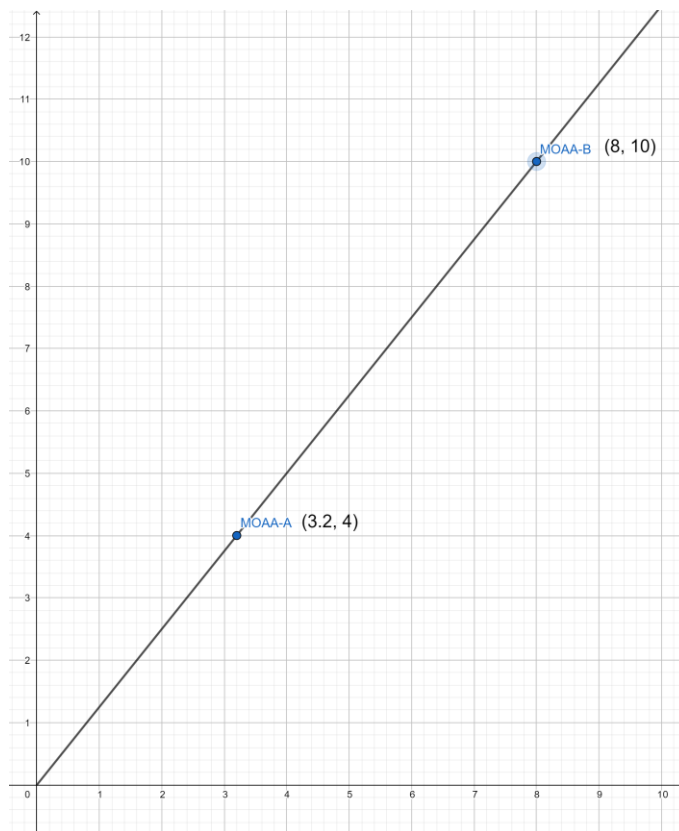


Sample Paper from MOAA 2018 Online Selection Test

1. The MOAA team discovered an extraterrestrial system consisting of 3 planets displaying physical rules outside of our understanding. Below is a $\log T - \log a$ graph plotted by the team, where T is the period of the planet and a is the semi-major axis of the planet in arbitrary units.

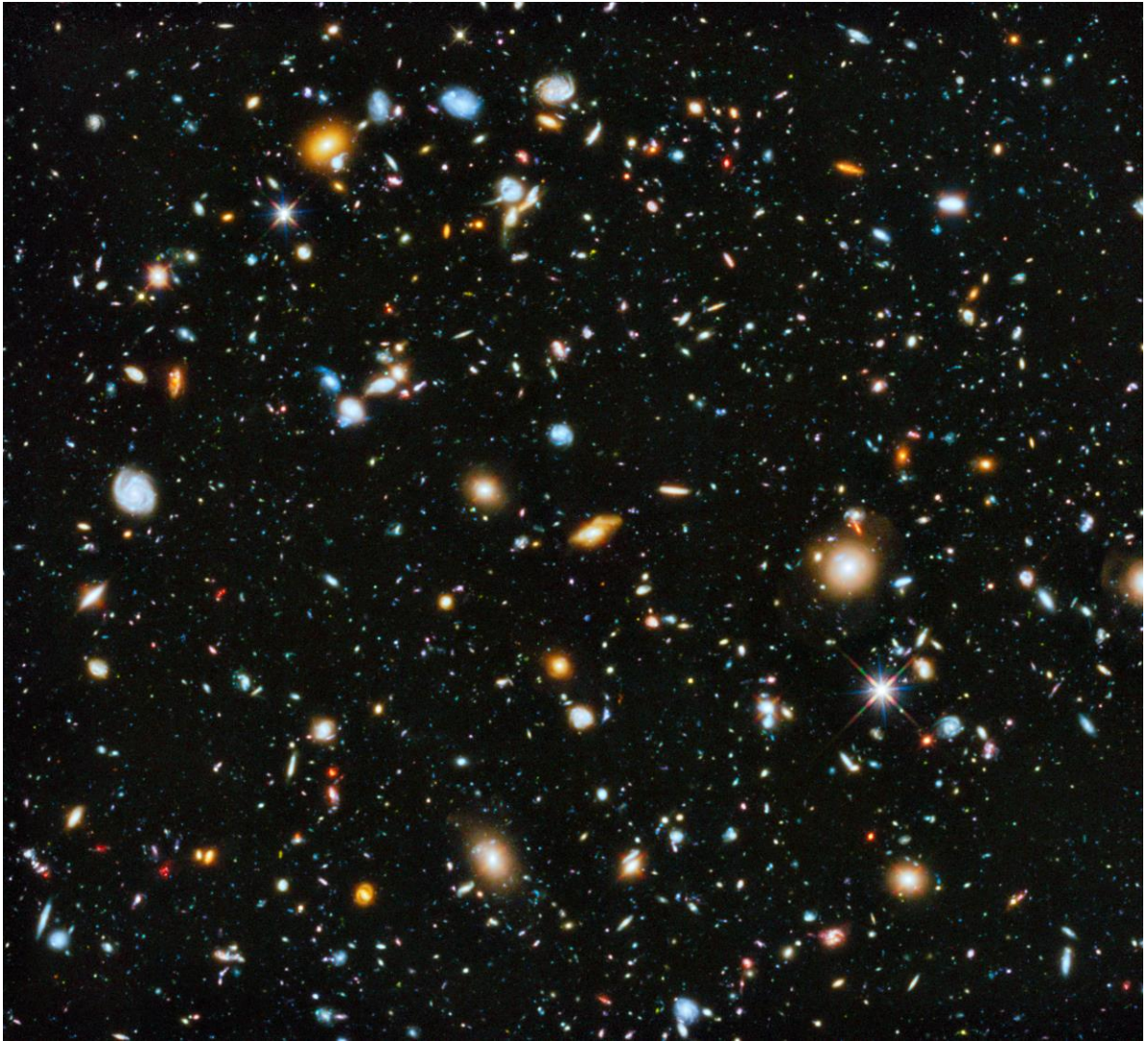


Due to a technical error, the point for the third planet MOAA-C has been left out. It is known that the period of MOAA-C is 10^9 .

What is the semi-major axis of MOAA-C?

- A. 7.2
B. 2×10^{10}
C. $10^{\frac{5}{36}}$
D. $10^{7.2}$
2. An important property of a telescope is its ability to gather light. This “light-gathering power” is proportional to the area of the telescope’s objective. Investigating the differences between a reflector telescope with an 8-inch radius and a refractor telescope with a 9-inch diameter, how do their “light-gathering power” compare?

- A. The refractor collects 0.14 times the light the reflector collects.
 - B. The refractor collects 0.79 times the light the reflector collects.
 - C. The refractor collects 0.563 times the light the reflector collects.
 - D. The refractor collects 0.316 times the light the reflector collects.
3. Below features a famous photograph “Hubble Ultra-Deep Field (HUDF)” featuring a tiny portion of the sky. (Credit: Wikipedia)



The image is composed of about 10,000 galaxies captured over an exposure time of one million seconds. At this rate, how many years would it take to photograph all the estimated 7×10^{11} galaxies in our observable universe?

- A. 7×10^9
- B. 7×10^{13}
- C. 2×10^6

D. 2×10^2

4. On the day this test began (1/7/2018), the Moon can be seen setting upon sunrise and sets fully around 9 a.m. What is the phase of the Moon?

A. Waxing Crescent
B. Waxing Gibbous
C. Waning Gibbous
D. Waning Crescent

5. Below tabulates the mass, diameter, and distance from the Sun of the 4 gaseous planets. Which of the planets below can float on water if they were put together into a bathtub?

Planet	Mass (kg)	Diameter (m)	Distance from Sun (m)
Jupiter	1.9×10^{27}	1.43×10^8	7.78×10^{11}
Saturn	5.7×10^{26}	1.21×10^8	1.43×10^{12}
Uranus	8.7×10^{25}	5.11×10^7	2.87×10^{12}
Neptune	1.0×10^{26}	4.95×10^7	4.50×10^{12}

A. Jupiter
B. Saturn
C. Uranus
D. Neptune

6. Mercury rotates around its axis every 58.65 Earth days, and completes a revolution around the Sun every 87.97 Earth days. What is the fraction of the Mercurian (Hermean) year passed in two Mercurian (Hermean) days?

A. $\frac{2}{3}$

B. 1

C. $\frac{3}{2}$

D. $\frac{4}{3}$

7. Below is the formulation of Newton's Law of Gravity.

$$F_g = G \frac{m_1 m_2}{R^2}$$

mass 1 (kg)

mass 2 (kg)

Force of gravity between mass 1 and mass 2 (N)

The universal gravitational constant ($\text{N m}^2/\text{kg}^2$)

Distance from the center of mass 1 to the center of mass 2 (m)

Where $G = 6.67 \times 10^{-11} \text{Nm}^2\text{kg}^{-1}$.

Which of the following pairs of masses experience the greatest gravitational force?

- A. Two masses of 1kg separated by 2m apart.
- B. Masses of 1kg and 2kg separated 0.5m apart.
- C. Masses of 0.5kg and 1kg separated 0.25m apart.
- D. Two masses of 4kg separated by 2m apart.

8. Participants from last year's Malaysian Team for IOAA had a debate once. The debate went as below.

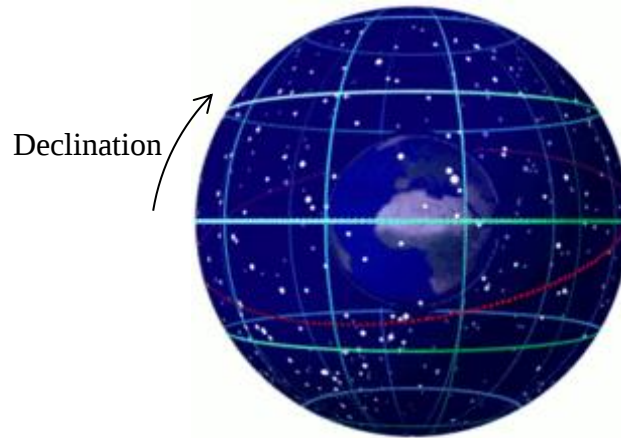
- Qi Zhong : The Earth experiences a greater gravitational pull from the Moon as it has a greater mass!
- Ashley : No, the Moon experiences a greater gravitational force, else how could it ever orbit the Earth?
- Jin Khang : Ok, let's look back at the falling apple analogy, like how Newton did. See, the apple falls down cause of gravity, and the Earth falls up. Their accelerations are the same, but the Earth's velocity and motion is too subtle due to its greater mass!
- Bor Feng : Woah, wait, so who is correct? You guys are confusing me!
- Yong Sheng : Let's wait for MOAA 2018! I'm sure we would find out then!

Whose statement is correct?

- A. Qi Zhong
- B. Ashley
- C. Jin Khang
- D. None of the above

9. The celestial sphere is an imaginary sphere concentric to Earth. All objects in the sky are projected upon the inner surface of the celestial sphere. We measure the position of objects in the sky using coordinates similar to that of Earth's latitude and longitude, which we call declination and right ascension respectively.

Below is an image from Wikipedia showing the concept of the celestial sphere.



Declination on the celestial sphere is defined from the angle subtended between the celestial equator and the point of interest. For example, Polaris is located approximately at declination $90^{\circ}N$. An interesting fact is that the altitude of Polaris (angle above the horizon) denotes one's latitude of observation on Earth.

If Rayson sees a star of declination $30^{\circ}S$ at zenith (directly overhead), what's the latitude of observation?

- A. $30^{\circ}N$
 - B. $60^{\circ}N$
 - C. $30^{\circ}S$
 - D. $60^{\circ}S$
10. Imagine you and your friend race around a circular track at different speeds on the same starting point. After some period of time, both of you will meet again some point around the track. This time duration is called the **synodic period** between you and your friend. Mars orbits around the Sun every 1.88 Earth years. What is the synodic period between Earth and Mars?
- A. 2.88 years
 - B. 0.46 years
 - C. 0.53 years
 - D. 2.13 years
11. In the study of galactic dynamics, we have proposed a parameter named Toomre's stability criterion (or Safronov-Toomre criterion) as a measure of the stability of a

differentially rotating, gaseous accreting disc. The Toomre's stability criterion Q , which is a dimensionless constant can be written as

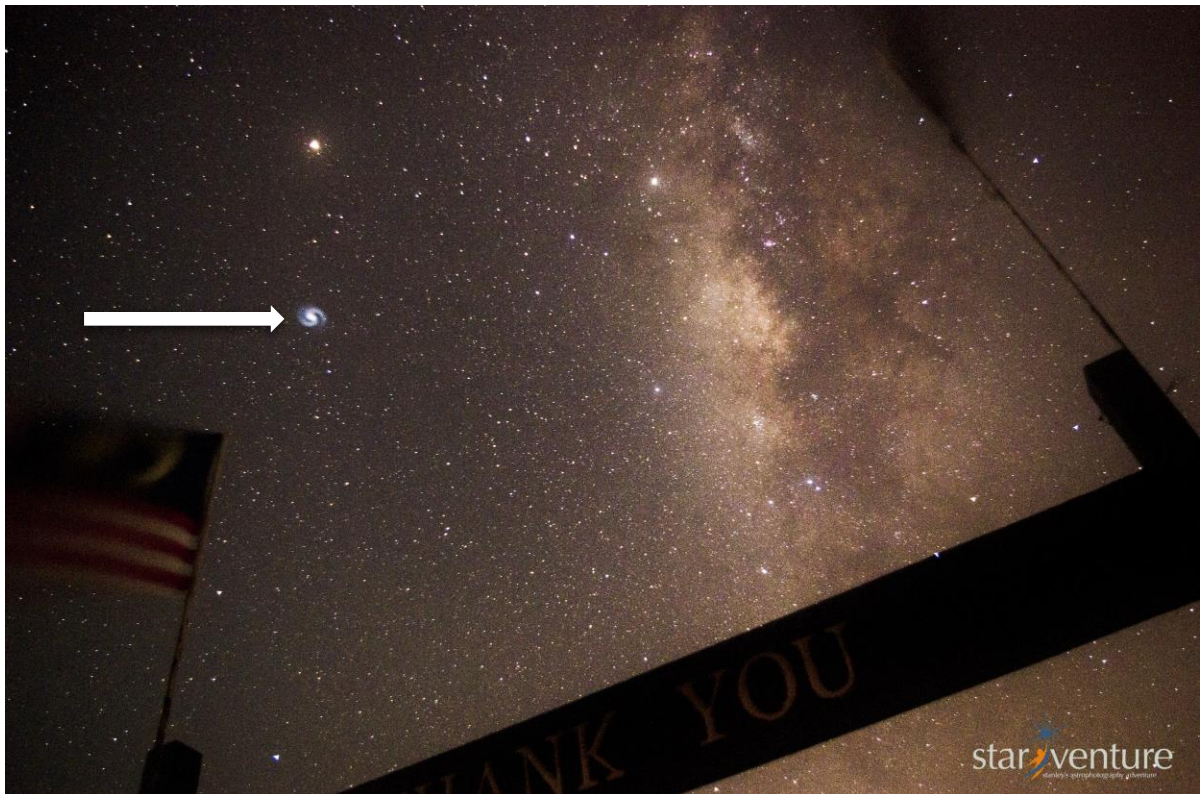
$$Q = \frac{c_s \kappa}{\pi G \Sigma}$$

Where c_s is the speed of sound, κ is the epicyclic frequency and G is the gravitational constant.

What does Σ most likely represent?

- A. Disc volume density
- B. Disc surface density
- C. Disc scale height
- D. Disc angular momentum

12. Below is a starscape photograph captured by Stanley Tang on Gem Island, Pahang on GMT+8 0552, 12 May 2018.



A blue speck of light is spotted on the picture, moving from left to right relative to the background stars, designated by a white arrow. As reference, the red spot above it is our neighboring planet, Mars.

What is the object?

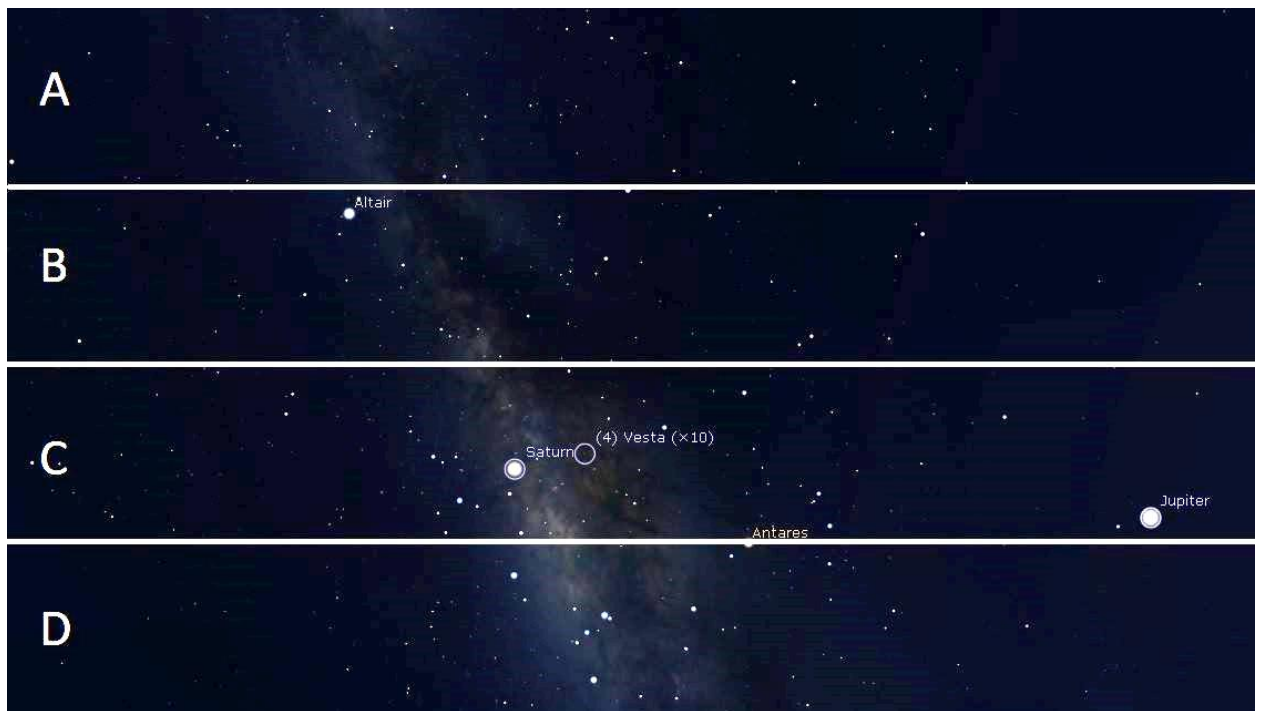
- A. Supernova
- B. Second stage rocket degassing
- C. Barred-spiral galaxy
- D. Artifact of the lens (Lens flare)

13. Given an overwhelmingly large piece of paper, with a thickness of 0.5mm , approximately how many times do you need to fold it in half for the thickness to reach the Sun from Earth?

Given the average distance from Earth to Sun is 1A.U. or $1.5 \times 10^{11}\text{m}$.

- A. 7
- B. 38
- C. 48
- D. 3×10^{14}

14. Below shows a night sky simulation from Stellarium. Planet Mars has been removed from the picture. Which division would Mars most likely be?



- A. A
- B. B
- C. C
- D. D

15. Color index is used by astronomers to compare the relative temperature of a group of stars. From our knowledge about the electromagnetic spectrum, we know that hotter objects emit brighter light at shorter wavelengths (bluer lights), whereas colder objects emit brighter light at longer wavelengths (redder lights).

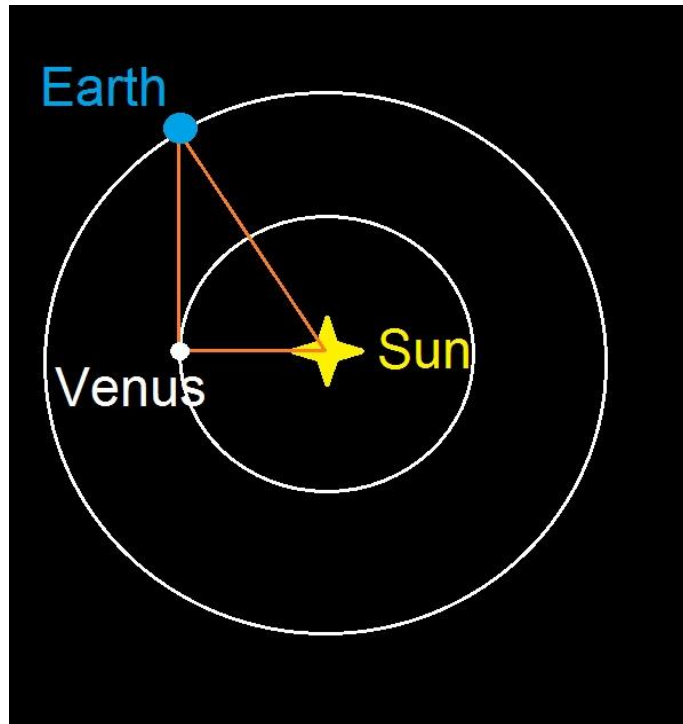
The table below is the data collected by Fongky in 2006 at McDonald Observatory, Texas using the 0.8m telescope with B (445nm) and V (551nm) filter bands.

Star	B Magnitude	V Magnitude
1	12.28	12.47
2	11.87	11.73
3	13.43	13.89
4	11.01	10.92

Magnitudes denote the logarithmic brightness of celestial objects, in this system devised by the astronomer Hipparchus, a star with 5 magnitudes higher than another star is 100 times dimmer.

Fongky needs to arrange the stars in the table above in incremental sequence from cold to hot. Which of the following sequence is correct?

- A. 3, 1, 4, 2
B. 2, 4, 1, 3
C. 4, 2, 1, 3
D. 3, 1, 2, 4
16. An object of mass m performing circular motion of radius R must experience a net force of magnitude $m\omega^2 R$ through the center of orbit, where ω is its angular velocity. For satellites orbiting Earth or any other gravitating mass, the force is given by the mutual gravitational force, $\frac{Gm_1m_2}{R^2}$. A geostationary satellite is a satellite that remains stationary relative to Earth, by means the time it takes to complete one revolution around the Earth's equator is equal to the time the Earth takes to revolve around its axis. A mistake was made in positioning a geostationary satellite and it was placed in an orbit above the equator that was 1km too high. What can you conclude about the satellite?
- A. The satellite moves clockwise relative to Earth as viewed from North.
B. The satellite moves anticlockwise relative to Earth as viewed from North.
C. The satellite is stationary relative to Earth as viewed from North.
D. Cannot be determined due to insufficient data.
17. Below is a schematic diagram of the relative positions of the Sun, Earth and Venus at some point of time as viewed from above.



At what point of time can Venus be seen with the naked eye?

- A. Before sunset
- B. After sunset
- C. Before sunrise
- D. After sunrise

18. The elongation of a planet is defined by its angular distance between the Sun and the planet, or in other words, the angle subtended by the planet and the Sun as seen from Earth. For inferior planets (planets that are closer to the Sun) relative to Earth, the greatest elongation occurs when the angle $\angle \text{Sun} - \text{Planet} - \text{Earth}$ is a right angle. Calculate the ratio of the greatest angular distance between the Sun and Mercury to that of Venus.

Take the orbits of Mercury and Venus be circles of radii 0.38 A.U. and 0.72 A.U. respectively.

- A. 0.48
- B. 0.53
- C. 1.89
- D. 2.06

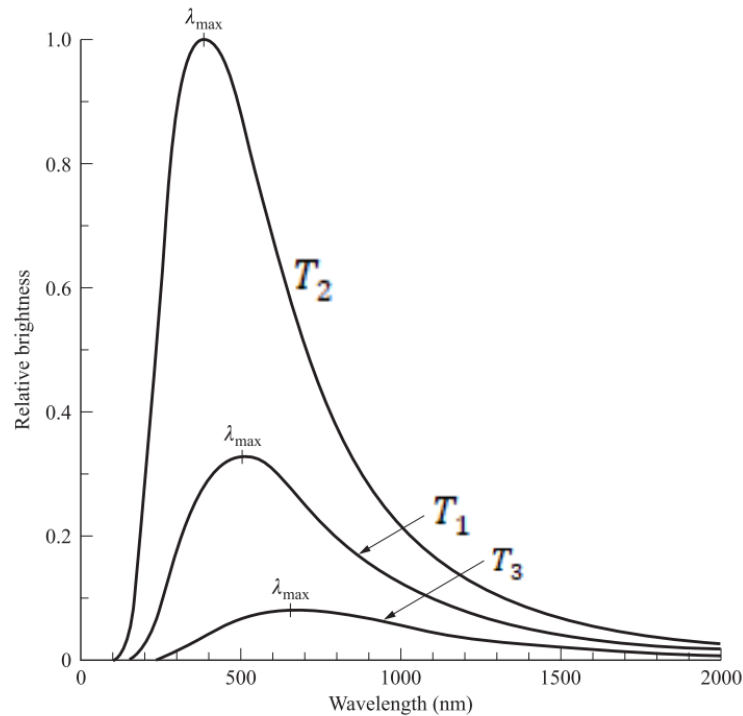
19. M31, or Andromeda galaxy is a neighboring galaxy in our local group. Spanning an angular diameter of 3° in the sky, it is even larger than our full moon. Approximately how many full moons could the angular diameter of M31 fit?

Our moon is on average 384400km away from us, and has a radius of 1750km .

- A. 3
- B. 4.5
- C. 6
- D. 7.5

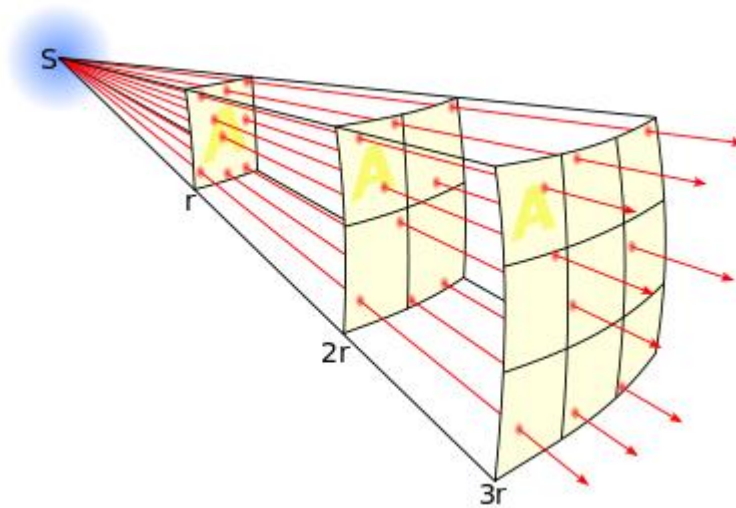
20. Wien's displacement law is one of the fundamental laws of radiation. It states that the peak (or maximum) wavelength λ_m from thermal radiation of a blackbody follows that $\lambda_m T$ is a constant, where T is the blackbody's temperature.

Below is a graph showing the spectral distribution of thermal radiation by objects of temperature T_1 , T_2 and T_3 . How are their temperatures related?



- A. $T_1 < T_2 < T_3$
- B. $T_2 > T_1 > T_3$
- C. $T_3 > T_1 > T_2$
- D. $T_3 < T_2 < T_1$

21. Light from a point source distributes radially like an expanding sphere, with the light embedded on the surface. The “surface density” of the light, or flux decreases with distance, but the total amount remains the same. A schematic diagram is shown below. (Credit: Wikipedia)



What is the ratio of flux received by an observer 3m away from the light source compared to another observed 1.5m away from the first observer?

- A. 9:4
- B. 1:2
- C. 2:1
- D. 3:2

22. An object of mass m performing circular motion of radius R must experience a net force of magnitude $\frac{mv^2}{R}$ through the center of orbit, where v is its velocity. For orbits formed from gravitational pull, the force is given by the mutual gravitational force, $\frac{GMm}{R^2}$. It is known that the escape velocity (minimum velocity to escape the gravitational pull of some mass M) is $\sqrt{\frac{2GM}{R}}$.

In some catastrophe, the mass of the Sun has drastically decrease. What is the minimum factor of mass of Sun left to eject the Earth from its orbit?

- A. $\frac{1}{4}$
- B. $\frac{1}{2}$
- C. $\sqrt{2}$
- D. $\frac{1}{\sqrt{2}}$

23. The apparent motion of our sky is due to our observation of relative positions of celestial objects from the Earth's rotation. In Malaysia, where we are near the equator, how long should we wait for a star just above the eastern horizon to rise to an altitude of 25° ?

- A. 100 minutes
- B. 375 minutes
- C. 120 minutes
- D. 200 minutes

24. (Free-Response Question)

Recently, there has been a conspiracy theory circulating on the internet claiming that the Earth is flat. If this were to be true, predict what would be different than now due to the effect of gravity from the new distribution of mass? Give at least 2 predictions.

25. (Free-Response Question)

Due to tidal friction, our Moon has been receding from Earth, what would be the consequence of this phenomena? Give at least 2 predictions.