Astronomy 101 Exam 2 Form Dkey

Name: ______________________________

Lab section number: _________________

(In the format "M0**". See back page; if you get this wrong you may not get your exam back!)

- Exam time: one hour and twenty minutes
- Please put bags under your seats to allow proctors to move around the room.
- Please choose the **best** answer to each question.
- You may use only pencils and pens for this exam; no notes, **cellphones, or smartwatches** are allowed.
- If you have a question, raise your hand, and a proctor will assist you.
- You may use a single-sided 8.5x11 inch page of notes you wrote yourself
- Do not attempt to communicate with anyone other than teaching staff during the exam.

Good luck!

Lab Schedule

Section	Instructor	Time
M024	Jiaxin Sun	Monday 8:00AM-9:20AM
M003	Pan Dong	Monday 9:30AM-10:50AM
M004	Pan Dong	Monday 11:00AM-12:20PM
M005	Pan Dong	Monday 12:45PM-2:05PM
M006	Pan Dong	Monday 2:15PM-3:35PM
M007	Suman Kundu	Monday 3:45PM-5:05PM
M008	Suman Kundu	Monday 5:15PM-6:35PM
M009	Suman Kundu	Monday 6:45PM-8:05PM
M010	Suman Kundu	Monday 8:15PM-9:35PM
M027	Julian Georg	Tuesday 3:30PM-4:50PM
M028	Julian Georg	Tuesday 5:00PM-6:20PM
M029	Julian Georg	Tuesday 6:30PM-7:50PM
M030	Julian Georg	Tuesday 8:00PM-9:20PM
M025	Ohana Benevides Rodrigues	Wednesday 8:00AM-9:20AM
M011	Ohana Benevides Rodrigues	Wednesday 9:30AM-10:50AM
M012	Ohana Benevides Rodrigues	Wednesday 11:00AM-12:20PM
M013	Scott Bassler	Wednesday 12:45PM-2:05PM
M014	Jiaxin Sun	Wednesday 2:15PM-3:35PM
M015	Sarthak Gupta	Wednesday 3:45PM-5:05PM
M016	Sarthak Gupta	Wednesday 5:15PM-6:35PM
M017	Elizabeth Lawson-Keister	Wednesday 6:45PM-8:05PM
M018	Elizabeth Lawson-Keister	Wednesday 8:15PM-9:35PM
M019	Sarthak Gupta	Thursday 5:00PM-6:20PM
M020	Sarthak Gupta	Thursday 6:30PM-7:50PM
M031	Ohana Benevides Rodrigues	Thursday 8:00PM-9:20PM
M026	Elizabeth Lawson-Keister	Friday 8:00AM-9:20AM
M021	Elizabeth Lawson-Keister	Friday 9:30AM-10:50AM
M022	Jiaxin Sun	Friday 11:00AM-12:20PM
M023	Jiaxin Sun	Friday 12:45PM-2:05PM

Reference

Kepler's three laws of orbital motion state:

- Planets orbit in ellipses with the Sun at one focus
- The line connecting a planet to the Sun sweeps out equal areas in equal times
- The time T required for a planet to orbit the Sun is related to the orbit's semimajor axis A by $T^2 \propto A^3$.

These laws are equally valid for other gravitationally-bound orbits.

Newton's three laws of motion state:

- An object with no net force acting on it travels in a straight line at a constant velocity.
- If a force acts on an object, this creates an acceleration on it, with that acceleration given by $F = ma$ or equivalently $a = F/m$.
- If object A exerts a force on object B, object B exerts an equal force in the opposite direction on object A

Newton's law of universal gravitation states:

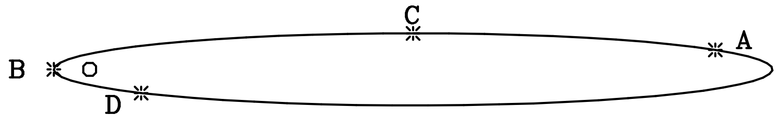
- The force of gravity between two objects is given by

  $$F_g = \frac{Gm_1m_2}{r^2}$$

  where m_1 and m_2 are their masses and r is the distance between their centers.

(Question comet-orbit-energy)

1. Consider a comet in the following very eccentric orbit that orbits clockwise:



At which point is the kinetic energy of the comet increasing?

(A) Point A
(B) Point B
(C) Point C
(D) **Point D**
(E) Since energy is conserved, the kinetic energy is the same everywhere

Point D is the only place where the planet's distance to the sun is decreasing. This means that at that point its potential energy is decreasing, so its kinetic energy must be increasing.

(Question universal-gravitation-consequence)

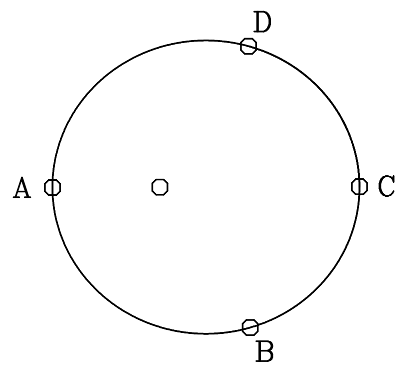
2. Which of the following *is* explained by Isaac Newton's laws of universal gravitation and mechanics, but *not* explained by Kepler's laws of orbital motion?

(A) The fact that Mercury appears to move backwards in the sky periodically
(B) The fact that Earth is closer to the Sun during December than during June
(C) The fact that Halley's comet spends most of its time far from the Sun, and is only close enough to the Sun for us to see it for a tiny fraction of each orbit
(D) **The slight motion of the Sun due to Jupiter's gravity**
(E) The fact that the more distant moons of Jupiter take longer to go around than the closer moons

Kepler's laws place the Sun at a fixed focus of an ellipse. This is only approximately true if a very large planet's gravity tugs the Sun around a little bit.

`(Question four-points-one)`

3. Here is the orbit of the dwarf planet Fido.



At which shown point is the planet moving the *slowest*?

(A) Point A

(B) Point B

(C) **Point C**

(D) Point D

(E) It is impossible to tell from the figure given

Kepler's second law says that planets move fastest when nearest the Sun, and slowest when furthest from it.

(Question three-asteroids)

4. Three asteroids are floating in space as shown. Their masses are given, expressed in arbitrary units, and the distances separating them are shown, also expressed in arbitrary units.

Which asteroid exerts a stronger gravitational force on the asteroid labeled A?

(A) The force exerted by asteroids B and C is equal.
(B) **Asteroid B**
(C) Asteroid C
(D) It is not possible to tell from this picture.

Asteroid B has a stronger force. This can be calculated pretty simply; the force from B is equal to $G(4)(3)/(2^2)$*, while the force from C is equal to* $G(6)(3)/(4^2)$*. The first one of these is larger; the 3's and G's are the same in both, leaving us with* $4/4$ *compared with* $6/16$*.*

(Question ellipse-shape-discovery)

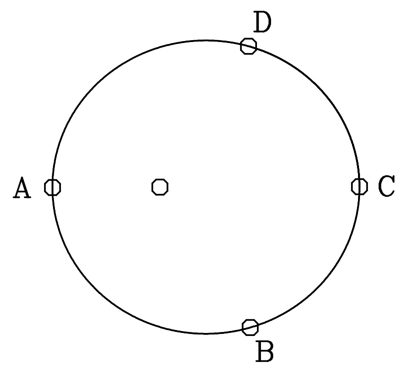
5. Which advance in astronomy led *most directly* to the discovery that the planets travel in elliptical orbits?

(A) The observation of Jupiter's moons through a telescope made by Galileo
(B) The discovery of the mathematical form of the law of gravity by Isaac Newton
(C) **The precision measurements of the positions of the planets in the sky made by Tycho, Sophie, and Kepler**
(D) The correction of mathematical errors in the *Almagest* made by Islamic mathematicians
(E) The realization that retrograde motion could be easily explained by a heliocentric model by Copernicus

Kepler needed the precise data taken at Uraniborg to distinguish between the circular-orbit model of Copernicus and the correct elliptical shape of planetary orbits.

`(Question four-points-two)`

6. Here is the orbit of the dwarf planet Fido.



At which shown point is the planet *slowing down*? The planet moves counterclockwise in its orbit as seen here.

(A) Point A
(B) **Point B**
(C) Point C
(D) Point D
(E) It is impossible to tell from the figure given

At position B the planet is getting further from the Sun.

`(Question planet-data-table-third-law)`

7. Galileo saw four large moons of Jupiter using a telescope. Here is a table showing how far they are from Jupiter.

Moon	Distance from Jupiter (km)
Io	421,800
Europa	671,100
Ganymede	1,070,400
Callisto	1,882,700

Which of the following things could be predicted from these data based on Kepler's laws?

(A) Ganymede and Callisto will have more eccentric orbits than Io and Europa

(B) **Europa takes longer to orbit Jupiter than Io**

(C) Io's orbit has the greatest difference between its aphelion and perihelion distance

(D) Callisto is the most massive of these moons

(E) None of the above, since Kepler's laws only apply to planets, not moons

Jupiter's moons also follow Kepler's laws. According to Kepler's third law, more distant objects take longer to orbit.

`(Question gravity-strength)`

8. A spacecraft is floating halfway between the Earth and the Moon. Which object exerts a larger force on the spacecraft? *(Thanks to Jen for the question!)*

(A) There is not enough information for us to tell.

(B) The spacecraft exerts a force on the planets, not the other way around.

(C) **The Earth**

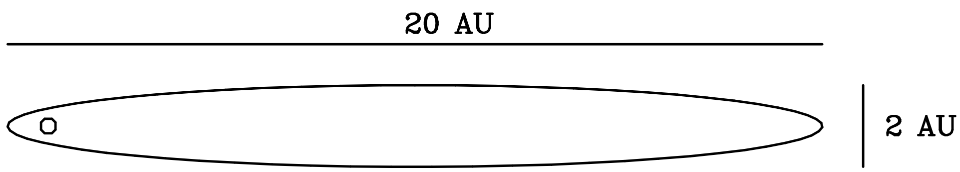
(D) Both exert the same force on the spacecraft.

(E) The Moon

Since the distances are the same, the only thing that differs is the mass of the object pulling on the spacecraft. Since the Earth is more massive, it exerts a larger force.

(Question thirdlaw-semimajor)

9. Suppose an asteroid orbits in a highly eccentric orbit, shaped as shown.



Earth's orbit is nearly circular with a diameter of 2 AU. It has an orbital period of 1 year. Saturn's orbit is nearly circular with a diameter of around 20 AU; it has an orbital period of around 30 years.

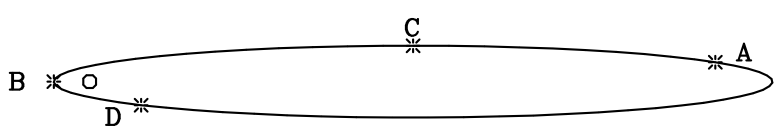
Will this asteroid's orbital period be closest to:

(A) 0.5 year
(B) 1 year
(C) 15 years
(D) **30 years**

According to Kepler's third law, the orbital period depends on the length of the semimajor axis. This asteroid has the same semimajor axis as Saturn and will have the same orbital period.

(Question comet-potential-energy)

10. Consider the highly eccentric orbit of a comet shown below.



At which labeled point does the comet have the most *potential energy*?

(A) **Point A**
(B) Point B
(C) Point C
(D) Point D

It has the most potential energy when it is the furthest from the Sun.

`(Question grav-force-mass)`

11. Suppose I take a large rock (mass 20 kg) and a small rock (mass 10 kg) to the surface of the Moon and drop them from the same height. How does the *gravitational force* on the large rock compare to the gravitational force on the small rock?

    (A) **The gravitational force on the large rock is twice as large as the gravitational force on the small rock**

    (B) The gravitational force on the large rock is the same as the gravitational force on the small rock

    (C) The gravitational force on the large rock is four times as large as the gravitational force on the small rock

    (D) In order to figure this out, you also need to know the sizes of the rocks

    If two objects are in the same place, then the gravitational force $F = GMm/r^2$ *differs only by their mass* m.

`(Question kepler-third-evidence)`

12. An astronaut is doing a "spacewalk" to repair the International Space Station, in orbit 250 miles (400 km) above the surface of the Earth. They float next to it without needing to hold on tightly. What principle of physics causes the astronaut to stay next to the Space Station?

    (A) According to Newton's law of universal gravitation, the Earth's gravitational force is equal on the astronaut and the Space Station, causing them to move together.

    (B) According to Newton's law of universal gravitation, the astronaut and the Space Station are so far away from Earth that Earth's gravity doesn't really affect them

    (C) **According to Kepler's third law of orbital motion, the astronaut must have the same orbital period as the Space Station, since they are in the same orbit, even though the Space Station is much more massive.**

    (D) According to Newton's first law of motion, objects in motion stay in motion in a straight line without an external force acting on them. Both the the Space Station and the astronaut are in motion, and without external forces acting on them, they will keep moving together.

    (E) According to Kepler's second law of orbital motion, the astronaut and the Space Station orbit around the same point.

    The orbital period doesn't depend on mass.

`(Question grav-force-combination)`

13. Suppose a person weighs 120 pounds on the surface of the Earth. That means that the force of Earth's gravity on her is 120 pounds.

    If she travels to the Moon, the strength of the Moon's gravitational force on her will be only about 20 pounds – that is, the Moon's gravity on its surface is 1/6 as strong as Earth's gravity on its surface.

    The mass of the Moon is about 1/96 of the mass of the Earth.

    The radius of the Moon is most nearly:

    (A) 1/36 the radius of the Earth
    (B) 1/6 the radius of the Earth
    (C) 1/96 the radius of the Earth
    (D) 1/2 the radius of the Earth
    (E) **1/4 the radius of the Earth**

    *If the Moon's mass is 1/96 as much as Earth's, one would expect its gravity to be 1/96 as strong, all other things being equal. But it is in fact 1/6 as strong, since it is much smaller than the Earth, and the gravitational force is inversely proportional to the square of the distance to the center (*i.e.* the radius). Note that 1/6 is 16 times as large as 1/96, and* $16 = 4^2$*; thus, the Moon is 1/4 the radius of the Earth.*

`(Question keplers-laws-apply)`

14. Which object do Kepler's laws *not* apply to?

    (A) **The asteroid 'Oumuamua, which was ejected from another solar system, is flying rapidly through ours, and will soon leave our solar system again and head to the constellation Pegasus**
    (B) Jupiter's moon Ganymede, in its orbit around Jupiter
    (C) The dwarf planet Eris, in its orbit around the Sun
    (D) The International Space Station, in its orbit around Earth
    (E) Kepler's laws apply to all of the above

    Kepler's laws describe the motion of any object whose motion is dominated by the gravity of a single large object that it is gravitationally bound to. 'Oumuamua (the name comes from the language of Hawai'i, and the ' mark is part of that language) isn't like this; it came from another solar system, and is not gravitationally bound to the Sun.

(Question gravity-properties)

15. Which of the following is *incorrect* about Newton's law of gravitation? *(Thanks to Kim for the question!)*

    (A) Doubling the mass of one object doubles the force of gravity between the two objects

    (B) The strength of the gravitational force between two objects decreases with the square of the distance between their centers

    (C) **The strength of the gravitational force attracting any two objects is *inversely* proportional to the product of their masses.**

    (D) Doubling the distance between two objects weakens the force of gravity by a factor of 2^2 or 4.

    (E) Every object in the Universe attracts every other mass

    The word "inversely" shouldn't be there; the strength of the gravitational force is proportional to the product of the masses of the gravitating objects. (It would make no sense that more massive objects felt less gravity!)

(Question keplers-third-law-twilo)

16. Suppose that a new planet Twilo is added to the Solar System. Twilo has the same size and mass as Earth, but is located in a circular orbit 5 AU from the Sun.

    Which of the following is true about Twilo?

    (A) **Twilo takes more than five years to orbit the Sun.**

    (B) Twilo takes less than one year to orbit the Sun.

    (C) Twilo orbits the Sun in five years.

    (D) Twilo takes between one year and five year to orbit the Sun.

    (E) Twilo orbits the Sun in one year.

    Kepler's third law says that $P \propto a^{3/2}$, where a is the semimajor axis (the radius for a circular orbit) and P is the orbital period. This means that a change in a leads to a greater-than-proportional change in P; multiplying a by five means that P increases by a factor of more than 5.

`(Question grav-force-distance-easy)`

17. Suppose that a new planet Twilo is added to the Solar System. Twilo has the same size and mass as Earth, but is located in a circular orbit 5 AU from the Sun.

    Which of the following is true about the gravitational force the Sun exerts on Twilo?

    (A) The gravitational force that the Sun applies to Twilo is 25 times stronger as the gravitational force that the Sun appplies to Earth.

    (B) The gravitational force that the Sun applies to Twilo is the same size as the gravitational force that the Sun applies to Earth.

    (C) The gravitational force that the Sun applies to Twilo is 1/5 as strong as the gravitational force that the Sun applies to Earth.

    (D) **The gravitational force that the Sun applies to Twilo is 1/25 as strong as the gravitational force that the Sun applies to Earth.**

    (E) The gravitational force that the Sun applies to Twilo is 5 times stronger than the gravitational force that the Sun applies to Earth.

    The gravitational force is inversely proportional to separation squared. If something is five times further away, the gravitational force is 1/25 as strong.

`(Question boats-on-lake)`

18. Two light boats are floating on the surface of Lake Onondaga. The red boat has three people in it; the green boat has one person in it. (Assume that all people have the same mass.) The two boats are tied together by a rope.

    The person in the green boat wants to pull the red boat to him. He pulls on the rope; after he pulls, the red boat is moving at one meter per second.

    How fast will the green boat be moving right after this happens?

    (A) It won't be moving at all

    (B) 1/3 meter per second

    (C) 1 meter per second

    (D) **3 meters per second**

    This is a version of the demo we did in class, but with boats instead of carts. Newton's third law says that the force on the red boat is of equal magnitude (and opposite direction) to that on the green boat. Newton's second law says that the acceleration is inversely proportional to the mass. Since the green boat has one-third the mass, it will experience three times the acceleration, and at the end be moving three times as fast.

`(Question copernican-advance)`

19. Which is true about the Copernican heliocentric model of the solar system?

    (A) It is unable to explain the phases of the Moon

    (B) It gives more accurate predictions than Ptolemy's geocentric model

    (C) **It predicts the retrograde motion of the planets without the need for epicycles**

    (D) It is a combination of the old geocentric model and the modern perspective; in it, the Earth orbits the Sun, and all the planets orbit the Earth

    (E) None of the above are true

    The main evidence that something was wrong with the Ptolemaic model was the need for complex epicycles to describe something as simple as retrograde motion.

`(Question galilean-moons-consequence)`

20. Galileo observed four moons orbiting Jupiter through the first astronomical telescope. What did he deduce from this?

    (A) That the orbits of these moons are elliptical, not circular

    (B) That the motion of these moons can only be explained using "epicycles"

    (C) **That not everything orbits the Earth**

    (D) That Jupiter's gravity gets weaker the further out you are from it, leading to the later discovery of Kepler's third law

    (E) More than one of the above

    Recall that Galileo's major contribution to our narrative was the advocacy of heliocentrism based on his observations. (This is why the Church went after him.)

`(Question parallax-two)`

21. *Parallax* is the apparent motion of an object against the background when the observer changes location. The *baseline* is the distance that the observer moves.
Which combination of factors will produce the largest observed parallax?

    (A) A short baseline when observing a nearby object

    (B) **A long baseline when observing a nearby object**

    (C) A long baseline when observing a distant object

    (D) A short baseline when observing a distant object

    This is based on what you did in lab, where you found that observed parallax is proportional to the baseline but inversely proportional to the distance to the object.

`(Question earth-round-discovery)`

22. Who first discovered that the Earth was spherical?

    (A) Christopher Columbus

    (B) Nikolaus Copernicus

    (C) Galileo Galilei

    (D) Isaac Newton

    (E) **None of the above; the Earth was known to be round thousands of years prior to the Renaissance.**

    The Greeks figured out that the Earth was round from the shape of the shadow on the eclipsed moon (and measured its size accurately). Other people around the world independently figured out that it was round well before the European Renaissance.

(Question earth-inflate)

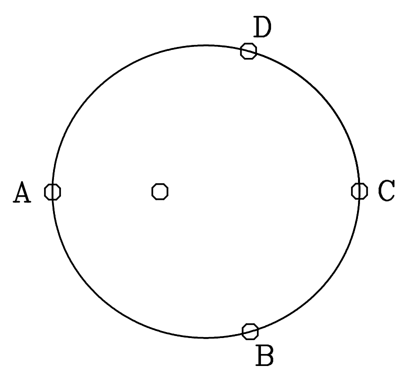
23. Suppose that someone weighs 180 pounds. *("Weight" refers to the force of gravity on an object.)* If Earth's size were increased by a factor of three, while keeping its mass the same, how much would they then weigh?

    (A) **20 pounds**
    (B) 180 pounds
    (C) 1,620 pounds
    (D) 540 pounds
    (E) 60 pounds

    The r in the denominator of the law of gravitation $F_g = \frac{GMm}{r^2}$ refers to the distance between the centers of the gravitating objects. In the case of someone standing on the surface of a planet, it is the same as the radius of a planet.
    If this is tripled, then the gravitational force goes down by a factor of $3^2 = 9$, giving 20 pounds.

(Question four-points-three)

24. Here is the orbit of the dwarf planet Fido.



    At which point does Fido have the largest *total energy*? *(Thanks to Landon for the question!)*

    (A) Point A
    (B) Point B
    (C) Point C
    (D) Point D
    (E) **The total energy is the same at all of the points shown.**

    Total energy is conserved.

`(Question grav-accel-mass)`

25. Suppose I take a large rock (mass 20 kg) and a small rock (mass 10 kg) to the surface of the Moon and drop them from the same height. How does the *acceleration due to gravity* on the large rock compare to the acceleration due to gravity on the small rock?

    (A) The gravitational acceleration on the large rock is twice as large as the gravitational acceleration on the small rock

    (B) **The gravitational acceleration on the large rock is the same as the gravitational acceleration on the small rock**

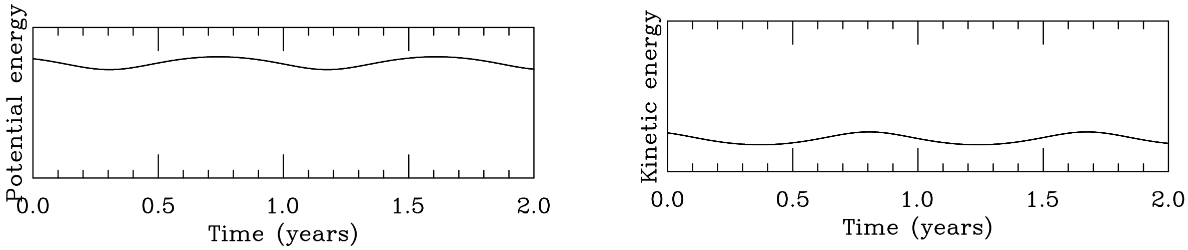
    (C) The gravitational acceleration on the large rock is four times as large as the gravitational acceleration on the small rock

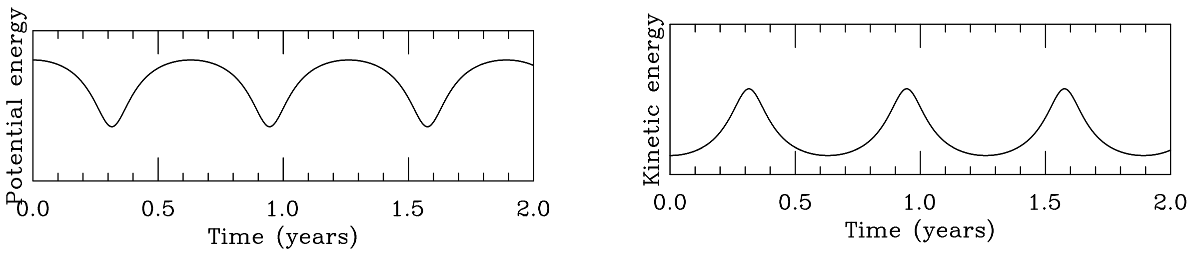
    (D) In order to figure this out, you also need to know the mass of the Moon

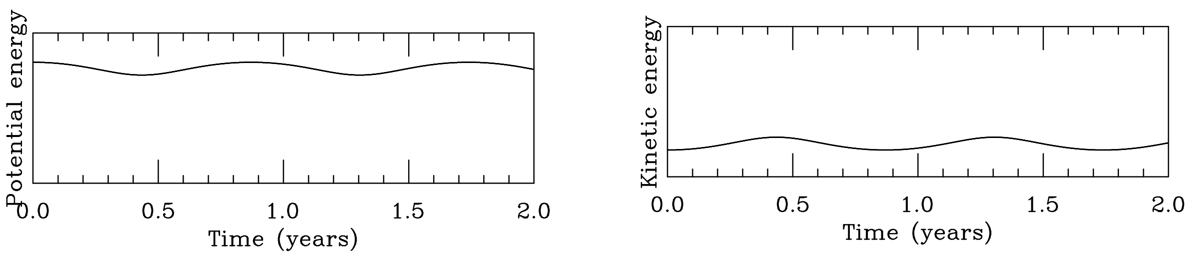
    The mass of the small object (the rock) cancels between $a = F/m$ *and* $F = GMm/r^2$*, yielding an acceleration of* $a = GM/r^2$*, which depends only on the mass of the large object (the Moon, in this case) and the distance from its center.*
    We saw in class that in a place with no air resistance (like the Moon), all objects fall at the same rate.

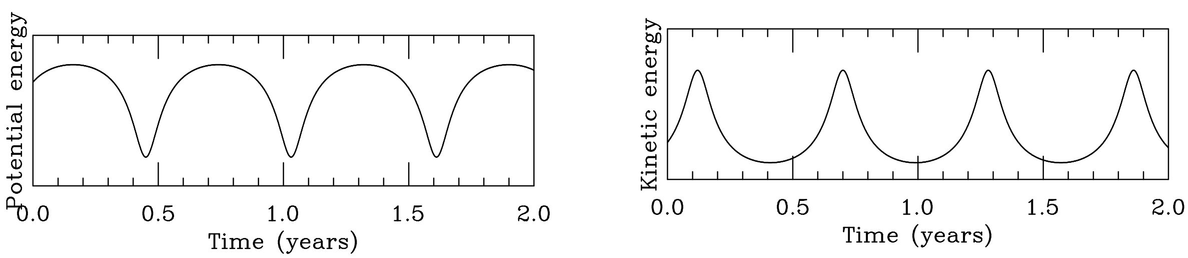
(Question eccentric-energy)

26. Here are some pairs of plots for kinetic and gravitational potential energy. Which one represents the fluctuation of KE and GPE for a planet in a strongly eccentric orbit, like Halley's comet?

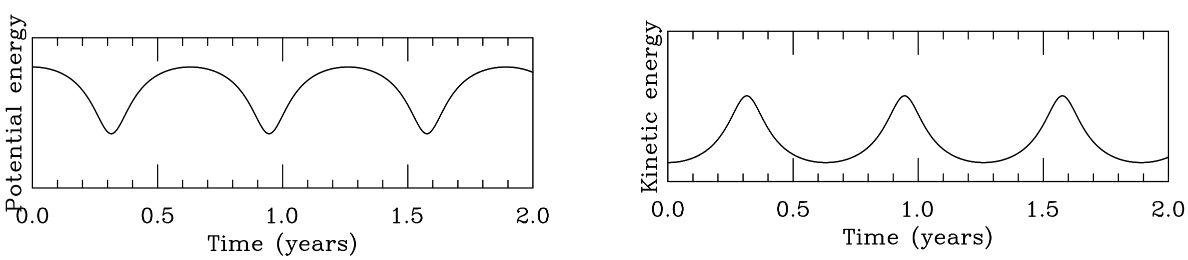
(A)


(B)


(C)


(D)


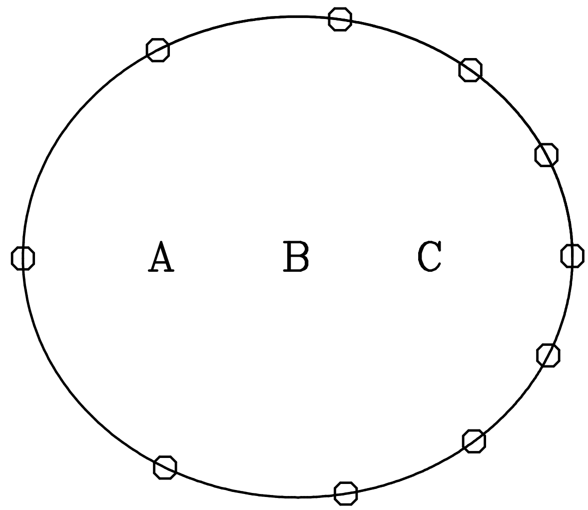
This graph is correct:



You know it's correct because the potential energy and kinetic energy always add up to the same value (potential goes up at the same time kinetic goes down), and because the large fluctuations point to a strongly eccentric orbit.

(Question find-sun-secondlaw)

27. An asteroid orbits the Sun in an orbit like the one shown below.



This asteroid takes ten months to make one complete orbit. Its position after each month is indicated, *i.e.* the labeled points are located one month apart.
Which position is the correct position of the Sun?

(A) **Position A**

(B) Position B

(C) Position C

(D) There's isn't enough information given to know for sure

The Sun could be at either A or C by the orbital shape alone, since they are the foci of the ellipse. But Kepler's second law says that planets move fastest near the Sun.

`(Question planet-data-table-second-law)`

28. Here is a table showing the orbital distances, orbital periods, and masses for the six planets known in Kepler's time. Jupiter is the most massive of these planets, and Mercury is the least.

Planet	Semimajor axis (AU)	Orbital period (years)	Mass (Earths)	Eccentricity
Mercury	0.38	0.24	0.06	0.206
Venus	0.72	0.61	0.81	0.007
Earth	1.0	1.0	1.0	0.017
Mars	1.52	1.88	0.11	0.093
Jupiter	5.20	11.86	318	0.048
Saturn	9.54	29.46	95.2	0.054

Of these objects, which one has the *greatest percent change* in its speed over the course of one orbit around the Sun?

(A) Jupiter

(B) **Mercury**

(C) Saturn

(D) Venus

(E) The speed of planets does not change as they orbit the Sun.

Objects change their speed when they get closer to and further from the Sun by Kepler's second law (or, alternatively, the conservation of energy.) This is related to their orbital eccentricity; Mercury is the most eccentric of the planets here.

`(Question parallax)`

29. What is true regarding the lack of observed parallax in the distant stars when we look at them first in the summer and then in the winter?

    (A) The lack of observed parallax was a piece of evidence used to argue that the Earth could not move

    (B) If we did observe parallax in the stars, we could use it to figure out how far away they are

    (C) Because a baseline of 2 AU is too small to observe parallax with the unaided eye, since the stars are so far away

    (D) We actually *do* observe parallax in the distant stars when observing them with modern instruments

    (E) **All of the above are true**

    All of the above are true; this was something emphasized more in the text and in the lab. Parallax is a handy way of measuring the distances to things, but the stars are very distant; 2 AU is the greatest baseline available to us, so the shifts that we can see for the very distant stars can't be seen except with modern telescopes.

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