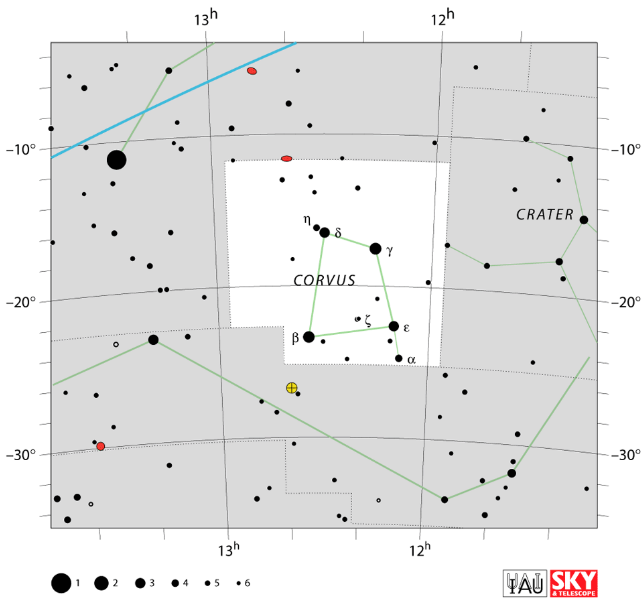
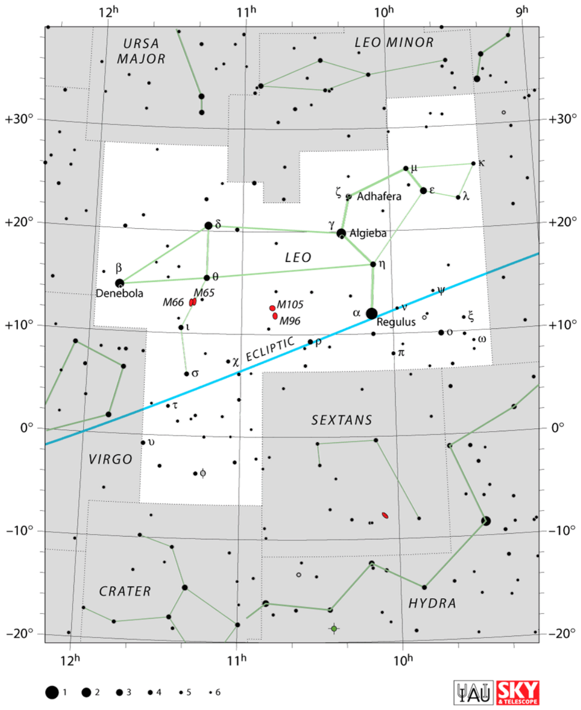
1. Below is an image of Comet Neowise 2020/F3 taken at an undisclosed location and time. What constellation is the comet in?

A

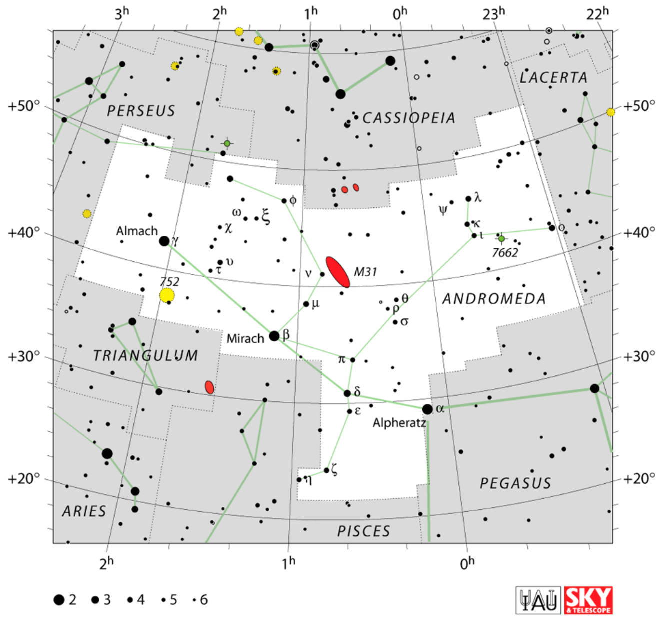


B.



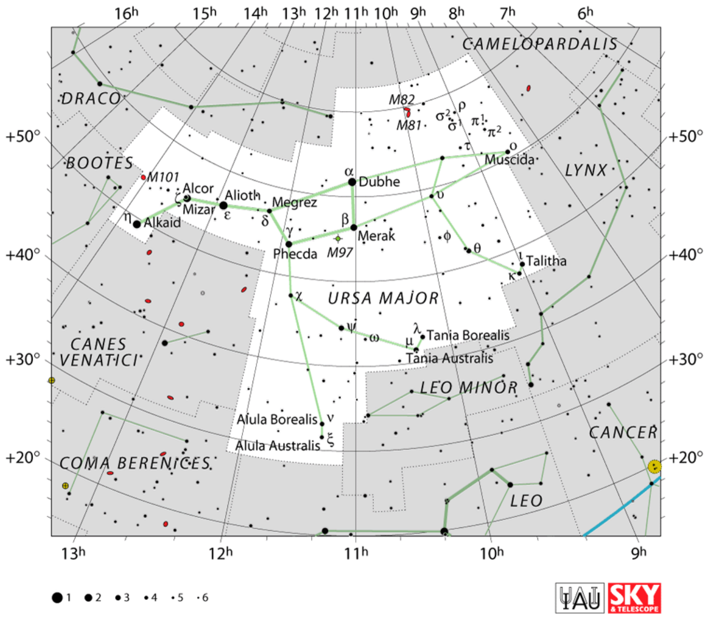
URSA MAJOR
LEO MINOR
LEO
SEXTANS
VIRGO
CRATER
HYDRA
ECLIPTIC
Adhafera
Algieba
Denebola
Regulus
M65
M66
M105
M96
12h
11h
10h
9h
+30°
+20°
+10°
0°
−10°
−20°
IAU
SKY & TELESCOPE

C.



PERSEUS
CASSIOPEIA
LACERTA
ANDROMEDA
TRIANGULUM
PEGASUS
ARIES
PISCES
Almach
Mirach
Alpheratz
M31
752
7662
3h
2h
1h
0h
23h
22h
+50°
+40°
+30°
+20°
IAU
SKY & TELESCOPE

D.



2. Two stars on the celestial sphere have equatorial coordinates (2h30m, +30°) and (4h30m, +30°) respectively. What is the angular distance between the two stars as seen from an observer on Earth?

A. 20°
B. 26°
C. 30°
D. 64°

3. What is the distance from the Earth to a satellite that orbits the Earth twice in a day? Assume a circular orbit.

A. 3000 km

B. 7×10^5 km

C. 3×10^4 km

D. 8×10^6 km

4. A Mars sized black hole would have a mass of about __ solar masses.

A. 10

B. 100

C. 1000

D. 10000

5. The table shows the observed angular size and actual diameter of four objects. Which object is the closest to Earth?

Object	Angular size	Diameter
A	10”	5000 km
B	7”	0.3 AU
C	39”	8×10^7 m
D	50”	0.0002 pc

6.

6. What is the ratio of light that can be collected by telescope A (diameter = 2m) and telescope B (diameter = 4m) in the same amount of time?

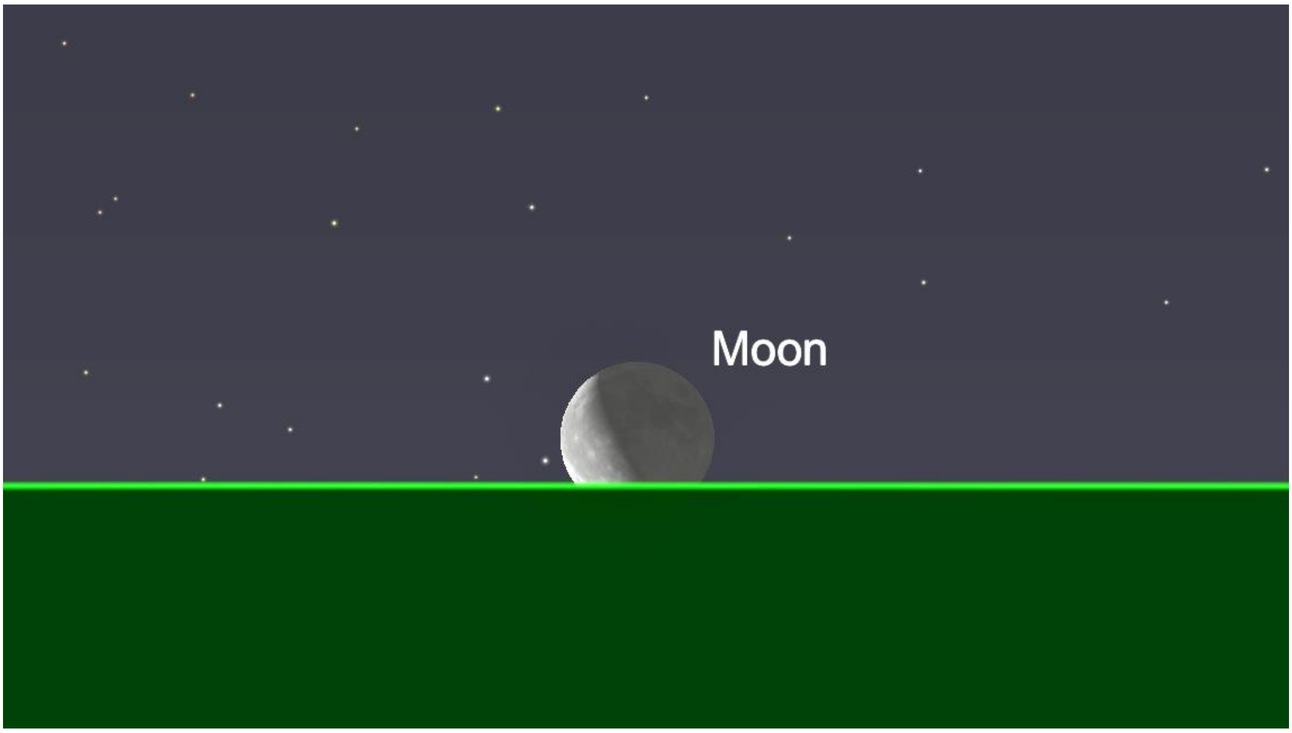
A. ¼

B. ½

C. 2

D. 4

7. One night, while facing East you see the Moon rising above the horizon just after 1am.



Which of the following statements are true?

(i) The Moon is past its full phase.

(ii) The Moon will rise earlier tomorrow.

(iii) The Moon will be less illuminated tomorrow.

(iv) The Moon is currently undergoing an eclipse.

A. i, ii

B. i, iii

C. ii, iii

D. ii, iv

8. When the planet Venus is observed from Earth, it appears to show phases similar to those of the Moon. Which phase of Venus would appear largest (in diameter) relative to the other phases?

A. Crescent phase

B. Quarter phase (‘D’ shape)

C. Gibbous phase

D. They all have the same size

9. In practice, we cannot directly measure the mass of individual stars; instead, what we can measure is the luminosity (i.e., brightness) of individuals stars. It is long known that the mass function dn/dM can be derived from the "luminosity function" dn/dL, i.e. counting stars with different brightness. But to do that, we need to the relation between the brightness and mass of stars.

   First derived in 1924 by Sir Arthur Eddington, it turns out that one drive from simple equations about ideal gas (the same that you have learned in school) to show that the luminosity of stars scales monotonically with the mass of stars, with

   $L \propto M^{\beta}$

   beta = 3. Taking all these into account, the luminosity function of stars should follow which of the following?

   a. $\frac{dn}{dL} \propto L^{-\alpha/\beta}$
   b. $\frac{dn}{dL} \propto L^{-(\alpha+1)/\beta}$
   c. $\frac{dn}{dL} \propto L^{-(\alpha+1)/(\beta-1)}$ **(answer)**
   d. $\frac{dn}{dL} \propto L^{(-(\alpha+1)/(\beta-1)-1)}$

10. One way to estimate the total mass of a galaxy like the Milky Way is by finding the escape velocity of stars. If stars are moving faster than the escape velocity, they would be ejected from the galaxy, and we would not see them as often. This, in turn, means that if we can investigate the occurrence of stars as a function of their velocity, the lack of stars above certain velocity is a tell-tale sign of the galaxy's mass. Let us consider a galaxy like the Milky Way, and there is a civilization like us locates at 10 kpc (1pc = 3 x 10^{16}m) from the Galactic center. If these aliens measure only a few-to-no star in their vicinity with a velocity larger than 300 km/s, they would have inferred that they live in a galaxy with a total mass of

    a. 10^11 Msun
    b. 10^12 Msun
    c. 10^13 Msun
    d. 10^14 Msun

    (ps. In fact, this simple idea remains one of the best ways to "weigh" the Milky Way).

11. In 2019, part of the Nobel prize was dedicated to the first detection of a planet outside our Solar system. Finding and characterizing planets outside our Solar system is one of the hottest topics in astronomy. The most common way to search for such “exo-planets” is by monitoring the luminosity (more precisely, the flux, i.e. the number of photons) that we receive from the star. If there is an exoplanet and transit between the star and us, the planet will block part of the light, causing a temporarily “dimming” star. Suppose an alien civilization outside the Solar system wants to detect the presence of Jupiter in the Solar system. What is the minimal precision requirement (in terms of flux) to infer the existence of Jupiter in the Solar system?

    a. **1%**
    b. 0.1%
    c. 0.01%
    d. 0.001%

12. The line-of-sight velocity of stars can be measured by collecting spectra from the stars. For example, the Gaia satellite collects spectra in the 847-874 nm wavelength range. A key motivation is that this region contains the Ca triplet absorption, which includes a key central feature at 854.2 nm. If we observe a star with this prominent feature located at 853.06 nm, the star is

    a. **moving toward us with a velocity of 400 km/s**
    b. moving away from us with a velocity of 400 km/s
    c. moving toward us with a velocity of 200 km/s
    d. moving away from us with a velocity of 200 km/s

13. We know that the Sun rotates. In fact, most stars rotate. However, there is a break-up velocity beyond which the star’s self-gravity can no longer support the centrifugal force due to the rotational. Stars with which of the following combination of the mass, radius and rotational period cannot exist?

    a. M = 5 Msun, R = 1 Rsun, P = 10 day
    b. **M = 5 Msun, R = 10 Rsun, P = 1 day**
    c. M = 1 Msun, R = 5 Rsun, P = 10 day
    d. M = 10 Msun, R = 5 Rsun, P = 1 day

14. The Las Campanas Observatory in Chile is one of the best sites on Earth to perform observation due to its clear sky. Which of the following targets are not/hardly observable from Las Campanas?

    a. **RA = 6h, Dec = 25 deg**
    b. RA = 0h , Dec = -50 deg
    c. RA = 18h, Dec = -25 deg
    d. RA = 12h, Dec = 0 deg

15. The Nobel Prize in 2020 was awarded to three scientists who jointly discovered the supermassive black hole at the centre of our galaxy. The key to their discovery hinges on the simple "high-school" fact that they detected a group of stars that orbit an unseen object following the Keplerian motion. For example, the famous star known as S2 follows a Keplerian motion with a semi-major axis of 970 AU and with a period of 16 years (yes, the scientists observe the same stars for more than two decades!), from which we can infer that there must be a black hole as massive as 3.56 x 10^6 Msun lurking at the centre of our galaxy.

    Let's consider a hypothetical Universe where we observe similar stars with a semi-major axis of 2000 AU and a period of 9 years. In this case, what would be the mass of the black hole?

    a. 10^5 Msun
    b. 10^6 Msun
    c. 10^7 Msun
    d. 10^8 Msun

    [note, the proper estimate of the black hole mass in the Milky Way is ~4.15 × 10^6 Msun, not 3.56 × 10^6 Msun, but we will not delve into the details here.]

16. Edwin Hubble first measured that galaxies further away from us are receding faster away from us. In particular, if we fit the velocity of galaxies as a function of the distance of the galaxies, we would get a slope known as the Hubble constant, H0. A fantastic property about H0 is that, by simply measuring the velocities of galaxies around us, a simple dimensional analysis of the H0 value can tell us the age of the Universe. Suppose we measure a Hubble constant of 10 km/s Mpc^{-1}, estimate the age of the Universe.

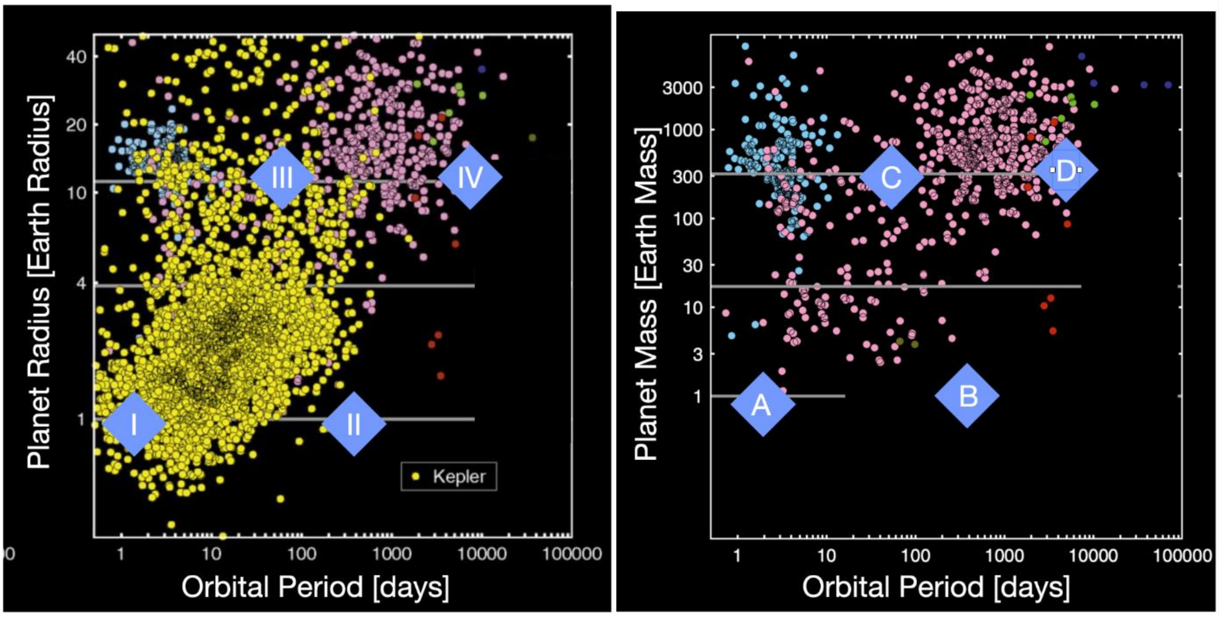
    a. 1 Gyr
    b. 10 Gyr
    c. 100 Gyr
    d. 1000 Gyr

17. It is known that for a special type of star, known as the Cepheid variable, the star's brightness oscillates with a fixed period, and the period correlates with the absolute magnitude of stars. This period-luminosity relation is known as Leavitt's Law. This relation, in turn, can be used to measure the distance of the stars. Assuming Leavitt's law:

    $$M_v = -2.43 log_{10}(P\,(in\ days) - 1) - 4.05$$

    Suppose we observe a Cepheid variable with an oscillation period of 100 days and an apparent magnitude of V = 7. How far is this star from us?

    a. 0.1 kpc
    b. 0.5 kpc
    c. 1 kpc
    d. 5 kpc



18. One of the marvels in modern-day astronomy is that we now have myriad ways to detect the planets outside the solar systems. Plotted below are the distributions of radii, masses, and orbital periods for known "exoplanets." If we were to plot the planets in our solar systems onto this plot, where would the Earth and Jupiter lie?

a. Earth: A/I, Jupiter B/II
b. Earth: B/II, Jupiter C/III
c. Earth: B/II, Jupiter D/IV
d. Earth: A/I, Jupiter D/IV

19. Which of the following phenomena is cause by the atmosphere of earth?

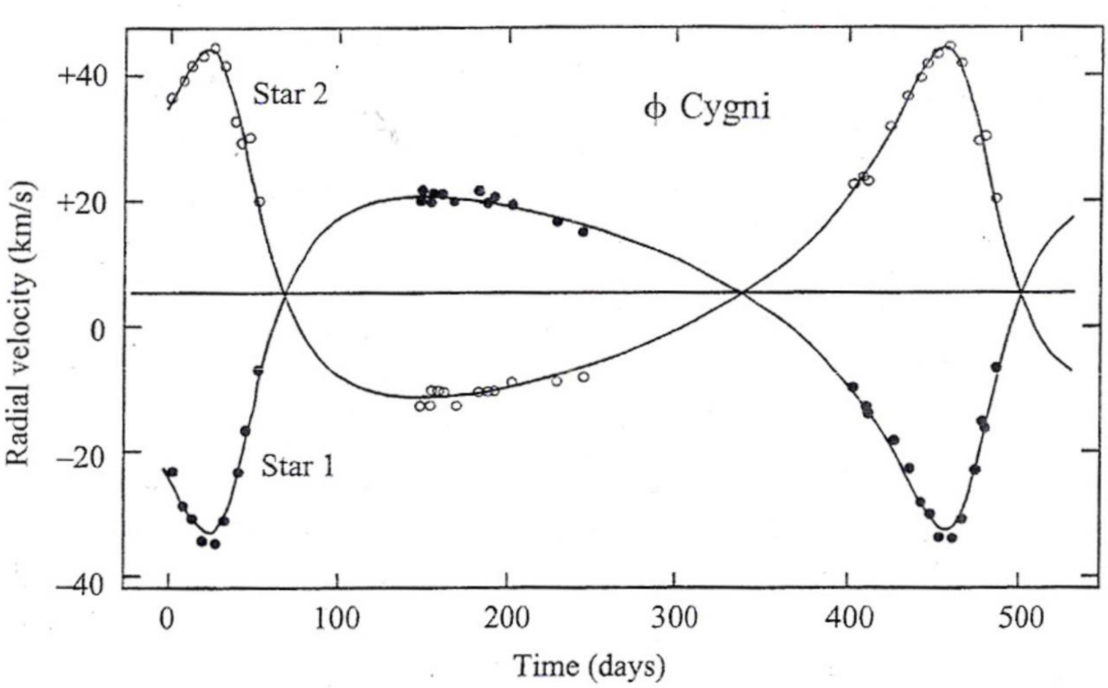
i. We can still see the sun even when it set below horizon

ii. The sun turns red while setting

iii. The sun become oval shape when setting

A i, ii
B ii, iii
C i, iii
D All of the above

20. Below shows the radial velocity curve for the spectroscopic binary φ Cygni.



Assume that in the binary system, Star 2 eclipses Star 1. How many days after Day 0 would the eclipse may be possible?

A. 50 days
B. 100 days
C. 400 days
D. 500 days

21. Pictures of the Sun at sunset were taken for 2 consecutive days in south Malaysia (assumed to be on the equator), right when the bottom edge of the Sun touches the horizon, on 1st February.

    How many degrees does the Sun shift between the two images and in what cardinal direction? Explain your answer in detail.

22. For hundreds of years before GPS navigation system is invented, sailors have been able to calculate the local longitude based on the time of transit of stars (stars crossing the local meridian).

A ship leaves Langkawi (Longitude: 100°E), at 21:00 (MYT) Malaysia Standard Time. The captain looks up and observes the star Regulus of Leo is on the meridian.

The ship sails west for 10 days, and the captain has again noticed that Regulus is on the meridian at 21:00 MYT.

(a) What is the longitude of the ship in the nearest degree?

Answer:

Earth rotation = 24h = 1,440m, Earth motion related to the star in a day (sidereal motion) ≈ 24/360 = 00:04
(Student may know this but if student derives this will get additional point)

After 10 days, the Regulus will rise 00:04 × 10 = 00:40,
In Malaysia, it will rise at 21:00 – 00:40 = 20:20 MYT.
But since the captain sees it at 21:00 MYT instead of 20:20, the local time at the ship's position has also changed due to the hour angle: 21:00 – 20:20 = 00:40
The longitude of the ship after 10 days = 100°E – ($40 \times \frac{360}{24 \times 60}$) = 90°E

(b) What is the local time at the longitude in question (a) when it is 21:30 MYT?

Answer:
MYT = UTC + 08:00
21:30 MYT = 13:30 UTC
Local time at the longitude in question (a) = 13:30 + $90 \times \frac{24}{360}$ = 19:30

23. The Kuala Lumpur Tower is 421 meters high. At a latitude of about 3°N, what is the ratio of the tower's shadow during the winter solstice to that during the summer solstice at local noon? You can assume that the axial tilt of the Earth is 23.5°.

24. You are an astronomy student wanting to build a radio telescope, pointing directly upwards at the sky, with a 10m diameter. Your university require the edges to be at least 2m high for safety purposes.

(a) If the edges of your 10m telescope is exactly 2m high, how high is the focal point of your telescope?
3.125m

(b) You decided instead to make the focal point the same height as the edge of your 10m telescope, so you can mount your receiver more easily. What height does the edge of your telescope has to be now?
2.5m

25. Suppose we observe a star at 10pc away from us, and the star has an angular diameter of 0.01 arcsec (1 arcsec = $5X10^{-6}$ radian). If we observe a periodic signal of exoplanet transit with a period of a year, and the transit dimming lasts for three days, estimate how far away the planet is from its host stars. Explain your reasoning.

[Hint: for simplicity, we will assume that the exoplanet transit through the star's equator and we have observed the transit edge-on]

Stellar diameter = D_* = 2 R_* = 10pc * tan(0.01 arcsec) ~ 22 R_sun ~ 0.1 AU

Let a to be the distance the planet is from the host stars, we have
2 pi a / D_* = P / T_transit ~ 365/3

a = 365/3 * D_* / (2*pi) = 2 AU

[Hint: note that, while the planet "intercepts" the irradiance from the host star with an area of pi R^2, where R is the radius of the planet, the planet emits energy spherically with a total surface area of 4 pi R^2].