Part 1: Multiple Choice (1.5 points each). Provide the single best answer to each of the following 40 questions or statements. There is no penalty for guessing. If two answers seem possible, choose the one that responds best to what is being asked.

1. Dr. Friscia submits a paper on his newest fossil findings to the Journal of Cool Fossils. The journal sends it out to review to two different reviewers in his field of fossil mammals. The fact that the paper was sent out to be reviewed demonstrates which aspect of modern science?
   a) Curiosity
   b) Experimentation
   c) Observation
   d) Repeatability
   e) Self-Correction

2. One reviewer of Dr. Friscia's paper declares, "This paper is genius! Friscia has surely found out a truth about the universe!" Why is this reviewer's opinion wrong?
   a) Any scientific idea is subject to challenge. This is a strength of science.
   b) New discoveries may overturn Dr. Friscia's findings.
   c) Science is self-correcting, so other scientists may try to repeat Dr. Friscia's research and find it wrong.
   d) Science never finds the truth, only hypotheses that are best supported by available evidence.
   e) All of the above.

3. Which is an example of teleological thinking?
   a) Regarding sub-atomic events as fundamentally indeterminate.
   b) Understanding the Copernican Revolution as the product of mid-16th century scientific disciplinary formations.
   c) Interpreting Max Planck as holding a traditional wave conception of light in 1900.
   d) Treating biological adaptations as the product of random mutations acted upon by the contingencies of natural selection.
   e) Explaining nebula as the universe's effort to produce solar systems.

4. Kuhn thought paradigm shifts originated in:
   a) large cultural and ideological movements.
   b) small expert communities with highly specialized skills and knowledge.
   c) political pressure from elites to change widely held views.
   d) economic pressure to secure funding for scientific research.
   e) attempts by scientists to fit the popular mood of the times.

5. The Copernican Revolution rejected:
   a) the "Crystalline Spheres" paradigm.
   b) the basic theological doctrines of the Catholic Church.
   c) the classical mechanics of Galileo and Newton.
   d) the Ptolemaic, or geocentric, system.
   e) Jesuit learning.

6. Why do many historians focus on the European history of science?
   a) with the Copernican Revolution of 1548, Europe became the first rational society.
   b) Europeans invented astronomy in 1500 before the Chinese.
   c) the Industrial Revolution and Imperialism of the nineteenth century led to the globalization of European modes of rational enquiry, observation, and experiment.
   d) with the advent of coal power & the factory system in England in the late 18th century proved the innate superiority of European scientific culture.
   e) effective astronomical, mathematical, and medical practices simply didn't exist in any non-European societies before their first contact with Europe.

7. What was Newton's view of the role of the natural philosopher (scientist) in hypothesizing first causes?
   a) equations that predicted outcomes were sufficient, the first cause was always the will of God.
   b) any mechanism that involved "action at a distance" was fundamentally anti-scientific.
   c) a predictive law without a posited causal mechanism was incomplete.
   d) description without explanation is beneath the intellect of a true scientist.
   e) the scientist should start with causation when observing any phenomenon, then move to the formulation of predictive laws.

8. Our Galaxy consists primarily of
   a) the Sun, Earth and other planets orbiting the Sun. solar system
   b) the Virgo Cluster along with Andromeda
   c) a supermassive black hole whose mass dominates everything else.
   d) 200 billion stars including the Sun, a dark matter halo and accumulated dust and gas.

9. Which of the following has your cosmic address in the correct order, from smallest to largest?
   a) you, Earth, Milky Way Galaxy, solar system, Local Group, Local Supercluster, Universe
   b) you, Earth, Local Group, Local Supercluster, solar system, Milky Way Galaxy, Universe
   c) you, Earth, Local Group, solar system, Universe, Milky Way Galaxy, Local Supercluster
   d) you, Earth, solar system, Local Group, Milky Way Galaxy, Local Supercluster, Universe
   e) you, Earth, solar system, Milky Way Galaxy, Local Group, Local Supercluster, Universe

10. If the Earth was added to the Sun
   a) the Sun's mass would roughly double.
   b) nuclear fusion in the Sun's core would be shutdown.
   c) the Sun would be ripped apart by the strong gravity of the Earth.
   d) the Sun would explode as a supernova.
   e) the Sun would barely notice and the change in the Sun's mass would be negligible.

11. The best estimate of the age of the Universe is closest to:
   a) 2 million years
   b) 65 million years
   c) 4.5 billion years
   d) 14 billion years
   e) The Universe is infinitely old

12. If the Sun was twice as far away, how would the force of gravity between the Sun and the Earth change?
   a) It would be twice as great.
   b) It would be four times as great.
   c) It would be four times weaker.
   d) It would be half as strong.
   e) It would be so weak as to be negligible.

$F_g = G\frac{m_1 m_2}{r^2}$ Sun → mill mor

$F_g = G m_1 m_2 \cdot \frac{1}{r^2}$

$G m_1 m_2 \cdot \frac{1}{r^2} = G m_1 m_2 \cdot \frac{1}{(2r)^2}$

$\frac{1}{r^2} = \frac{1}{4r^2}$ $\frac{1}{4}$

regular twice dist

13. If an alien astronomer located 30 light years away from the Sun used a powerful telescope to look at the Earth, what is something they might observe?
   a) Your parents before you were born
   b) Since we always see the distant universe in the past, they see us in the future about 30 years from now.
   c) They can decide when they want to see the Earth, so they could choose to see Dinosaurs.
   d) They would see us as we are right now, but redshifted by the expansion of the Universe.
   e) The cosmic microwave background from our location.

14. Which is the best description of the equivalence principle from Einstein?
   a) Particles have waves equivalent to those of photons.
   b) Experiments are affected by gravity in the same way as being in an accelerating reference frame.
   c) All inertial observers will measure the same speed of light.
   d) Each large region of the universe is equivalent to all similar regions.
   e) All wavelengths of light have an equivalent amount of energy.

15. Which description below best describes orbital motion in General Relativity?
   a) Masses pull on each other with a long range force and the objects accelerate towards each other due to this force.
   b) The centripetal force from circular motion is balanced by the gravitational force.
   c) Orbits are not stable in General Relativity.
   d) Objects follow the straightest possible line through curved space-time.
   e) Planets and stars suck all material towards them forcing objects to spiral inwards.

16. World War I affected European society by:
   a) leading to an extended period of economic and political stability.
   b) dramatically increasing the wealth of Europe.
   c) expanding the reach of contiguous land Empires like the Russian and the Ottoman.
   d) triggering two decades of economic upheaval, political revolution, total warfare, and genocide.
   e) convincing an entire generation of young European men that war was heroic and fun.

Bohm

17. Hidden variables theories of quantum mechanics hold that:
   a) the wave function only collapses to certainty upon measurement.
   b) the experimenter plays a role in natural outcomes. uncertainty
   c) forming classical predictive laws of nature would be possible in the sub-atomic realm if only scientists knew all the involved variables.
   d) the fundamental basis of physical reality is probabilistic.
   e) subatomic events are without singular causes in a traditional physical sense.

18. An example of a determinate process in nature is:
   a) two bodies being pulled together by gravity in accordance with the inverse square law.
   b) an atom of Uranium-235 decaying at a specific time.
   c) a particle travelling back in time to take the path that was being monitored.
   d) a version of the double-slit experiment in which light behaves as both a wave and a particle.
   e) the assortment of vertical and horizontal spinning electrons upon passing through a black box.

19. Heisenberg's uncertainty principle holds that:
   a) any experiment alters its object of study, regardless of that object's scale.
   b) technological interference with certain aspects of matter so as to measure them decreases the confidence of the measurement.
   c) sub-atomic events are fundamentally indeterminate until they are measured, and the more certain the experimenter is of one aspect of a quantum system, the less certain she becomes of all other aspects.
   d) the universe is a mysterious place, and scientists shouldn't be as confident as they are of their findings.
   e) only Hegelian philosophy can produce truth, scientific methods are doomed to produce only the illusion of certainty.

20. All three of these empires did not collapse during World War I:
   a) the Russian Empire, the French Empire, the British Empire
   b) the German Empire, the Spanish Empire, the Dutch Empire
   c) the British Empire, the French Empire, the Dutch Empire
   d) the British Empire, the Ottoman Empire, the Japanese Empire
   e) the Russian Empire, the Ottoman Empire, the Austro-Hungarian Empire

21. How can astronomers observe galaxies as they were early in the Universe?
   a. By looking far enough away they can identify galaxies where the light has traveled from them at much earlier time periods.
   b. They can't, but we can study similar young galaxies near the Milky Way.
   c. They can't, but we can model in computers what the Milky Way and other galaxies were like early in the Universe.
   d. They can't, but by studying the cosmic microwave background, we can model how gravity pulls matter together to make young galaxies.
   e. They can't, we know very little about early galaxies.

22. Did the Big Bang have a center?
   a) Yes, and we are near to it which is why galaxies are seen rushing away from us.
   b) No, the entire universe has always been uniform everywhere.
   c) No, it had several centers that have merged together.
   d) Yes, but we can't tell where it was because all "fragments" of an explosion will find everything rushing away from their location.
   e) Yes, and we see more matter in the direction of the center.

23. The expansion of the universe is occurring everywhere, but many things can hold themselves together during the expansion. Which of the following IS significantly affected by the expansion of the universe?
   a) The orbits of electrons around atomic nuclei.
   b) The orbits of the planets around the sun.
   c) The separation of very distant galaxies from each other.
   d) You are, but the rate is too small to notice.
   e) The diameter of the Earth.

24. The cosmic microwave background was an important early confirmation of Big Bang Theory because it showed that
   a) the Universe was once much hotter and denser.
   b) the Universe is transparent.
   c) that neutral atoms once dominated the universe.
   d) the Universe is opaque at great distances from us.
   e) More distant explosions take longer than the same explosions nearby.

25. What is the best interpretation of cosmological redshift?
a) As a galaxy flies through the Universe at high speed, its light is Doppler shifted.
b) Light loses energy when it travels long distances and appears redder when it arrives at Earth.
c) The atoms in the distant galaxy are expanding so they emit longer and longer wavelengths of light as time goes on.
d) Light emitted by a distant galaxy has stretched to longer wavelengths by the expansion of the Universe.
e) Spectrographs today have been stretched by the Universe and so measure light at longer wavelengths than when it was emitted.

26. How did Hubble measure the distance to nearby galaxies?
a) He took their spectra and calculated the redshift.
b) He identified Cepheids in the galaxies and compared their brightnesses to Cepheids in our own Galaxy.
c) He bounced radio waves off of the galaxies and timed the delay.
d) He measured their parallax angle at different times of the year.
e) He compared the size of the galaxies to the size of the Milky Way.

27. If the Hubble constant was half the value we actually measure (70 km/sec per Mpc), then the Universe would be _____. Remember this would mean galaxies at a given distance would be moving half as fast.
a) the same age as currently estimated.
b) twice the current estimated age.
c) half the current estimated age.
d) four times older than the current estimated age.
e) one quarter of the current estimated age.

if H.C. = 140
age = 6.7 billion
if 28 bill → twice

28. If you could observe an alien at a redshift of 0.5, which of the following would you notice?
a) You can't observe someone that far away because the cosmic microwave background would block you.
b) They move 50% slower than a similar alien observed nearby.
c) They move 50% faster than a similar alien observed nearby.
d) They move twice as fast as a similar alien observed nearby.
e) They are moving at half the speed of light away from you.

1.5x
longer

29. Observations of which types of objects first allowed astronomers to determine that the expansion of the Universe is accelerating?
a) Supernovae
b) Redshifts of distant galaxies
c) Planetary nebulae
d) Main sequence stars
e) MACHOs

30. If you were an extraterrestrial living on a planet in a galaxy 5 billion light years away from the Milky Way galaxy, what velocity pattern would you detect for the galaxies around you?
a) Most are receding—the ones farther away are receding slower
b) Most are receding—the ones farther away are receding faster.
c) The ones on your side of the Milky Way are coming towards you.
d) Most are coming towards you—the ones farther away are moving faster
e) Most are coming towards you—the closer ones are moving faster

31. If an object is moving AWAY from you at high speed, the Doppler effect will cause
a) its light to increase in wavelength. redshift
b) it to disappear.
c) it to appear bluer.
d) you to see more photons.
e) the speed of its light to decrease.

32. As the wavelength of light is increased, the photons becomes
a) bluer
b) redder
c) more energetic
d) greener
e) higher frequency

33. The Bohr model of the atom predicts that light is emitted when an electron
a) spirals into the nucleus.
b) jumps from an outer orbit to an inner orbit.
c) remains in the same state.
d) is removed from the atom.
e) moves to a higher energy level.

34. When we take a spectrum of a hot gas, we can determine its chemical composition because
    a) each type of atom has a unique set of emission lines.
    b) the spectrum shows the unique redshift of each element.
    c) the blackbody radiation shifts to different frequencies.
    d) the electrons in each element spiral into the nucleus at a different rate.

35. The cosmic microwave background was produced about 380,000 years after the big bang when:
    a) the first stars formed.
    b) the first supernovas exploded.
    c) nuclei first formed and released energy from fusion.
    d) electrons and nuclei combined to form the first neutral atoms and photons were free to travel across the Universe.
    e) dark matter created the first galaxies.

36. Did Einstein's 1905 paper "On the Electrodynamics of Moving Bodies" embody a paradigm shift, and why?
    a) no, he was not a technical expert.
    b) yes, it caused everyone in Europe to pay more attention to practical clock coordination.
    c) yes, it challenged long-held assumptions about what it means for two events to occur simultaneously.
    d) yes, it challenged long-held assumptions about the difference between object A moving towards stationary object B and object B moving towards stationary object A.
    e) both c and d.

37. Which three technologies were not newly essential to the Second Industrial Revolution of 1850-1900:
    a) the steam engine, steam trains, the textile factory
    b) industrial chemistry, electrical telegraphy, electrification
    c) petroleum power, the Bessemer process for making steel, the Haber-Bosch process for fixing nitrogen from the atmosphere
    d) rifled firearms, ammunition cartridges, municipal lighting
    e) electric clock coordination, military use of trains, global telegraph networks

38. How did the Nazi government *start* destroying the Central European Jewish community in the 1930s before the commencement of World War II in Europe?
    a) they forcefully expelled all Jewish people from Germany.
    b) they removed all Jewish academics from university posts.
    c) they murdered Jewish people in large numbers.
    d) they put Jewish people in concentration camps.
    e) they denied Jewish people basic citizenship rights and removed them from academic posts and government jobs.

39. Einstein's 1905 theory of clock coordination differed from practical coordination schemes in that:
    a) Einstein's theory had no central "master clock," just individual reference frames.
    b) Einstein's theory suggested that a "master clock" was required to coordinate all other clocks against it.
    c) Einstein's theory had no relationship to technology.
    d) Einstein's theory assumed a difference between the relative motion of a coil and a magnet depending on which one was moving and which one was stationary.
    e) Einstein's was based in pure theoretical physics, and had nothing to do with the culture and economy of early nineteenth-century Europe.

40. How did German unification in 1871 affect the course of world history?
    a) it upended the balance of power in Europe by creating the largest national population and national economy on the continent west of Russia.
    b) it led to the World Wars due to Germany's threat to their neighbor's security, and Germany's perception of their neighbor's threat to them.
    c) it gave birth to a new global center of research and education in the physical sciences.
    d) the wars of German unification humbled both the French and Austro-Hungarian empires, setting the stage for their eventual dissolution in the twentieth century.
    e) all of the above.

Part II: Short Answer Questions (Points as marked). Use the space provided on this test sheet to respond to each of the following questions with a short answer.

1. What is a paradigm shift, for Thomas Kuhn? What are the steps that a scientific community must go through to reach a paradigm shift? How is this community constituted? Give two examples of paradigm shifts from class, and explain how they meet Kuhn's definition. **(10 points)**

↳ small group of experts

↳ Copernicus, Black Body

For Thomas Kuhn, a paradigm shift is a shift in a certain idea or belief that is observed amongst a small group of experts, rather than a large-scale cultural revolution. In order to reach a paradigm shift, the scientific community must have some form of evidence that falsifies or refutes a previously ~~held~~ accepted idea, and in turn revise that idea, or introduce a new one in its place.

Two examples of paradigm shifts are the Copernican Revolution and Planck's shift from viewing energy as waves to finite quanta while he was solving the Black Body problem. The Copernican Revolution meets Kuhn's definition, since it wasn't ~~initially~~ widely accepted amongst the general public until well after it was accepted in the scientific community. Furthermore, it already encompasses a shift in ideas, as the scientific community shifted from viewing the solar system as ~~a~~ geocentric to heliocentric. Planck's shift also fits this definition, since this information was generally only relevant to the scientific community, and thus never ~~played~~ played a large role in the public's ideas. His idea was also a finite shift between different ways of viewing energy.

2. Explain the local context of the composition of Einstein's classic 1905 paper "On the Electrodynamics of Moving Bodies." Explain how this local context was one of many variables that allowed Einstein to view time in a novel way. **(5 points)**

~~train station, patent office~~

3/5

During the time when Einstein composed his 1905 paper, he worked at a local patent office in Bern & took the tram to get to work on a daily basis. At the tram station, Einstein noticed how every clock there was synchronized with each other, which led him to start thinking of what it truly means for two events to occur simultaneously. Ultimately, this led him to his viewing of time as something that is relative, as well as his system for synchronizing clocks that accounted for the time it takes light to travel between two distant events.

Historical context?

3. What two properties of galaxies did Hubble measure and compare to discover the Universal expansion? **(5 points)**

Hubble measured and compared the redshift, or the wavelength, of different galaxies, and observed universal expansion. He found that the redshift vs. distance relationship was linear, in that galaxies that were further away were redshifted more than those that ~~were~~ were closer, which means that the farther galaxies are moving away from us at faster rates. Thus, ~~he~~ he found that the Universe is not only expanding, but accelerating in its expansion.

5/5

4. Describe two ways the curvature of space and time near the Earth has been measured (not theory but actual measurements we discussed or were in the text)? **(5 points)**

(4)

The curvature of space and time was measured when scientists were trying to figure out why Mercury's orbit was faster than it should have been according to Newton's law of gravitation, after Einstein developed his theory of general relativity. This was measured near the Earth using the orbit of the moon, and using projectiles considering projectiles that ~~have to~~ are horizontally thrown with enough velocity to enter the Earth's orbit.

(5)

5. What **evidence** do we have that electrons in atoms live in quantized energy levels? **(5 points)**

~~Spectrum of atoms~~

Every different atom has a unique set of spectral emission lines, which represent finite values that electrons in atoms represent. Furthermore, when electrons jump between energy levels in an atom, a finite amount of light that is equal in energy to the energy difference between the energy levels is either absorbed or released. ✓ ✓

5

6. If the was an explosion at one location in space, the "fragments" of that explosion would all observe other "fragments" moving away just like the observed redshift vs. distance relationship discovered by Hubble. Briefly describe two ways we know the Big Bang was NOT an explosion in space. **(5 points)**

~~homogeneous universe → no center~~ ~~black hole~~

We know that the Big Bang was not an explosion in space, due to the fact that the universe is homogeneous, on a massive scale. If the Big Bang were an explosion, it would have a center, around which there would be a higher density of galaxy clusters, with that density decreasing if one were to move away from the center. Our universe, on a large scale, does not differ in density, though, in different regions — it is the same everywhere, and thus has no center. Furthermore, if the Big Bang were an explosion, all of the matter in the universe would have to have been extremely densely packed into a tiny volume at one point, which would have created a black hole. In this scenario, there would have been no explosion and no creation of the universe in the first place.

5

7. If the Cosmic Microwave Background was produced 380,000 years after the big bang, then why do we still see the light today? **(5 points)**

The cosmic microwave background was produced after electrons and nuclei were first close to combine & produce neutral atoms, during which photons were also free to travel freely around the universe. During this time, the universe was, as it is today, rapidly expanding. This expansion redshifted the photons so much that they were stretched into radio waves that can be detected from any point in the universe. Those radio waves continue to travel today, which is why we can still detect them.

irrelevant to the question

1.5