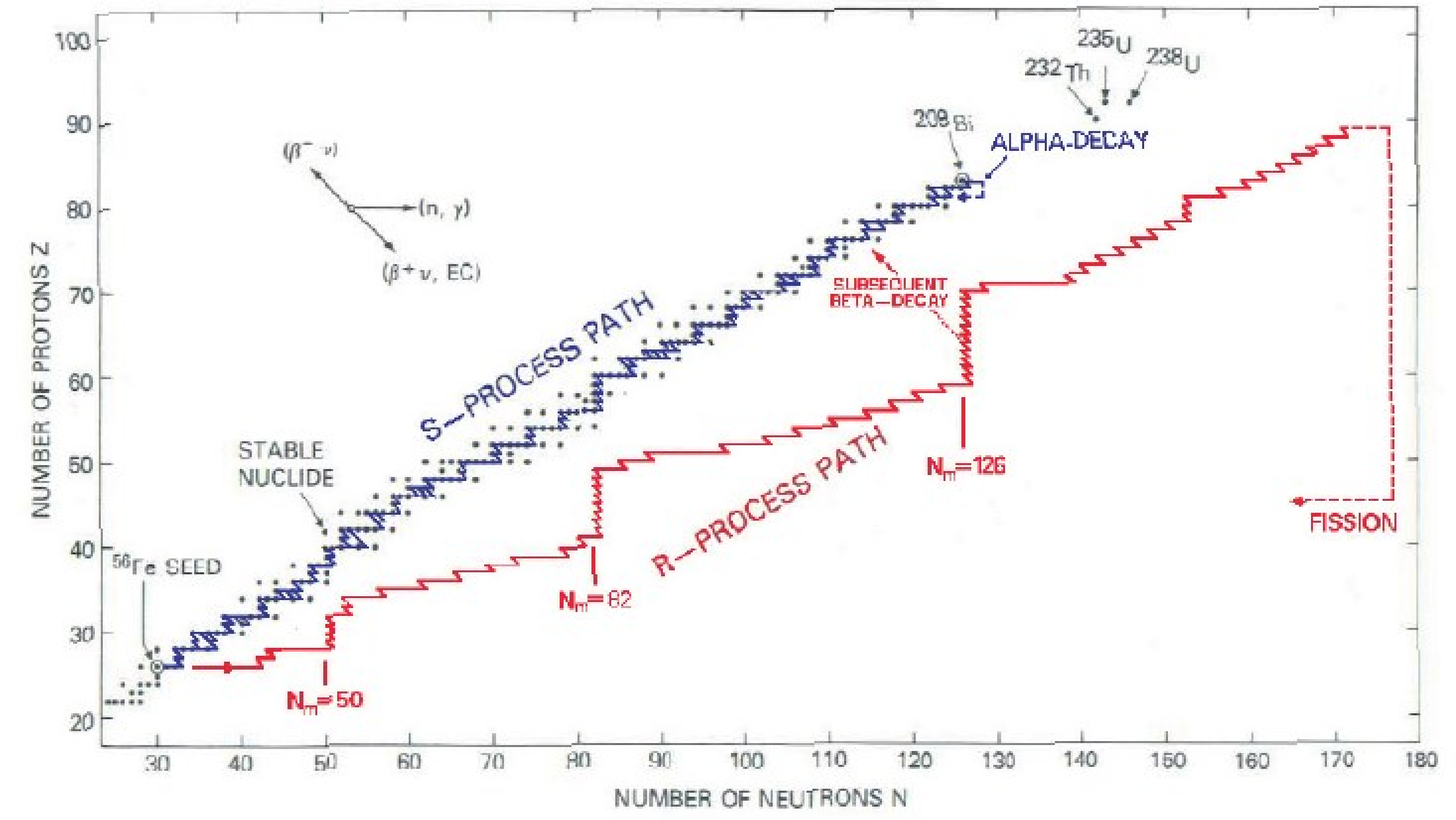
- Elements with atomic numbers greater than that of nickel have increasingly smaller binding energy per nucleon and are only formed in stars during highly energetic events.

- **Answer: False**
- The first part is correct (H2 Physics).
- The second part is incorrect as the s-process allows the formation of atomic nuclei heavier than iron via neutron capture and subsequent slow beta-decay, in the interior of late-stage (primarily AGB) stars.

Solutions

Q1 (c)

- A relevant diagram (s-process creating nuclei more massive than iron)



Solutions

Q1 (d)

- Hydrogen in some form is the dominant component of interstellar matter in both emission and reflection nebulae, and account for the differences in their appearance.

- Answer: False
- The first part is correct, since interstellar gas is predominantly molecular or atomic hydrogen.

- (Continued next slide)

Solutions

Q1 (d)

- The second part is incorrect - in emission nebulae, hot massive stars produce sufficient high-energy UV photons to cause significant ionisation of molecular H, giving emission nebulae their characteristic red colour due to strong emission from the Hα line.
- In reflection nebulae, the energy from nearby stars is insufficient to ionise H but sufficient to render dust clouds visible by scattering, giving reflection nebulae a bluish colour due to greater scattering of shorter wavelengths (Rayleigh scattering).

Solutions

Q1 (d)

- A relevant diagram (emission and reflection nebulae in Orion Molecular Cloud complex)

Solutions

Q1 (e)

- The energy required to power the electromagnetic beams of a pulsar along its magnetic poles results in its observed period increasing continuously.

- Answer: True/False
- The fast rotation generates an electrical field from the motion of the magnetic field, which accelerates charged particles creating the pulsar's beams.

- (Continued next slide - justification depends on the type of pulsar and external forces considered)

Solutions

Q1 (e)

- Answer: True
- By conservation of energy, the rotational energy of the (rotation-powered) pulsar decreases due to emission of the beams, slowing the pulsar’s rotation (spin-down).
- This assumes the absence of external forces and that the moment of inertia of such pulsars remains unchanged.

Solutions

Q1 (e)

- **Answer: False**
- Rotation-powered pulsars however do experience inherent glitches (temporary decreases in rotation period) that interrupt the monotonic spin-down.
- This occurs due to internal processes that transfer angular momentum from the faster-spinning superfluid core to the (decoupled) outer crust.

- OR

- (Continued on next slide)

Solutions

Q1 (e)

- However, huge stresses on the surface of the pulsar due to the to twisting on the strong magnetic field lines may result in neutron starquakes, where the crust adjusts itself closer to a shape closer to a perfect sphere.
- This decreases the moment of inertia of a pulsar and results in a persistent decrease of the observed period above that predicted by pulsar spin-down.

- OR
- (Continued next slide)

Solutions

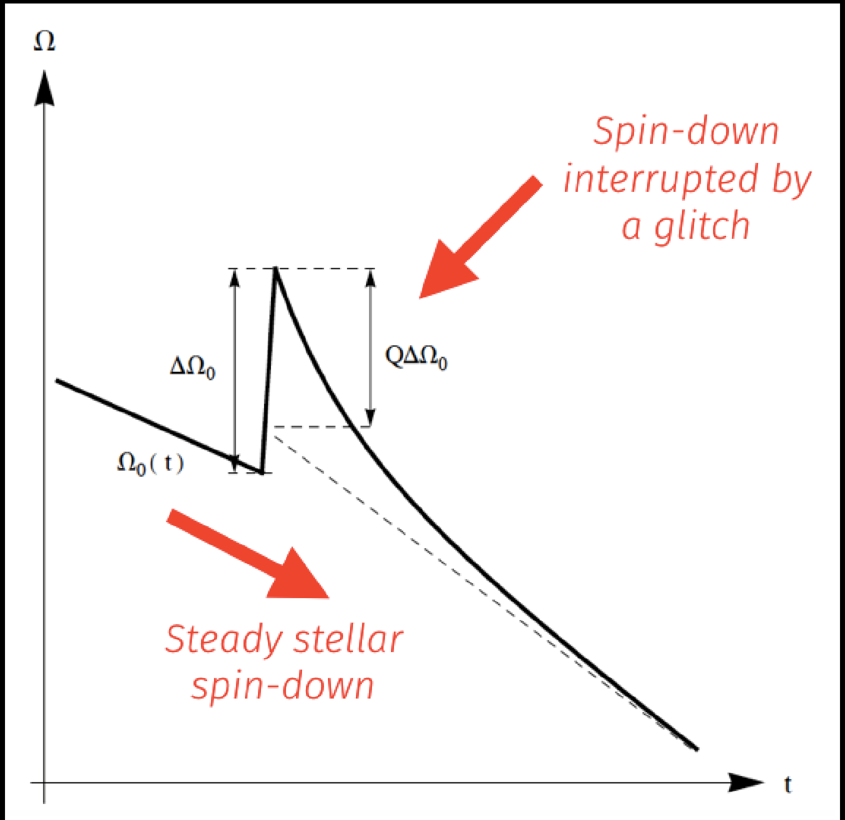
Q1 (e)

- However, not all pulsars are rotation-powered and exhibit a monotonic spin-down, as some pulsars are powered by accretion of matter from a companion star in a binary system.
- For accretion-powered pulsars, the gravitational potential energy of accreted matter powers the electromagnetic beams, and these pulsars exhibit irregular spin-up and spin-down behaviour depending on the rate of accretion.

Solutions

Q1 (e)

- A relevant diagram (effect of spin-down and glitches on rotation-powered pulsars)



Solutions

Q1 (f)

- The distribution of bodies of different masses (at different radii) in a gravitationally bound system remains unchanged with time in the absence of gravitational forces.

- **Answer: False**
- Even though such a system is closed, cluster members (stars/galaxies) both evolve and also gravitationally interact in a chaotic manner.

- (Continued next slide)

Solutions

Q1 (f)

- Due to the equipartition of kinetic energy during gravitational interaction of cluster members, over long timescales (the relaxation time), dynamical mass segregation occurs where high-mass members sink towards the cluster's center, whereas low-mass members are promoted to higher orbits.
- Some low-mass cluster members may be entirely ejected from the system in gravitational interactions with high-mass members (cluster evaporation).

- <u>OR</u>

Solutions

Q1 (f)

- For star clusters, high-mass members will evolve more quickly and reach their end-of-life phases, hence over long timescales, the overall distribution of bodies of differing masses will increasingly be dominated by low-mass cluster members across the entire radii of the system.

Solutions

Q1 (g)

- Variations in the surface brightness of an observed galaxy across its cross-sectional area may be used to improve the accuracy of an estimate derived from a standard candle.

- **Answer: True**
- This is the surface brightness fluctuation (SBF) distance indicator and is a statistical method relying on the non-uniformity of galaxy brightness profiles.

- (Continued on next slide)

Solutions

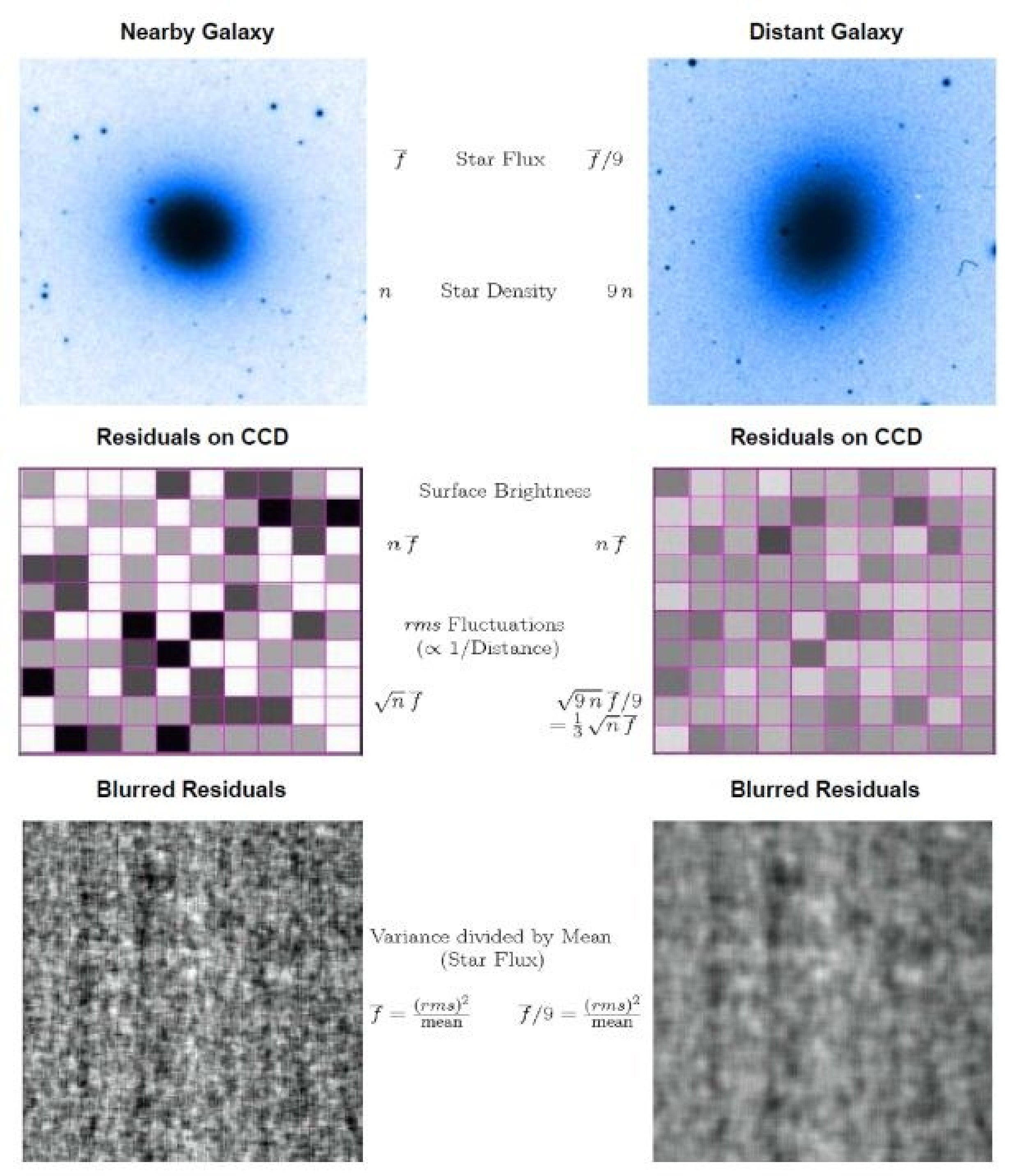
Q1 (g)

- Whilst the mean surface brightness of a galaxy (in absence of extinction) remains largely unchanged with distance, distant galaxies have a smaller (cross-sectional) angular area and thus the mean number of stars in each angular area is greater.
- By subtracting a smooth profile of the galaxy from the raw pixel data, we obtain residual noise whose r.m.s variation is smaller for more distant galaxies due to the averaging of the distribution of stars across the angular area.

Solutions

Q1 (g)

- A relevant diagram (SBF method applied to near and distant galaxy)



Solutions

Q1 (h)

- For a Newtonian telescope, removing the telescope tube in favour of an open truss design improves image contrast at the expense of image stability.

- Answer: True/False
- For "True" responses, you must explain both how the contrast improves and how the stability worsens.

- (Continued next slide - justification depends on which imaging/atmospheric effects are considered.)

Solutions

Q1 (h)

- Answer: True
- Replacing a poorly baffled/flocked tube with an open truss design (with light shroud) can improve image contrast by eliminating internal reflections of stray light in the tube.
- However, the truss tube may flex under the weight of the secondary mirror/focuser/eyepiece/camera, resulting in miscollimation of the telescope, reducing image stability.

Solutions

Q1 (h)

- Answer: False
- An open truss design increases the amount of stray light collected (if no light shroud is used), increasing the background brightness and consequently reducing the contrast of stars/DSOs relative to the background sky.

- OR

- (Continued on next slide)

Solutions

Q1 (h)

- An open truss design increases the amount of ambient air to the mirrors, allowing it to reach thermal equilibrium with the surroundings quicker.
- It also eliminates tube currents, improving stability.

- OR

- An open truss design reduces the OTA's weight, reducing strain on a motorised mount.
- This improves overall tracking accuracy and hence results in more stable images.

Senior DRQ 2

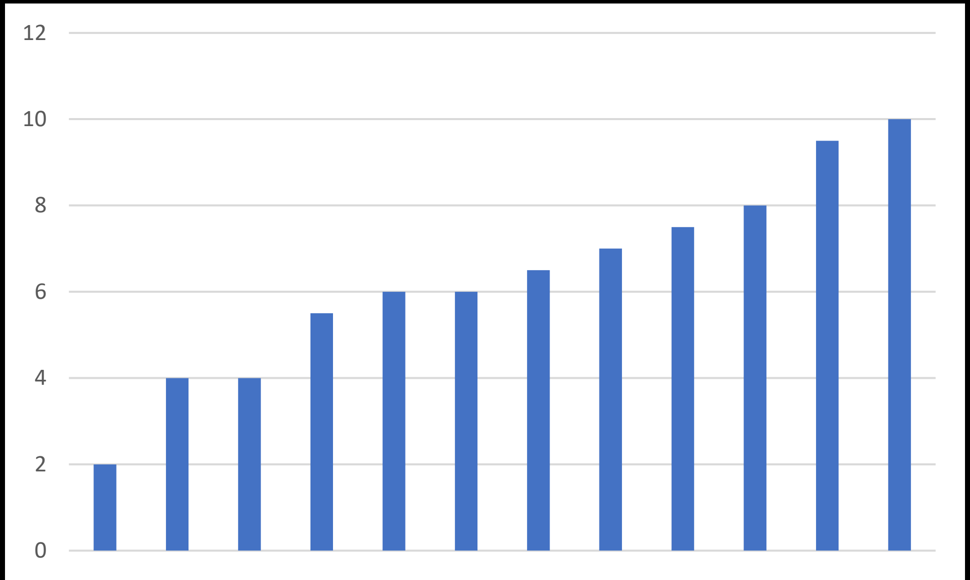
Brightest Day, Blackest Night

Camille

Unless otherwise stated, all images in this section that are NOT of scripts are taken from Google search.
Credits: Sora Yori mo Tooi Basho, Hotline Bling, The Terminator, Log Horizon, Danganronpa 3, Camille’s aurora chasing tour, Shokugeki no Souma

SNR DRQ2: Brightest Day, Blackest Night

- Idea behind the question:
  - Investigate polar day and polar night, and various related phenomena
  - Was meant to have a range of difficulties!
- Fun fact:
  - Question was written while on holiday in Tromso (Norway) and Kiruna (Sweden)
  - I was reminded of Green Lantern and just went along with it



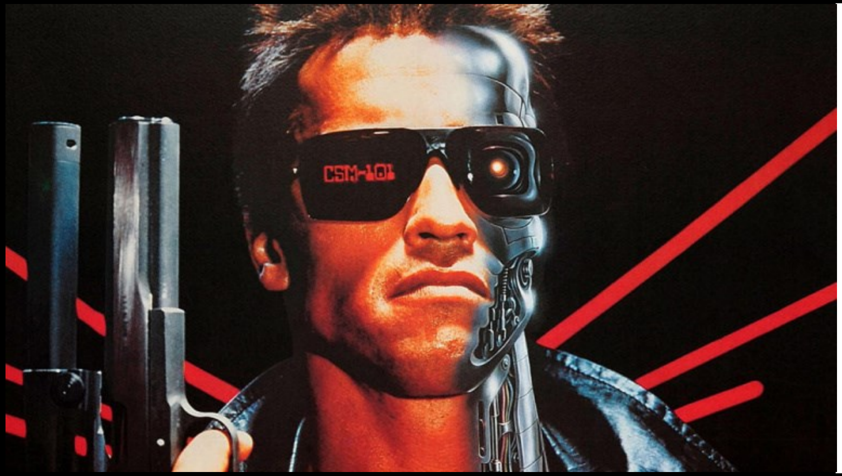
- Mean: 6.33
- Median: 6.25
- Modes: 4, 6

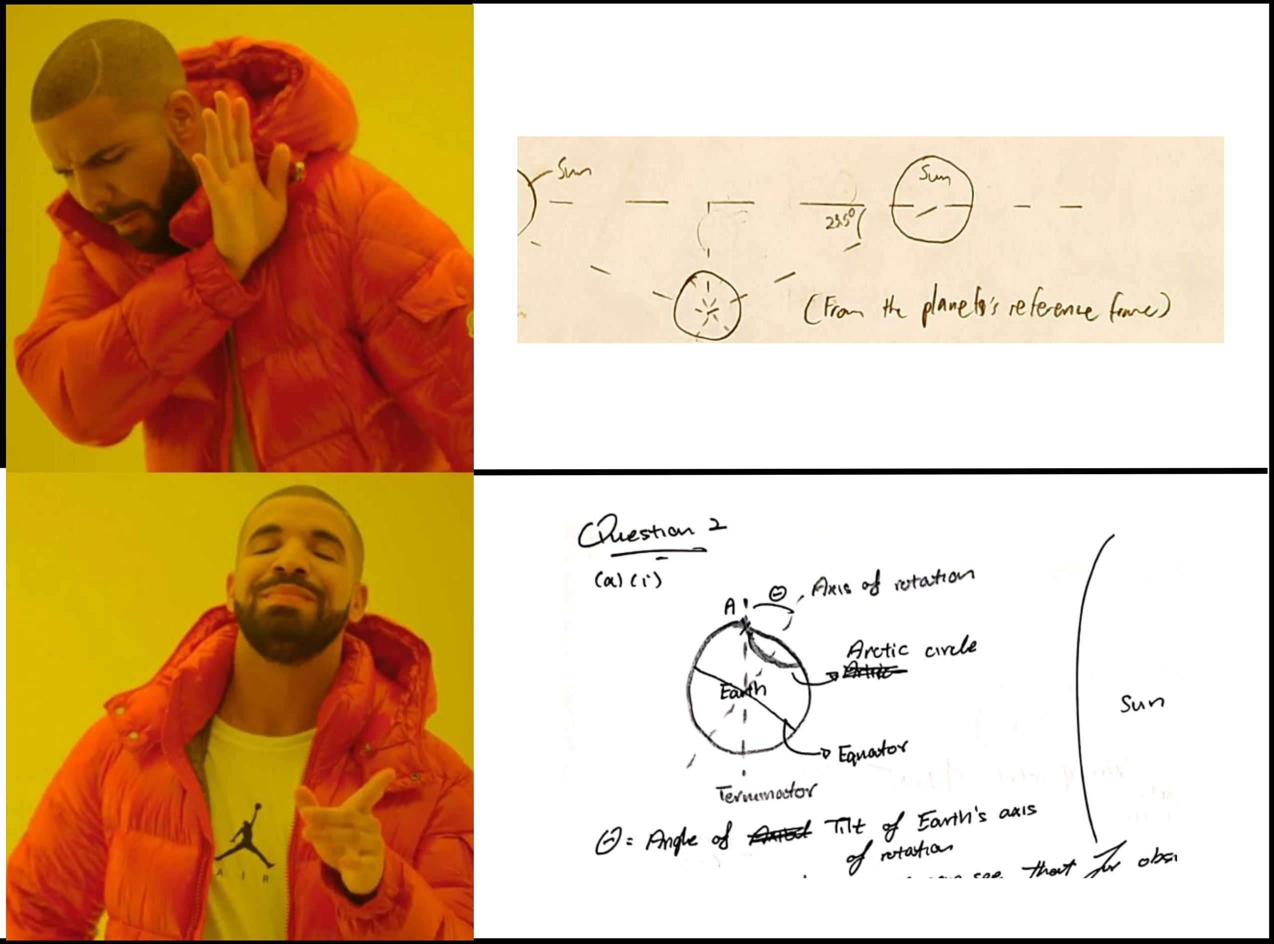
Part I: Brightest Day
Part II: Blackest Night

- Investigate polar day and polar night.
- Generally done alright!
- What you did right:
  - They're simple questions, and you hit most of the main points.
  - Diagrams were generally used well.
- What you did wrong:
  - Explanations are sometimes lacking.

Well-labelled diagrams

- A well-labelled diagram should:
  - Show everything relevant to what you want to explain, and
  - Be **well-labelled**!

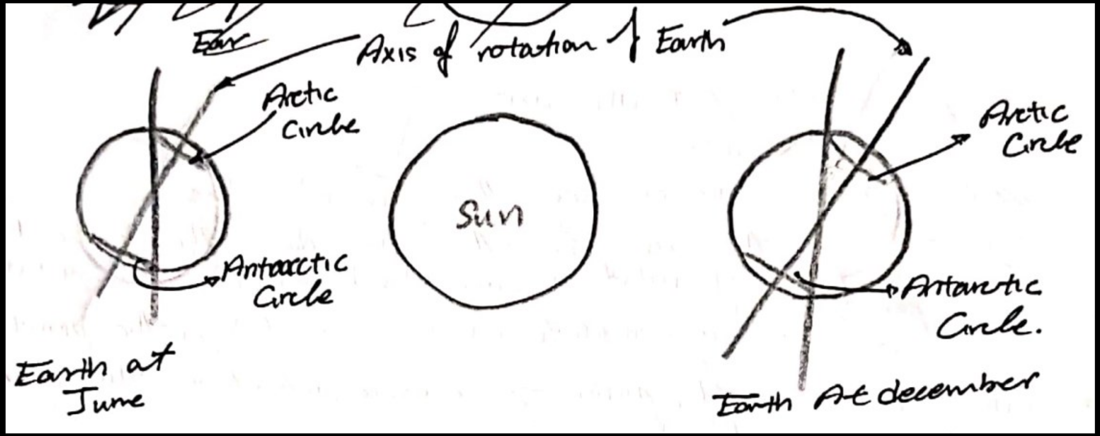




~~Romantic~~ Sunset at the Axial Poles

- Sunrise and sunset is due to Earth's orbital motion.
  - This part was well-understood.

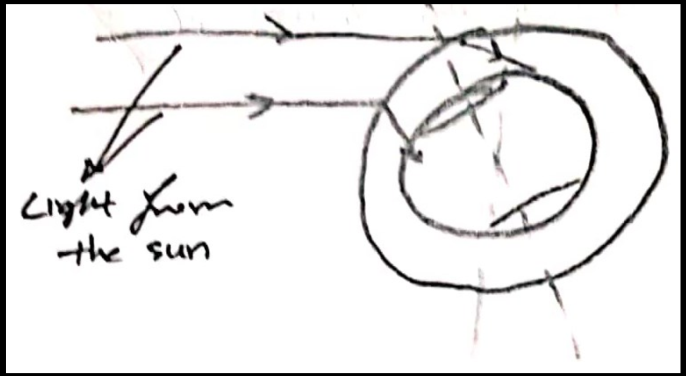
- But *why*?
  - Because movement due to rotation of Earth is zero!
  - So net motion of Sun through sky is due only to orbital motion!



This alone doesn't explain why the sun only sets once a year at the poles!

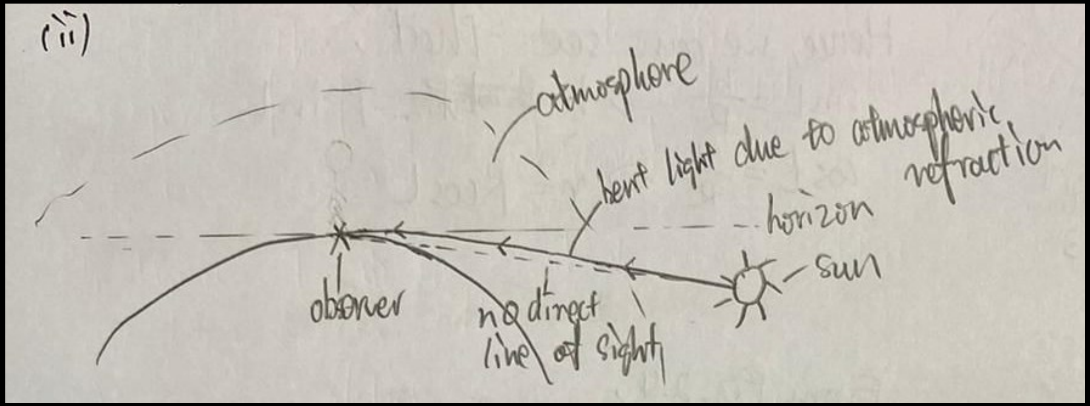
Atmospheric Refraction

- Bending of light as it passes through the atmosphere.
  - Allows polar day outside arctic circle!



This is atmospheric refraction.

- Generally points were hit, but *link back to polar day outside the arctic circles*!
  - Most answers did not do this.



But this is why polar day can occur outside the polar circles!

Part III: No (Part of) E.V.I.L. Shall Escape My S.I.G.H.T.

- Derivation of the Sunrise Equation.
  - …Or a variant, anyway.
- Easy-ish if you draw the diagrams!
- What you did right:
  - Drew the simple diagrams.
- What you did wrong:
  - Not much, actually.
  - But so many of you hate math!
  - What did math ever do to you? :(

Part IV: Green ~~Lantern's~~ Light

- Standard question on aurorae!
- Tests knowledge on the mechanisms behind aurorae.
- What you did right:
  - *(This space intentionally left blank.)*
- What you did wrong:
  - I can Google your answers!
  - And they're word-for-word!
  - Most Googled answers are incomplete anyway!

Aurorae are…

- Beautiful.
- Due to excitation and de-excitation of molecules in the upper atmosphere.
- Caused by two primary culprits: Oxygen (green) and Nitrogen (purple).

Actual photos taken by pros while setting this question ------------------------------------>

(Hands were definitely frozen in the taking of these pictures.)

The Aurora Recipe

- You will need…
  - 1x Solar wind (including charged particles)
  - 1x Magnetosphere
  - Oxygen (low pressure)
  - Nitrogen (low pressure, optional, for decoration)
  - 1x Observer (wrapped like winter burrito)
  - 1x Camera and tripod
  - 1x Plane ticket to polar region

- Step 1: Allow solar wind to impact magnetosphere.
- Step 2: Leave mixture until charged particles spiral along field lines into upper atmosphere.
- Step 3: Ensure charged particles collide with gases until excitation occurs.
- Step 4: Leave gaseous mixture until de-excitation occurs.
- Step 5: Fly to polar region. Using camera and tripod, observe green light from oxygen. If desired, add nitrogen for additional colours.

Special Edition: Google and You

- It is *okay* to Google things you don't know.
  - In fact, that's how you learn many new things!

- It is *not okay* to copy everything wholesale from Google!
  - Information online can be inaccurate or incomplete.
  - Copying others' work without due credit is considered plagiarism!
  - Sometimes, it doesn't answer the question!

- You should…
  - Use Google as a very abundant *source* of information.
  - Extract only the relevant pieces of information, form them into a cohesive whole, and then *create* an answer!

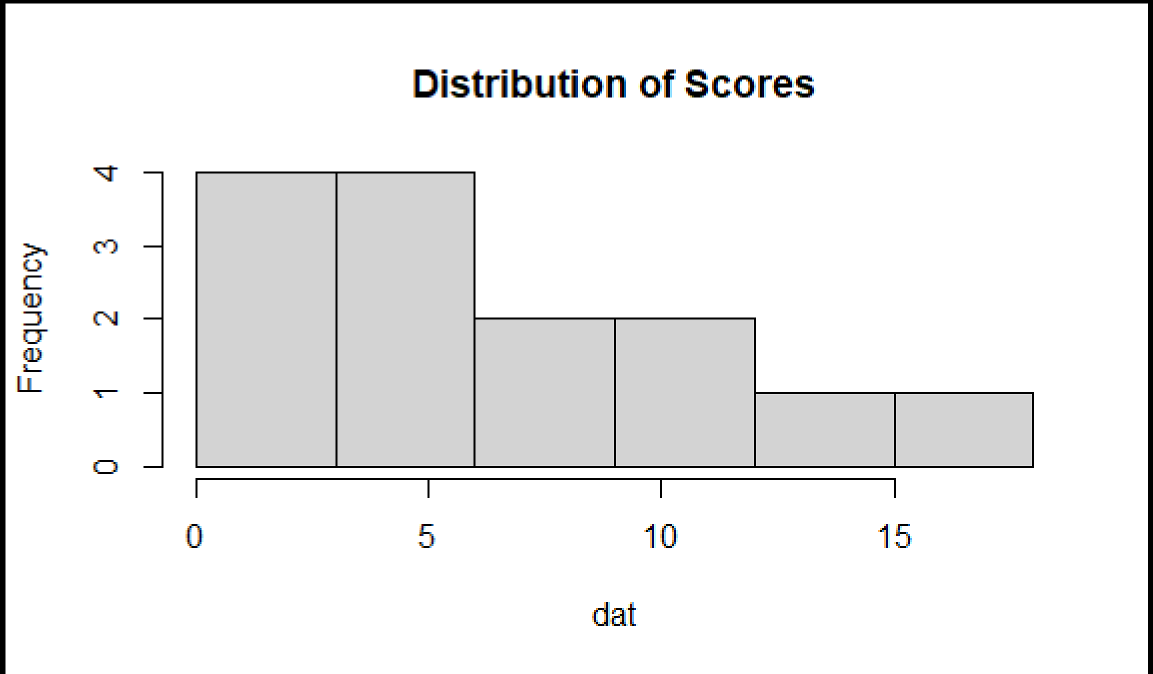
SNR DRQ 3

Astronomical Project – Galaxy Morphology

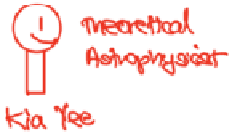
Hong Kiat

Overall Comments

- Teams who actually tried this (like properly and not just pick and do certain parts) did pretty well
- WHY YOU NO DO GRAPH QUESTION(S) FREE MARK ?!?!?!?! (Teams who did the graph question generally scored pretty decent)
- Average: 7.42
- Median: 6.5



Part I Astronomical Preliminaries



First off, we will kick off the project with a quick refresher course from our local theoretical astrophysicist!

(a) The crux of this project involves investigating the colours of the galaxy.

(i) Briefly explain what causes the colour of different galaxies to be different. [1]

(ii) Using your answer in part (i), suggest a reason why spiral galaxies tend to appear bluer as compared to their elliptical counterparts. [2]

- Generally well done
- For (a)(ii), there should be a reference to the structure of a spiral galaxy; ie the presence of a spiral arm in which star formation is active

  i.e Spiral Arm -> Active Star Formation -> More Blue Stars; [2]
  i.e Just Active Star Formation -> More Blue Stars; only [1] since you did not really explain/account for “More”

Part II Data Collection and Image Processing

(b) According to Grace, $fracdeV$ is a good indicator to use to classify a galaxy as elliptical or spiral. In her words:

"The smaller the value of $fracdeV$ - that is, the closer it is to 0 - the more likely it is to be a spiral galaxy."

Using the information above, explain why this **might possibly** be true. [1]

- Not so well done ☹
- Reading Comprehension! Try to infer from the passage why such a trend is true.

  From the question;
  -> Fracdev ~ 1
  -> Fit with equation (1)
  -> Likely to have bulges/elliptical

- Hence, (if you are not so particular about logical fallacies; and since question said "might possibly" be true)
  -> Fracdev ~ 0
  -> Mismatch with equation (1)
  -> No dominant central bulge
  -> Possibly Spiral

(c) There are two different distances, namely, r and d. Recall that

- r is the distance between the centre of the galaxy to a point located in the vicinity of the galaxy, and
- d is the distance between the galaxy and us (Earth).

A fellow astronomer is confused with the subtle differences in these two distances, and claims that an equivalent form of equation (4) holds with d replaced by r. That is, this astronomer claims that

$$\mu(r) = m - 2.5\log_{10} A + 5.0\log_{10} r.$$

Explain why this equation does not make physical sense. [1]

- Not so well done too ☹
- Why you repeat the question?!?!

(c) the equation does not make physical sense as r and d are not the same quantities. ?

This is basically just repeating what the question is asking!

(d) With the help of equation (4) and relevant formulas from the Formula Book, show that equation (4) implies that

$$L = k \exp\left(-\frac{\ln 10}{2.5}\left(\mu - 5\log_{10}\frac{d}{10} + 2.5\log_{10} A - 5\log_{10} d\right)\right),$$

where all distances are measured in parsecs, L is the luminosity of the galaxy, M is the absolute magnitude of the galaxy, μ is the surface brightness of the galaxy, and k is a constant.

(Hint: Two formulas from the Formula Book are relevant. One relates absolute magnitude and apparent magnitude, and the other relates absolute magnitude and luminosity.) [2]

(e) (BONUS) Show that equation (3) follows from equation (1) under certain physical considerations. Consequently, show that $b \approx 7.67$. [2]

- Either you know or you don't (Basically just some tedious algebraic manipulation once you have obtained the relevant equations!)
- One team manage to get [1] for (e), since the method is sound but the formula is not available in formula booklet/this question :(
- For (e), the trick is just to recall that we already have luminosity from (d), and equation (3) is an intensity equation! By definition of intensity, $Intensity = d(Luminosity)/d(Area)$ and you obtain (e) immediately!

Part III Data Analysis on Galaxy Morphology

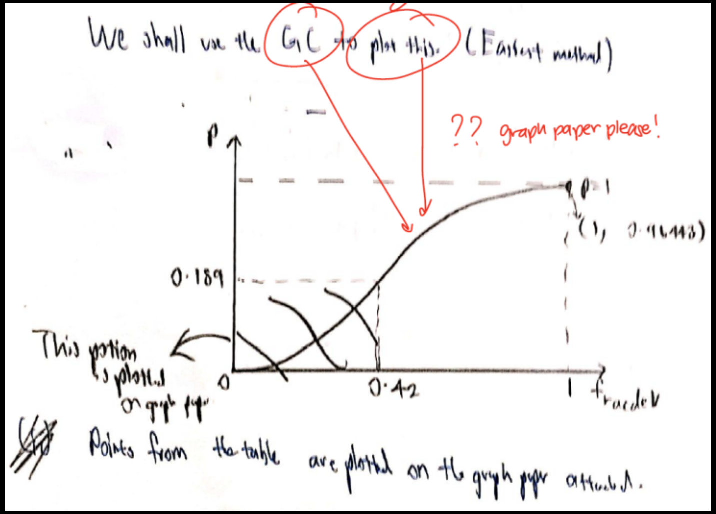
- Basically just a graphing question with some points awarded if you read through the background knowledge
- WHY YOU ALL NEVER DO THIS PART?!?!?!!!! The graph and the plotting of points are worth [4]!!!!! Plus some giveaways here and there ☹

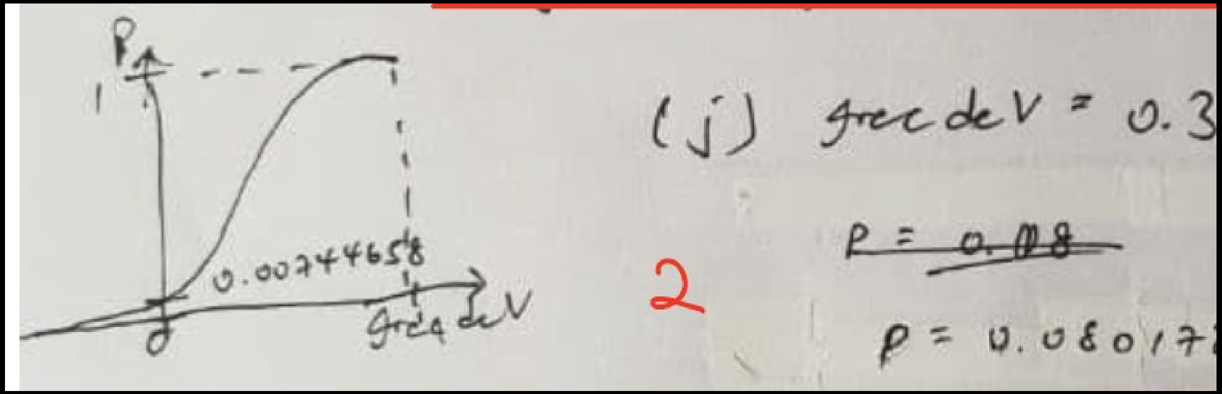
(h) On the same piece of graph paper, using p as the y-axis and $fracdeV$ as the x-axis, do the following.

(i) Draw the logistic regression curve obtained in equation (8).

(Hint: What is the best way to *draw* a curve, given its equation?) [3]

(ii) Plot all the points in the subset shown in Table 1. For each datum, we set $p = 1$ if the spiral galaxy is red, and $p = 0$ if the galaxy is blue. [1]

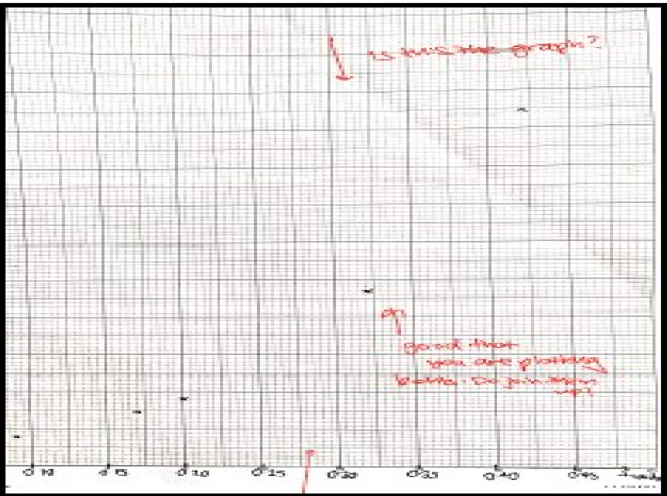


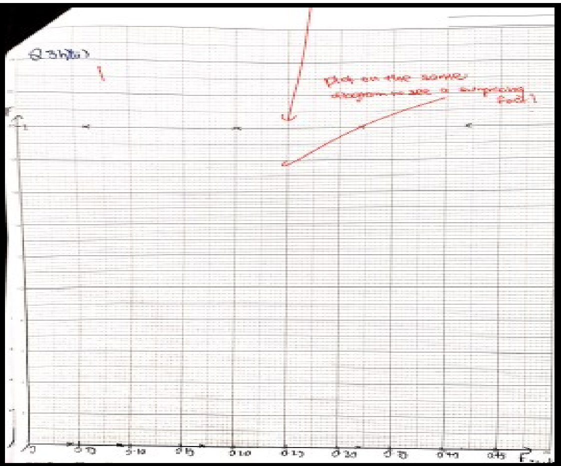


(h) On the same piece of graph paper, using p as the y-axis and $fracdeV$ as the x-axis, do the following.

(i) Draw the logistic regression curve obtained in equation (8).

(Hint: What is the best way to *draw* a curve, given its equation?) [3]

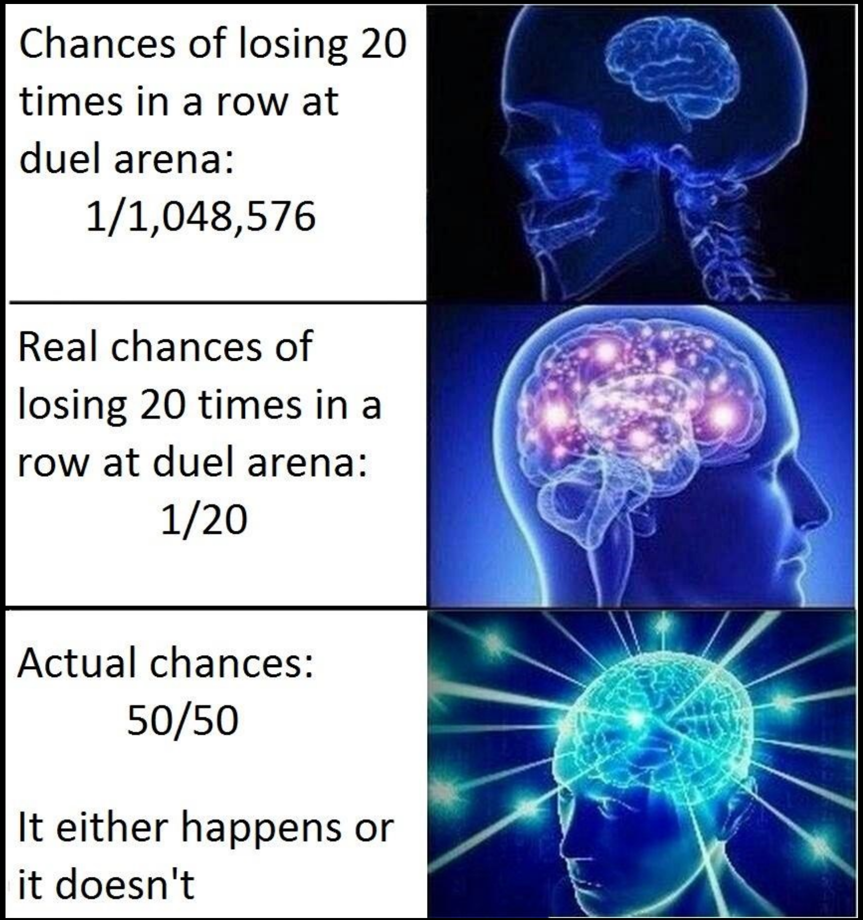




(j) Suppose you are provided with the following image.

Figure 3: A pair of blue spiral galaxies.

You are also told that both spiral galaxies in the image above have $fracdeV = 0.3$. What is the probability that the *Spiral Galaxy Classifier*™ classifies **both** galaxies correctly? [2]



Part IV Results and Discussion

- This part is basically testing if you have understood the objective of the question:
  Part I gives you the relevant background knowledge
  Part II tells you what this fracdev thing is all about
  Part III is basically a free graph question (WHY YALL NEVER DO ?!?!?!) with some terminologies introduced

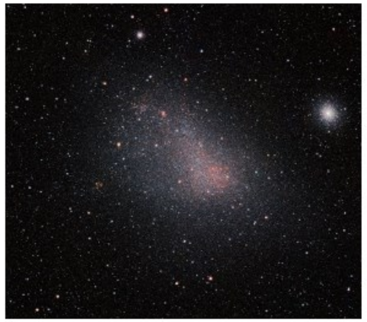


Figure 4: Image of a well-known irregular galaxy, the Small Magellanic Cloud.

Is the probability of getting a "Galaxy is Red" result greater than 0.5, or is it less than 0.5? Justify your answer. [2]

- For this, either you get it or you don't. This reinforces and check if you have actually understood Part II on fracdev. (Some of the better teams weren't able to get it ☹)

Part IV Results and Discussion

(m) From Table 1, we have observed a red spiral galaxy. Discuss and explain how some of these red spiral galaxies could have formed.

(Note: To score full credit for this question, you will need to give at least two possible explanations as to how these red spiral galaxies are formed.) [3]

- Part I provides you with the background to argue for this. Hence, you should ultimately link your solution to star formation, as it is the main reason (as you have explained in Part I) that accounts for the difference in colour.
- Any other solutions that are not linked to star formation are only given [1] max for that suggestion.

SNR DRQ 4

The Comet Hunt

Sichen

Summary

- Generally well done (compared to other questions)
- However a lack of rationality check is seen (whether the result make sense)
- Confusion with the application of ideal rocket equation (given in formula booklet)
- Confusion with basic JC syllabus concepts

Rationality Check

- Generally have no idea what order of magnitude the result should be
- Particularly bad in the exhaust velocity of rocket fuel and the Hill radius of the comet
- When in doubt always check with values for Earth or values given in the formula booklets/question.

Hill Radius

Average radius $r = a\sqrt{1-e^2}$

$$= 3.979 \times 10^{8}\,\text{m}$$

$$r_H = 3.979 \times 10^{8} \sqrt{\frac{10^{13}}{3 \times 1.989 \times 10^{30}}} = 5.15 \times 10^{-1}\,\text{m}$$

The radius an asteroid can capture another object is 50cm? When the asteroid's smallest side is over 1km ?

Hill Radius

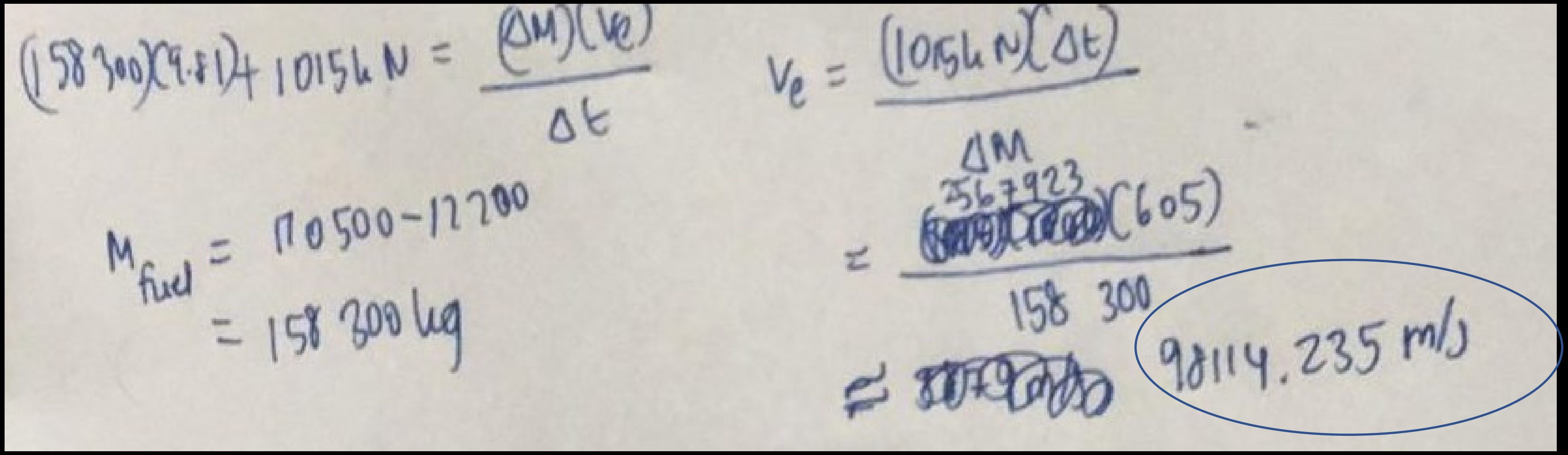
$$r_H = \left(\frac{186\times10^{6} + 849.7\times10^{6}}{2}\right)\sqrt[3]{\frac{1\times10^{8}}{3(1.989\times10^{30})}}$$

$$= 1.7978\times10^{17}$$

$$= 1.80\times10^{17}\ \text{m}$$

The radius an asteroid can capture another object is about 10 light years? So we can capture Sirius with an asteroid?

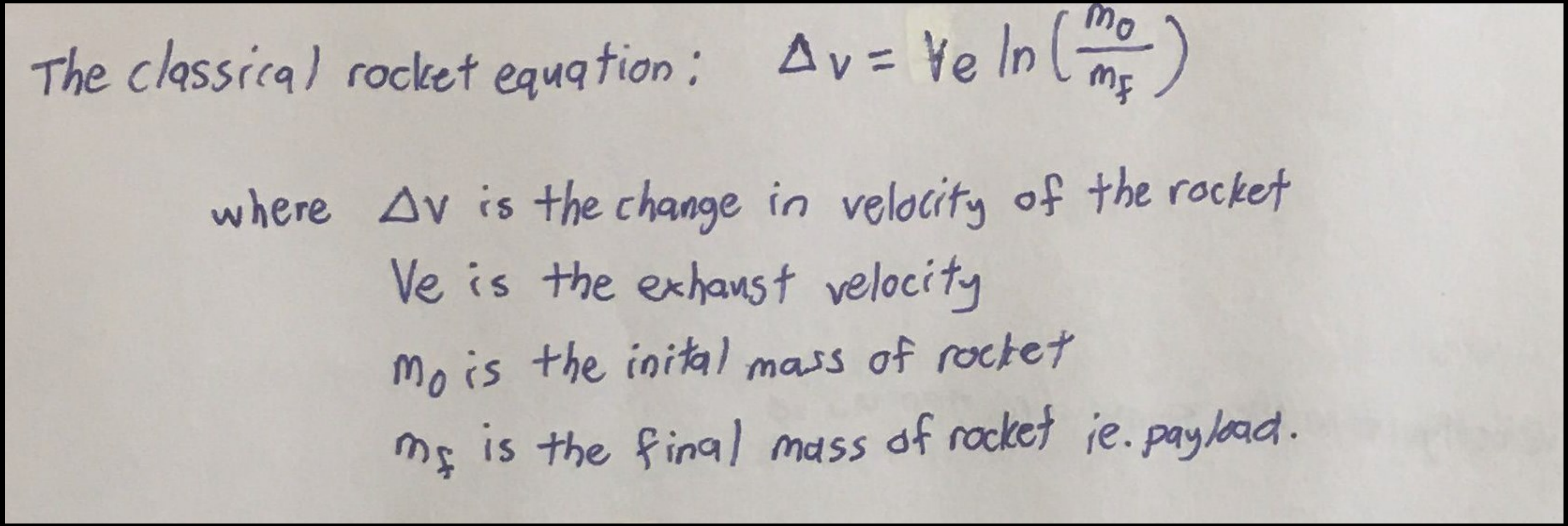
Rocket exhaust velocity



The exhaust velocity of a rocket’s fuel is greater than the escape velocity of solar system(~72km/s)?

Ideal Rocket Equation

- This is one of the equations given in the formula booklet
- However seem like not a lot of you know how to apply/derive this



The classical rocket equation: $\Delta v = V_e \ln\left(\frac{m_0}{m_f}\right)$

where Δv is the change in velocity of the rocket

V_e is the exhaust velocity

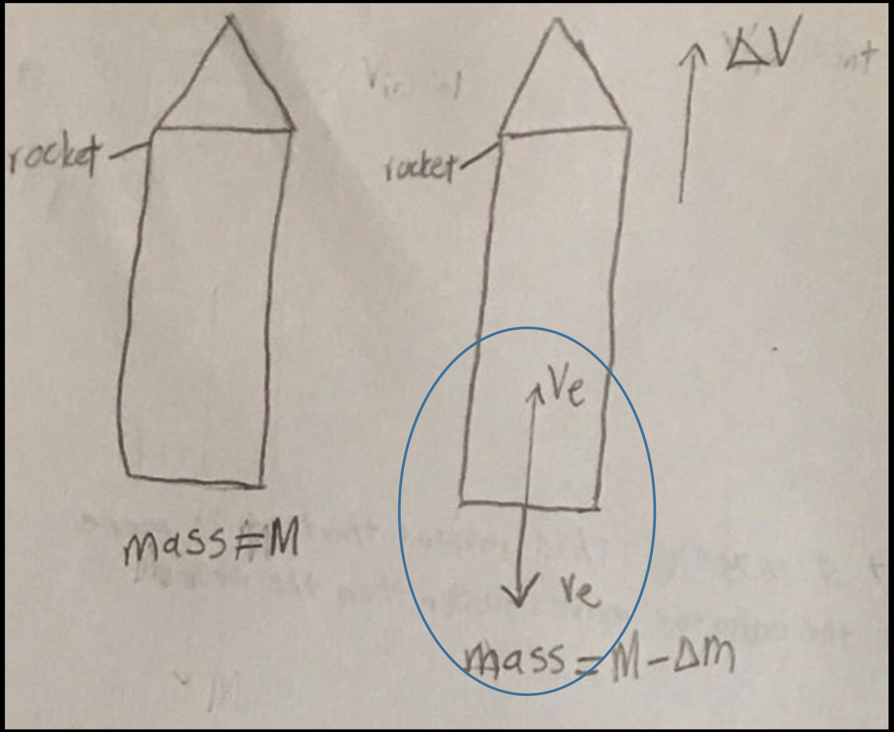
m_0 is the inital mass of rocket

m_f is the final mass of rocket ie. payload.

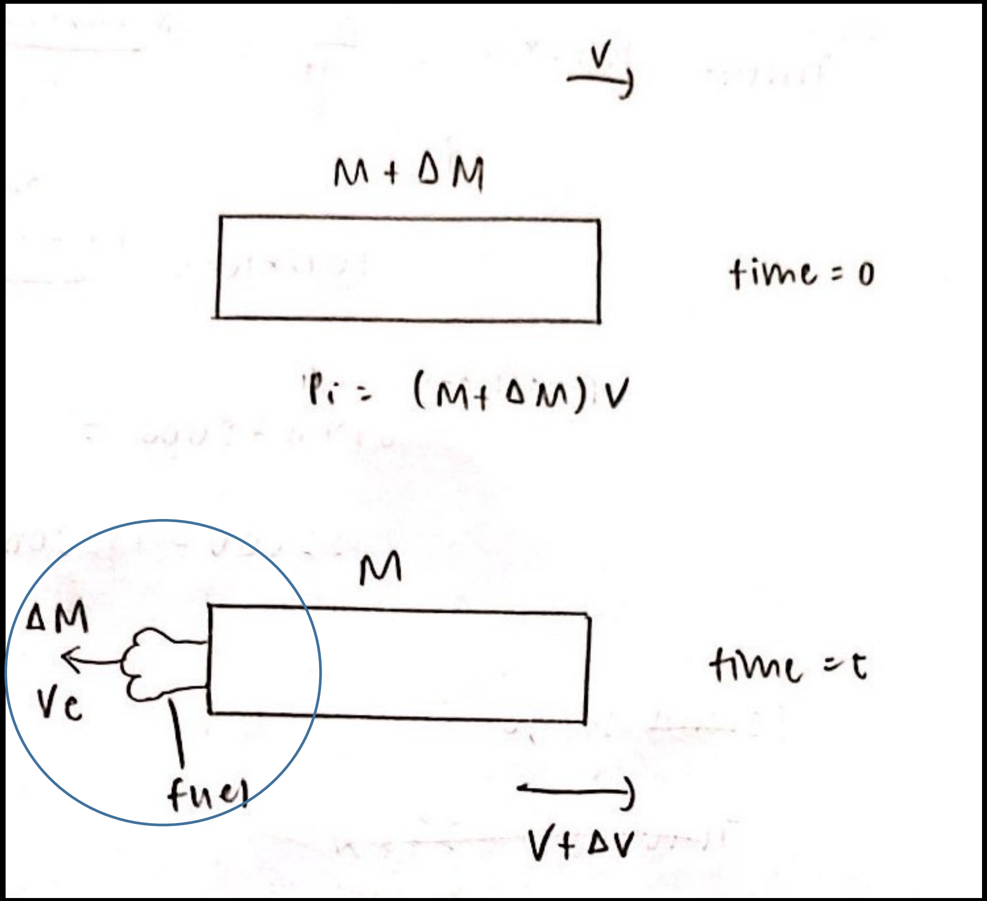
Free-body diagram

- This is taught in all JC and some secondary school
- However many of you seemed unable to draw it properly
- Many draw it in the frame of reference of the rocket
- This frame however does not yield useful equations since Newton’s Second Law doesn’t apply
- This frame have an varying acceleration so even a simple understanding of equivalence principle cant help

Free Body Diagram



Law of conservation of exhaust velocity?



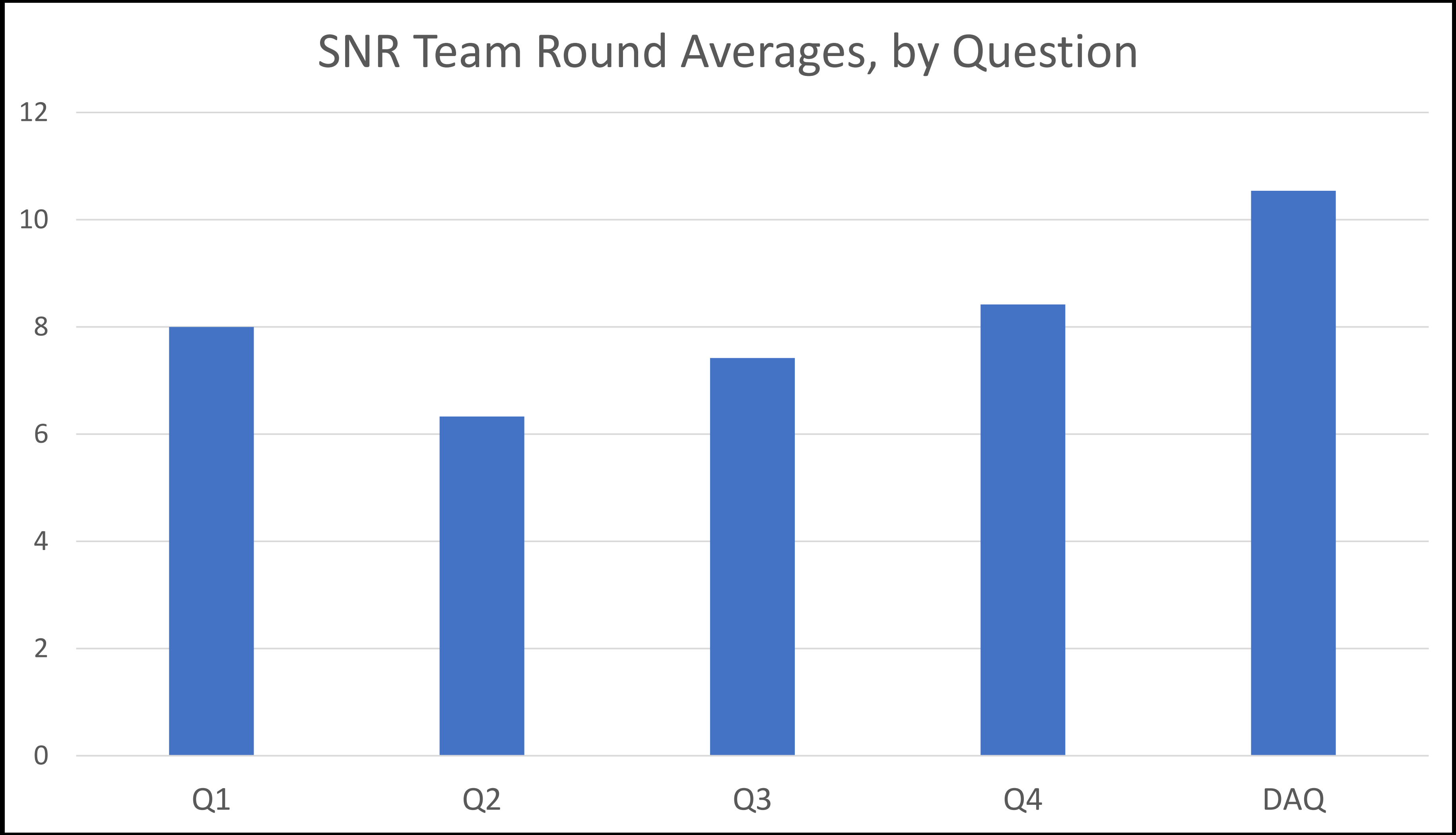
Suddenly the exhaust of the rocket lost its velocity when travelling with the rocket when it is ejected?(this is very common error)

Conclusion

- Generally quite well done compare to previous years
- Please revise JC syllabus as it is often relied upon in DRQ questions
- Please make sure you understand the equation given in the formula booklet

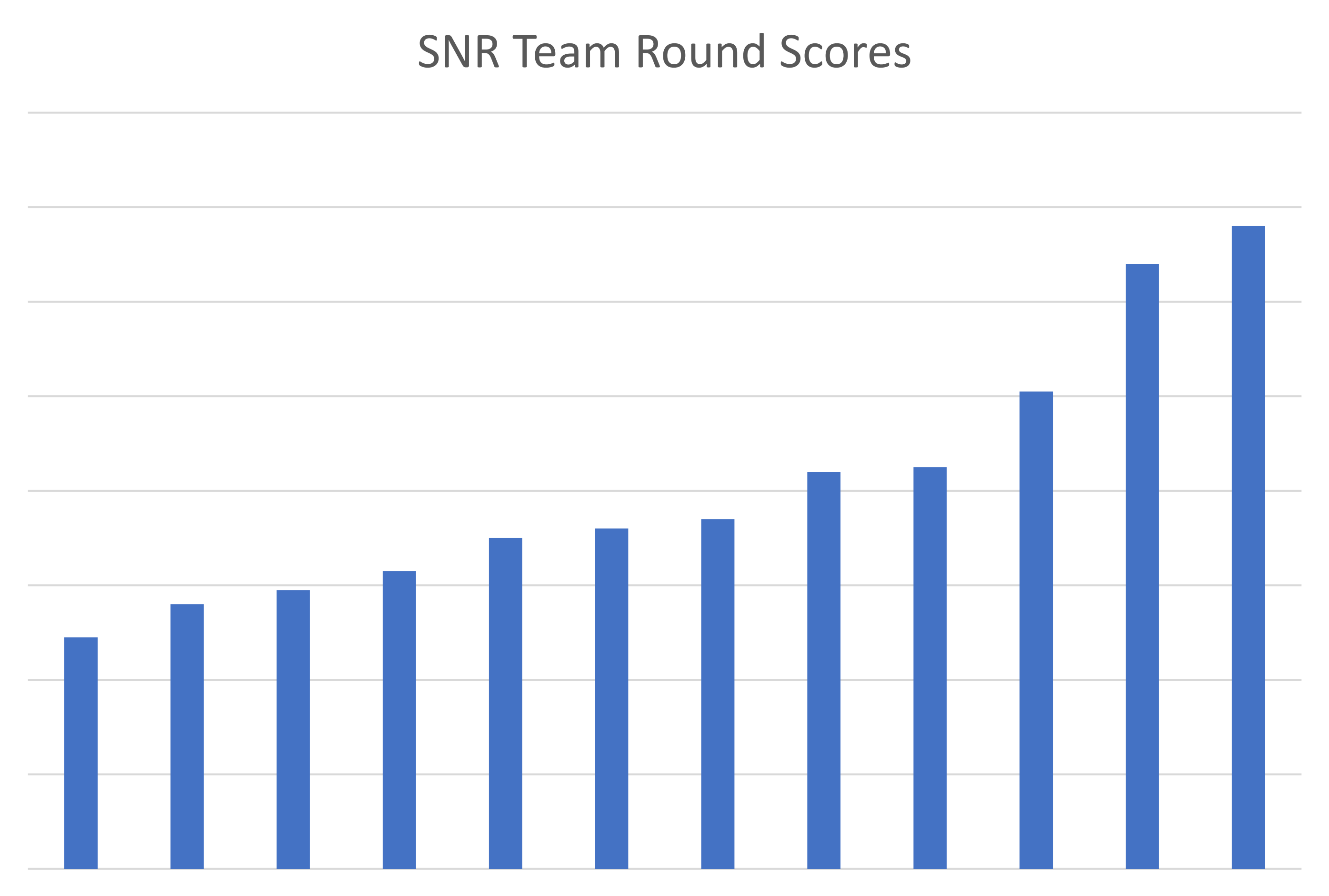
Team Round
Summary Statistics

Team Round Question Averages



Team Round Overall Statistics

- Mean: 40.7
- Median: 36.5
- Std. Deviation: 13.8



Obs Round
Summary Statistics

Please see the answer key for solutions

Obs Round Overall Statistics (out of 100%)

- Mean: 66.5
- Median: 70.1
- Std. Deviation: 14.2