Sample questions for the preparation for the final exam in Planetary System Astrophysics ASTC25.

In the quiz, your work is that of a scientific editor of a text to be published. Please read the questions very carefully! They are sometimes tricky, e.g. only one word is wrong. Please review carefully the lecture notes/recordings and chapter 15 of our textbook. **Circle at least one wrong word** in wrong sentences. I have used **boldface** to indicate words that could be circled. Some questions below have no answers and some have "N" answer but no indication of wrong word(s).

A general advice for these questions and for written problems as well. Learn to use Keplers laws efficiently. This is an example. When you are asked if the period of a planet at 0.05 AU from the star is 2.5 days, then you could, of course, use your calculator and do the full calculation: P = circumference/velocity = $2\pi a/\sqrt{GM/a} = 2\pi\sqrt{a^3/GM}$ (I hope that now you are familiar with the basic equation of dynamical astronomy $v = \sqrt{GM/a}$) i.e. $2\pi((0.05 \cdot 1.5 \cdot 10^{13}/(6.673 \cdot 10^{-8} \cdot 2 \cdot 10^{33}))^{1/2}$. This way, there are many chances to mix or miscalculate something. You'll save some valuable time if you think this way: $P \sim a^{1.5}$, so in order to reproduce the result of P=1 yr at $a = 1$ AU, we must have $P/(1yr) = (a/AU)^{1.5}$ (at least for the sun, otherwise we must multiply the r.h.s. by $\sqrt{M_\odot/M}$. So $P = 0.05^{1.5}$ yr, or $365 * 0.05 * \sqrt{0.05}$ days. That's a quicker calculation! It's just $3.65 * 0.5 * \sqrt{5} \approx 1.825 * 2.25 \approx 4$ days, not 2.5 days (no calculator needed).

Try to do a similar problem in your head: what is the Keplerian speed around the sun at the distance just outside the 10th planet UB313, $a \approx 100$ AU? That speed at 1 AU is 30 km/s (around the sun, otherwise multiply by a square-root of star mass in solar masses). In general, if one gets used to this trick, then one rarely needs to use the gravitational constant in simple orbital calculations.

Part II – TRUE-OR-FALSE quiz (please mark with Y or N for Yes or No in front of the statement. You will also be asked to put phrases or words or numbers you think are incorrect in chevron marks. Only some such words are marked below, so there is no single correct marking for each "N" sentence.
Disregard language erros and typos, errors in the quiz are about physics/astrophysics/math.

? [1] Very accurate distance and size of the Moon was obtained by the hellenistic astronomer Aristarchus of Samos in the 3rd century BC.

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Y [1] The Earth-Moon distance was known to Newton to be 60 times the Earth's radius. He computed using the known kinematics that the Moon is subject to 3600 times weaker acceleration than an apple falling from a tree. This confirmed the $1/r^2$ gravitational force law.

N [1] The equation of relative motion (acceleration, to be precise) of 2 massive bodies reads $a = -GM\mathbf{r}/r^3$, where M is the **reduced mass of the system**, $1/M = 1/m_1 + 1/m_2$, and $\mathbf{r}$ is the distance vector from the more massive to the less massive body.

Y [1] The specific angular momentum vector reads $l = r \times \dot{r} = const.$, were r is the radius vector and $\dot{r}$ its time derivative.

N [1] Laplace-Runge-Lenz vector **varies** in proportion to the sun-planet distance.

Y [1] Fermi's paradox asks why extraterrestrial civilizations are not observed, although it seems unlikely that they do not exist.

Y [1] Magnetorotational instability in disks produces the anomalous viscosity and powers the viscous evolution of disks. This process and the photoevaporation eventually remove the protoplanetary disks after a few million years from the time of system formation.

Y [1] Lagrangian description is the description of changes happening to a moving elements of a fluid. Eulerian description states how fluid elements flow (and what pressure and density they have) in a coordinate system that is not bound to fluid elements.

Y [1] Brown dwarfs have masses between 13 and 80 Jupiter masses. Stars of solar composition and mass above this range fuse hydrogen into helium. Objects with lesser mass do not fuse Deuterium and so can be spectroscopically distinguished from the brown dwarfs.

Y [1] Protoplanetary disks normally have a flaring shape (z/r growing with radius r).

? [1] The escape speed from the Earth is equal 7.9 km/s.

Y [1] Circular (Keplerian) speed of heliocentric motion at 1 AU is almost 30 km/s.

Y [1] Saturn is able to deflect a spacecraft initially bound gravitationally to the sun, so that it escapes from the sun into the Galaxy.

Y [1] Planetary transit caused the sun-like star HR2012 to go down 1% in brightness. Astronomers deduced that the planet has a physical radius similar to Jupiter.

? [1] Pluto has a big satellite Charon. Their rotation is synchronized with the orbit such that Pluto and Charon are always turned with the same side toward each other.

N [1] If the atmosphere is thin, the scale height of density and pressure is given by soundspeed squared v_s^2, and the gravitational acceleration at the surface g of a planet like so: $H = g/v_s^2$

N [1] The time scale of giant planet formation in the solar system was of order **60 Myr**.

N [1] Oort cloud extends out to about **150 AU** from the sun.

? [1] In 2017-2020 two interstellar objects were discovered by astronomers, traveling on hyperbolic orbits in and out of the Solar System: I/1 Oumuamua and I/2 Borisov. The second is a comet.

Y [1] Io's surface is only hundreds to a thousand years old, due to the ongoing resurfacing by volcanic eruptions containing sulphur.

N [1] The migration of planets inside accretion disks is a consequence of the **gas drag** acting on a planet.

? [1] Tidal torque between a planet, on which a day lasts 27 hours, and a moon which has orbital period 24 hours, slowly increases the distance between the bodies.

Y [1] Enceladus has active ice geysers. This creates a diffuse ring of dust and gas around its orbit.

N [1] Meteorites **completely burn** in the upper atmosphere upon encountering the Earth, leaving only bright trails in the sky.

Y [1] A typical chemical composition of a planetary system includes olivine (Mg,Fe)SiO_4 and pyroxene (Mg,Fe)SiO_3.

Y [1] Giant planets in our system have fairly similar rock+ice core masses, but widely differing gaseous envelope masses.

Y [1] Mars has wind-swept planes and dunes, even dust devils.

? [1] Mars has geological formations showing the presence of water in the past.

N [1] Dust disks found around a significant fraction of all nearby stars contain micron-sized particles. Their total mass is not well known from observations, because we cannot directly detect the countless **smallest** particles, which typically contain the bulk of the disk's mass.

Y [1] Theoretical calculations of dust destruction and replenishment in collisional cascades tell us that dusty disks around stars must have started with $\sim 10^2$ Earth masses of solids, and thus are planetary systems.

Y [1] Venus has a very large greenhouse effect warming its atmosphere. It is due to its dense atmosphere of a greenhouse gas CO_2.

? [1] Triangular Lagrange points are **always unstable** equilibria, because they are effective potential maxima in the restricted 3-Body problem.

N [1] One of the methods of planet hunting is through microlensing surveys. This technique **uses microscopic lenses** in the optics of a telescope to achieve simultaneous tracking of the luminosity of many stars.

Y [1] Galilean satellites are in commensurable motion (in orbital 1:2:4 mean motion resonance). This causes a non-zero orbital eccentricity of Io, which then causes its tidal heating.

Y [1] The first dusty disk around a normal main-sequence star was found in 1983 when satellite IRAS was sent into orbit by the European Space Agency and NASA, and Vega was found to have a large IR excess of radiation over the stellar surface output.

Y [1] Beta Pictoris, Fomalhaut, AU Mic, and many other main-sequence stars have rings of dust larger than of our system of planets (i.e., radius $r > 40$ AU).

N [1] At the end of its main-sequence life, our sun will lose a substantial amount of mass from the envelope. If this happens in an axisymmetric fashion and slowly, and as a result the Earth and planets will gradually **approach** the sun.

N [1] Eccentricity e in 2-Body problem depends on energy E **but not** on angular momentum L

? [1] The first plants on the surface of Earth released 2-3 Gyr ago large quantities of molecular oxygen (O2).

Y [1] First biochemical signs of life have been detected in 3.8 Gyr-old rocks.

N [1] Since the blackbody temperature **drops as the square of the distance**, at 5 AU (around Jupiter) we expect the temperature of $\sim (280\text{ K})/5^2 \approx 12$ K.

N [1] Comet's **gas tail** is normally more yellow-tinted, curved and shorter than its dust tail.

N [1] In a laboratory setting, Urey and Miller subjected the "primordial soup" of gases thought

to compose the primordial atmosphere on Earth. Adding energy of electrical discharge, they obtained **DNA** of non-biological origin.

Y [1] The M-type metallic asteroids are cores of once-larger asteroids broken up by collisions in the asteroid belt.

? [1] Saturn's rings have a large Cassini division near the 2:1 mean motion resonance radius with satellite Mimas.

Y [1] It is likely that the first living cells on Earth were using RNA to pass the genetic information to offspring.

N [1] The gaps in the C-ring of Saturn are called **Kirkwood** gaps.

N [1] Gravitational instability of disks is **sensitive** to the chemical composition of the gas that also forms the star, thus giant protoplanets are unlikely to form with the help of this process.

Y [1] Comets are (very approximately) half-and-half ice and rock. In general, these two components are of the same order of abundance in the Universe.

N [1] Tides raised by the Moon on Earth are responsible for the slow lengthening of the 24-hour day on Earth. **To compensate,** we have a leap day on 28 February, added every four years.

Y [1] Mercury's spin period is in a 2:3 commensurability with its orbital period.

Y [1] The goodness parameter Q on Jupiter is much larger than on Earth, i.e. Jupiter does not strongly damp tides raised by the moons.

Y [1] Dwarf planet Eris is very similar in size to than Pluto.

N [1] In order to gradually increase the speed of an Earth satellite, one needs to apply forces in the **forward direction** along its orbit.

Y [1] Isolation mass is a final mass, which the planetesimals achieve growing in a protoplanetary disk in runaway regime.

? [1] Without gravitational focusing, there would be no runaway accretion.

Y [1] Migration type I happens inside the protoplanetary gas disk. The body has insufficient mass to gravitationally open a gap.

Y [1] Type III migration is a fast migration that can shift the planet either inward or outward

Y [1] Everything else being equal, higher albedo causes a higher temperature of an object and more scattered starlight.

Y [1] Beta Pictoris is a star surrounded by extensive edge-on disk. Occasional infall of FEBs (falling evaporating bodies) is an evidence of large comets or asteroids in that system.

N [1] The oligarchic growth is when not one but several fairly mutually isolated bodies run away from the rest of the population in terms of mass accretion rate,

N [1] There was a large impact 25 Myr ago, which left noble-metal imprints in sedimentary rocks, and caused biological extinction all over the globe.

? [1] One-third of comets are on extremely extended orbits with periods reaching 1 Myr.

? [1] Oort cloud is occasionally gently disturbed by stellar fly-bys.

? [1] We have found 18 comets that came from outside the solar system

? [1] 3.9-3.3 Gyr ago the epoch of late heavy bombardment of lunar surface ended.

? [1] Subduction zones in the middle of oceans produce chains of volcanic islands.

? [1] The shepherding mechanism of rings by moons relies on gravitational forces effectively attracting the rings and the perturbing moons together in the radial direction. A stable ring results if there are two moons, inner and outer, to herd it.

? [1] Small moonlets like Daphnis open narrow gaps inside Saturn's rings.

Y [1] Specific energy on an elliptic orbit depends on the semi-major axis only: $E = -GM/2a$.

N [1] The ellipse equation reads: $r = a(\mathbf{1} + \mathbf{e})/(1 + e\cos\theta)$

Y [1] The generalized 3rd Kepler's law reads $P^2/a^3 = (2\pi)^2/GM$

? [1] The type-III migration mechanism relies on mass transfer across a partial gap opened in the vicinity of a planet

Y [1] The escape speed from a spherical body is $\sqrt{2}$ times larger than the Keplerian (circular) speed near its surface.

Y [1] In Orion nebula disks are seen against a bright background of gas clouds illuminated by the newly born stars.

N [1] Up to **99 percent** of rest mass (mc^2) initially in an accretion disk is released in the form of radiation.

Y [1] Mass accretion rate of classical T Tauri stars can be much larger than $\sim 10^{-8} M_\odot$/yr.

Y [1] The total amount of matter processes by the disk appears observationally to be of order 10^{-2} of the solar mass, over the few-million year lifetime of the disk.

? [1] The vertical balance of gravity and the pressure gradient force in a circumstellar disk yields the approximate equality between the half-thickness ratio z/r and the Mach number (orbital velocity / soundspeed).

Y [1] The anomalous viscosity in accretion disks is often taken to arise from the coupling of partially ionized gas to magnetic fields, which eventually create magnetic instability known as MRI (magnetorotational instability). It consists of field line stretching and field amplification in a differentially rotating, shearing disk.

? [1] A typical size of a protostellar disk equals 10 AU.

Y [1] The Shakura-Sunyaev parameter α needs to be of order $\alpha \sim 10^{-2}$ in order to account for the observed mass flow rates in protostellar T Tau disks.

Y [1] Drag forces on planetary bodies from solar wind and other interplanetary gas and dust are totally negligible. Strongly affected particles are those smaller than small stones, e.g. sand and dust.

? [1] Total angular momentum is a conserved quantity in an N-body system of gravitating bodies

? [1] Total mechanical energy is a conserved quantity in an N-body system of gravitating bodies

? [1] Laplace-Runge-Lenz vector is a special vector that is conserved in a 2-body system of particles interacting via gravity.

? [1] Eccentricity $e > 1$ means that the body is on an elliptic orbit, $e < 0$ means that it is unbound and can escape from the system.

N [1] Kepler's 3rd law states that a planet with and orbit twice as large as a given orbit, has a period of motion /bf eight times longer than the first planet.

? [1] The time scale of giant planet formation is of order 100 Myr.

Y [1] Minimum Mass Solar Nebula is a model of surface density of solids which just suffices to build, with 100% efficiency, the rocky/icy parts of our planetary system. It does not account for comets ejected into the Galaxy, for instance.

Y [1] Jupiter is about 1000 times less massive than the sun

N [1] From nearby stars, an alien observer would be able to detect the transits of Jupiter in front of the sun as a ∼10 percent dimming of the sunlight for several hours, every twelve years.

N [1] The method described in the previous question is called Doppler spectroscopy.

Y[1] The first planets ever discovered outside the solar system were found by Alex Wolszczan using radio telescope in Arecibo, Puerto Rico. Three planets circle around a neutron star known as millisecond pulsar.

? [1] Except for those which are very close to the stars, the orbits of extrasolar planets are nearly circular.

? [1] Eccentricity of planetary orbits may be due to planet-planet gravitational interactions or due to disk-planet interaction during their formation period.

? [1] The close-in giant planets called hot Jupiters are probably so close to their host stars because of the migration inside the protoplanetary disk from a larger original distance.

? [1] Kepler observatory was working in a near-Earth orbit

? [1] Fomalhaut is a normal star with a prototype dust-dominated replenished disk, just like beta Pic and Vega.

? [1] Coronograph cancels out the light from the central source such as a star and reveals the presence of a much fainter source of light nearby, such as a planet, using destructive interference of waves received by two or more antennas.

? [1] More than two thousand extrasolar planets have been found with the Kepler Space Telescope

? [1] Chemical similarity of stellar composition causes chemical similarity of materials like dust, which is currently identified spectroscopically, in extrasolar planetary systems.

? [1] Bacterial spores might travel aboard meteorites ("lithopanspermia"), thus affording them better protection from high-energy radiation in space.

? [1] Some meteorites found on Earth have come from the surface of Mars

? [1] Spores and bacteria can survive for a long time in conditions approximating those of interplanetary space.

? [1] Habitable zones of less massive stars are wider and located further from the star than in the solar system

? [1] Life could have started with RNA, which evolved into DNA.

? [1] In the 1920s, Russian biochemist Alexander Oparin and English geneticist J.B.S. Haldane, independently worked on the theory of spontaneous life generation.

? [1] Supporting this theory, in 1953, American chemists Stanley Miller and Harold Urey showed that some amino acids can be chemically produced from ammonia (NH3) and methane (CH4).

? [1] Fermi Paradox proves that we are truly alone in the universe; this is called rare Earth hypothesis.

? [1] Self-destruction of civilizations is a possible resolution to Fermi's paradox.

? [1] The cooling sequence can be summarized as: CO binds at the highest temperature. Olivines and pyroxenes (silicates) are dominant, (Mg+Fe+SiO), then H_2O sweeps all the remaining oxygen at 150-180 K.

? [1] HD14169A has a large disk seen in HST observations. This so-called transitional disk has spiral features and a gap confirmed by recent observations

? [1] The most likely reason why our Jupiter didnt obtain a larger mass: the nebula was already disappearing and not enough mass was available.

? [1] type-III migration is caused by Lindblad torques

? [1] type-III migration is very insensitive to disk density gradients and easily proceeds through regions with large density differences

? [1] Corotational torques can cause rapid inward drift of a planet, if gas is transferred from orbits on the inside the perturber to the outside. To conserve angular momentum, satellite then moves in.

? [1] Amorphous silicates are typical dust grains precipitating from gas, for instance in the interstellar medium, with no regular crystal structure

? [1] Crystalline grains have the same chemical composition, but atoms form a regular crystal structure, thought to be derived from amorphous grains by some heating (annealing) effect at temperatures up to 1000 K.

? [1] Thermal radiation measurements and images (at wavelengths of 10 microns and larger) tell us how the starlight-scattering area is distributed around the star.

? [1] Scattered light observations tell us how the thermally emitting area of particles is distributed around the star.

? [1] Terrestrial planets can eject planetesimals out of the solar system in a single encounter

? [1] Kuiper belt was discovered by D. Jewitt and J. Lu in 1893

? [1] Pluto has a large moon Charon, and Eris (the largest dwarf planet) has a large moon Dysnomia

N [1] Bond albedo is the percentage if of incident light **absorbed** by an object