DSO (20 points)

1. G
    a. WORTH 2 POINTS
    1RST POINT: thin, elongated region of stars and interstellar gas that extends into space from a galaxy
    2ND POINT: Tidal tails occur as a result of galactic tide forces between interacting galaxies
    b. Late
2. F
    a. Large galaxy cluster
    b. 4
3. IMAGE: I NAME: 3C 273
    a. WORTH 7 POINTS
    POINT 1: draw black hole with disk around it
    POINT 2: draw jet coming out of both sides from nucleus
    1 POINT PER LABEL:
        i. Jet
        ii. Accretion disk
        iii. Board-line region
        iv. Supermassive black hole
        v. AGN- active galactic nucleus
4. J
    a. Virgo
    b. Supermassive blackhole
    c. AGN
5. D, F, H

MULTIPLE CHOICE AND SHORT ANSWER (20 points)

1. D
2. C
3. A; while E is correct it's not always correct
4. C

5. **B**
6. **B**
7. **B**
8. **M, K, G, F, A, B, O**

9. **4 POINTS IN TOTAL**
   1 POINT: Gravity has the ability to act like a lens magnifying distant objects
   1 POINT: General theory of relativity: we know that mass curves the space around it and this theory also predicted gravitational lensing
   1 POINT: which is a side effect of light traveling along the curvature of space and time where light passing near a massive object is deflected slightly towards the mass
   1 POINT: talk about uses of gravitational lensing- like that it can be used to observe invisible things in the universe- dark matter because it has mass so it can gravitationally lens light
10. **A**
11. **4 POINTS in total**
    1POINT: Letters of the alphabet were originally used to classify stars by their hydrogen spectral prominence.
    3 POINTS: However, it became apparent that it would be more efficient to classify them by temperature, so the letters were rearranged by decreasing temperature.
    TIE BREAKER #1: Angelo Secchi
12. **2pts: (Ho)^-1 where Ho is the Hubble Constant = 13 billion years (convert seconds to years). 1pt: Hubble Time.**
13. **O**

MATH

1. **20. Use distance modulus and convert lightyears to parsecs. Also significant figures bro. 16 → 20 for 1 significant Figure. (3 points, one for light years to parsecs, one for using distance modulus, one for the correct answer of 20)**

2. **Image should be a circle with the sun rotating around the perimeter. Force should be pointing towards the center (Sag. A*), velocity tangent to the circle (should be pointing in a clockwise direction), and acceleration inwards (same as force).(3 points, one for correct direction of force,one for correct direction of acceleration, one for direction of velocity)**
3.
    a. **1pt: 2.9 AU +- 0.1AU. Use Kepler's Third Law to determine A, which is the semi-major axis of the star's orbit, also the mean distance.**
    b. **1pt: No it would NOT be accurate. 1pt: Answers may vary, but something similar to a) Milky Way is gravitationally viscous and thus has no singular center of mass. b) In such an asymmetrical galaxy, stars don't conserve their angular momentum in the same way that they do in an "isolated" system. 2pts may be awarded if the participant answers yes AND provides an answer along the lines of incorporating a deviation factor specific to the galaxy measured through other means.**
    c. **2pt: 1.07 km^3 +- .03 km^3. Use the equation for the Schwarzchild radius and mass of 100. solar masses to determine the radius, and use the formula for the volume of a sphere to determine the star's volume at the time.(one for the equation for Schwarz child radius and one for the correct anwser)**
4. **2.5E5 parsecs**
    a. **Use the given constant absolute magnitude of -19.3 for Ia SNe and distance modulus to determine the distance. (one point for the use of distance modus and one for the correct answer)**
5. **80 megaparsecs. Use Hubble's Law and given velocity to solve for distance in mpc. (one point for the use of Hubble's law and one for the correct answer)**
6.
    a. **1.5E6 m (2pts). Formula: Rs = (2GM)/c^2 where M is the body's mass and Rs is the radius.**

7.

a. **Acceptable answers range from 6.57E4 km/s away to 7.48E4 km/s away (1 point). Measure Ha wavelength to be between 8000 to 8200 angstroms. Convert and use redshift formula v = c(y-y0)/y0 where y0 is lab-observed wavelength and y is the environmentally observed wavelength to determine velocity.**
b. **Acceptable answers range from 887 mpc to 1.01E3 mpc. (2 points). Use Hubble's Law formula: v = Ho*d where Ho is the Hubble Constant (74 km/s/mpc) to determine the distance in mpc. (one point for using hubble's law, one point for the right awser)**
c. **Acceptable answers range from -21.0 to -21.3 (1 point). Use distance modulus my dude c'mon. FYI if you didn't know, absolute magnitude is defined as the apparent magnitude from 10pc away so I just did some funky wordplay on you.**
d. **1pt: No, it's not logistically valid. 2pt: The distance modulus only works properly for nearby bodies. Further distances inhibit calculations by means of dark clouds which may adulterate the actual apparent magnitude were there no clouds.**