Midterm and Final Exam Files

I will post a Review Sheet containing thirty or so questions similar to the ones below, and state that the midterm will be six or eight of these, to be answered in one hour. The Final Exam will be similar, on a larger scale.

When asked for approximate times, the right century is enough.

Before Galileo

1. Explain briefly what features of the Babylonian numbering and measuring systems were superior to ours.

2. Approximately when and where was Thales? What did he contribute to the development of science? How did he measure the height of a pyramid? How did he measure the distance away of a ship?


4. Approximately when and where was Pythagoras? Briefly, what did his followers believe? Why did they think the stars moved across the sky daily?

5. Draw a couple of diagrams to prove Pythagoras’ Theorem, that is, reproduce two equal squares containing four identical triangles, as in the flashlet.

6. Reproduce the Pythagoreans proof that the square root of two is irrational, that is, it isn’t a fraction.

7. Approximately when and where was Socrates? What did he spend his time doing? How and why did he die?

8. Approximately when and where was Plato? What institution did he found? What was its purpose? What did it say above the doorway?

9. Describe with sketches Plato’s Five Regular Solids. Prove that there can only be five.

10. Plato made a specific suggestion to the astronomers as to how they should try to account for the motion of the planets. What was it?

11. Approximately when and where was Aristotle? What was his school called? What were the four elements? Why did things move? What’s the difference between what he called “natural motion” and “violent motion”? What were his quantitative rules of falling motion?

12. Approximately when and where was Strato? What two arguments did he give against Aristotle’s description of natural falling motion?
13. Approximately when and where was Eratosthenes? Describe how he figured out the size of the earth.

14. Approximately when and where was Aristarchus? Explain how he figured out the distance to the moon.

15. How did Aristarchus try to find the distance to the sun? How accurate was he? What important conclusion could he reach anyway?

16. Approximately when and where was Archimedes? How did he prove the crown was a fake?

17. Over what period of time approximately did science and mathematics flourish in Alexandria? Name three famous mathematicians and/or scientists who worked there. Why did it end?

18. How did Hipparchus and Ptolemy account for the difference in length of the four seasons? How is it accounted for now?

19. How did Ptolemy account for the retrograde motion of Mars? How is it accounted for now?

20. Write a paragraph on how the Nestorians were an important link in the chain of transmission of Greek knowledge to the West. Give a couple of dates and places.

21. Approximately when was Baghdad built? When was the House of Wisdom founded? What was the contribution Hunayn? Where was he from?

What were the important contributions of Indian mathematics and science to Baghdad?

22. Over approximately what period of time did mathematics and science flourish in Baghdad? Why did it end? Explain the origin of the words algebra and algorithm.

23. Approximately when and where was al-Tusi? How did he explain back-and-forth motion in terms of combined circular motions?

24. Where is Cordoba? Over approximately what period of time did science and learning flourish in Cordoba? Why did it end? When was Averroes? What was his main contribution?

25. When was Aristotle first taught in England? Sketch the chain by which Aristotle’s works finally made it to England.

26. Approximately when and where was Roger Bacon? What did he invent? Where did he get his ideas on science?

27. When did Copernicus live, approximately? What was his main contribution to science? What reasons did he give for introducing a new model?
28. Sketch Ptolemy’s picture of the motion of Venus. Does it correctly account for the observed phases of Venus? Does Copernicus’s picture predict different phases of Venus than Ptolemy’s?

29. How did Galileo estimate the height of mountains on the moon?

30. Why did the discovery of Jupiter’s moons make Copernicus’s picture more plausible?

31. Explain how a sundial like the one behind Pavilion IV works (or would if the trees weren’t there). Explain clearly how it differs from an Australian sundial.

32. The next “New Moon” will be October 22. Immediately after that, the Moon will be a thin crescent, visible just after sunset. Draw a diagram showing the relative positioning of the earth, the sun and the moon at this phase.

33. If you looked through a telescope at Venus, would you see phases? If you did, what would be the apparent size of Venus at “full” as opposed to “crescent”?

34. Venus is called the evening star sometimes. Does that mean you can never see Venus in the early morning (before sunrise, of course)? Could you ever see Venus at midnight? Explain your answer with a diagram.

35. If you looked through a telescope at Mars, would you see phases? If you did, what would be the apparent size of Mars at “full” as opposed to “crescent”?

36. If you lived on the moon and watched the earth, would you see phases? Would you ever see the earth eclipse the sun? Would you ever see the earth set?

37. At this moment in time, is there anywhere on earth where the sun is directly overhead? Is there more than one place? Can you guess, very approximately, what the latitude(s) of the place(s) might be?

38. Draw a diagram making clear how an eclipse of the moon happens, and explain why there isn’t one every month.

39. Explain why we have seasons, with diagrams. What days mark the beginning of each season? Show where the Earth is on your diagram at the beginning of each season.

40. At the north pole, the Pole Star, Polaris, is always directly overhead. Is there anywhere where it is always on the horizon? (At night, of course!) If there is such a place, does it move around the horizon, or stay in the same spot?

Galileo, Kepler, Newton

In actual exam, *numbers might be changed.

2. Why are ants several feet long, as seen in movies like “Them” never going to bother us? Explain your answer.

3. Why can a cat fall through a greater distance safely than a horse can, even though the cat is a lot smaller? Explain your answer.

4. Why are there no mice in the arctic? Explain.

5. Why are lungs so complicated, instead of being like the inside of a balloon, for example?

6. Galileo claimed that Aristotle’s assertion that a brick weighing twice as much as another similar one would fall twice as fast led to a contradiction if the two were tied together. Explain.

7. Galileo used a pendulum to argue that something rolling down a ramp would pick up the same speed as if it fell the same distance. Recount his argument.

8. If something falls from rest for two seconds, what is its speed at the end of the two seconds? What was its average speed during the two seconds? How far did it fall? (Note: this question could appear with a different time interval.)

9. Galileo gave a simple rule for the ratios of the distance fallen in the first second, the second second, the third second, etc. What was it? What does it tell us about the average velocities in these successive periods?

10. A cannonball is shot horizontally from a cliff top at 100* meters per second (this number could change). Show on a diagram where the cannonball is after 1, 2, and 3 seconds.

11. A cannonball is shot horizontally from a cliff top at 100* meters per second. Show on a diagram vectors representing the velocity of the cannonball after 1, 2, and 3 seconds. Explain with a drawing how these vectors relate to each other and to the acceleration.

12. For a ball thrown vertically upwards at 20* meters per second, draw vectors representing its velocity after 1, 2, 3, 4, … seconds, and explain with pictures how these vectors are related to each other and to the acceleration.

13. In what direction is the acceleration of a car going at steady speed on a straight road over a hilltop? Explain with a diagram using velocity vectors.

14. If Newton’s cannon were on a mountaintop 7,000 km from the center of the earth, and we take it that something dropped from rest there falls 5 m in one second, use Pythagoras’ theorem to find how fast the cannon must shoot the ball for it to stay in orbit.

15. Approximately when and where did Tycho Brahe live? What did he do that no-one had done before? Describe briefly his picture of the solar system.
16. Approximately when and where did Kepler live? What did he think kept the planets moving? What was his first theory of the ratios of the radii of the planetary orbits? How did he get the data he needed to check his theory? Was it correct?

17. What three laws of planetary motion did Kepler discover when he analyzed the data?

18. State Kepler’s Third Law. Given the earth’s radius is 4,000 miles, and the moon’s distance is 240,000 miles, and knowing how long the moon takes to go around once, roughly estimate the time the space station, just above the earth’s atmosphere, takes to go once around.

19. State Kepler’s Third Law. If Pluto takes 250 years to make one circuit of the sun, and the earth is about 100,000,000 miles from the sun, roughly how far away is Pluto?

20. State Newton’s Laws of Motion. Discuss how they differ from Aristotle’s “Laws of Motion”, considering both horizontal and vertical motions.


22. State Newton’s Laws of Motion. State carefully what the action and reaction forces are between you and the rest of the universe if you are just standing still.

23. Assume a tennis ball weighs 50 grams (pretty close to correct): what is the gravitational force on the ball in Newtons? If I drop it on the floor, and it takes ½ second from my hand to the floor, how fast is it moving when it hits? Assume it is squashed by 1 cm as it bounces—how much time elapsed between its first contact with the floor and maximum squeeze? What was its deceleration? So, what, approximately, was the force of the floor on the tennis ball?

24. What is Newton’s Law of Gravitational Attraction? Explain how relating a falling apple to the Moon in orbit gave him the clue about how gravity between two objects varies with their distance apart.

25. Show how Newton’s Law of Gravitational Attraction explains Kepler’s Third Law of planetary motion, assuming the orbits are circles. (It’s still true if they’re not, but harder to prove.)

26. Prove by drawing a suitable diagram that the acceleration $a$ in circular motion at constant speed $v$, circle radius $r$, $a = v^2/r$ towards the center of the circle.

27. A car is going around a circular track of radius 100* meters at a speed of 10* meters per second, and at the same time is picking up speed at a rate of 1* meter per second per second. Show on a diagram the magnitude and direction of its acceleration.

28. If you stand on a skateboard and push yourself off from a wall, so you accelerate, according to Newton’s Law $F = ma$, what is the force $F$ causing the acceleration?
29. If you stand on a bathroom scale in an elevator moving up at a steady speed of 10* meters per second, would you expect the scale to indicate a different weight from that if the elevator were at rest? If the elevator rope breaks, and the elevator falls freely down the shaft, what would your weight read?

30. Show with clear diagrams the velocity and acceleration of a pendulum swinging through a big angle (say 120 degrees) at the middle and at the extreme of its swing.

**Einstein and Relativity**

1. Draw a diagram of the Michelson Morley experiment, and explain what they were attempting to measure. Why was the experiment put on a table that could be rotated? About how sensitive was their apparatus for the effect they were trying to detect?

2. What was the emitter theory of light propagation? What relatively modern experiment showed it to be false? Explain briefly.

3. How did Einstein generalize an idea of Galileo’s to explain the Michelson Morley result?

4. A clock moving past you at a huge speed like 0.8c appears to be registering time more slowly. Einstein found out just how slowly by imagining a “light clock”. Explain briefly how one would work, and use it to calculate the “slowing down factor”—the time dilation.

5. Explain how, knowing that moving clocks register time more slowly, we can deduce that to a person on a fast-moving train, the world appears somewhat squashed in the direction of motion.

6. Explain in words how two clocks synchronized in one frame of reference can be unsynchronized in another, and, for the case of two clocks at the ends of a train of length $L$ in its rest frame, moving at $v$ down the track, prove that the lack of synchronicity is $Lv/c^2$.

7. Explain with an example how it is possible for two observers moving relative to each other both to see the other’s clock as running slow. Why doesn’t this inevitably lead to a contradiction?

8. For a train with length at rest exactly the length of a tunnel, as it goes through the tunnel it will be shorter (it’s moving fast) so can be trapped by bandits closing the doors at the ends when it’s inside. Assume these are humane bandits who open the door in time for the train to get out again. From the train’s perspective, the tunnel is shorter than the train, so explain how this sequence of events appears to a rider in the train. Does the rider ever feel trapped in the tunnel?

9. Give the definition of momentum of a moving object. Using Newton’s laws of motion, explain how, when two objects interact, the total momentum of the system—the two bodies taken together—stays the same throughout.
10. Explain how Einstein proved that if momentum is always conserved (as he believed it was) then mass must vary with velocity, and give the formula for the variation. When was this mass variation first observed in a lab? Guesstimate the mass increase of an airliner on an ordinary flight.

11. What is the definition of work? How much work does it take to lift 2 kg through 20 meters? How does this relate to “potential energy”? How much work does gravity do on the 2 kg mass if it is let fall for two seconds? How does that relate to its speed after two seconds? Explain the connection in this case between potential energy and kinetic energy.

12. If an object is moving at a speed very close to the speed of light, and a force acts on it pushing it in the direction of motion, is \( F = ma \) still correct? If not, how must it be changed? How much work does a force \( F \) do in one second at this speed? How does that relate to change in momentum in one second? If the speed really doesn’t change perceptibly, how do you account for the change in momentum?