Worksheet: Gravitational Potential Energy in a Radial Field

Q1: Which of the following formulas correctly shows the relation between the gravitational potential energy E between two objects with masses m and M, where their centers of mass are separated by a distance r?

A $E = -\frac{GM}{r^2}$

B $E = -\frac{GM}{r}$

C $E = -\frac{2GM}{r}$

D $E = -\frac{GMm}{r}$

E $E = -\frac{GMm}{r^2}$

Q2: The distance between the centers of mass of two massive objects is r. If this distance is increased to $3r$, by what factor does the gravitational potential energy between the two objects change?

A 3

B $\frac{1}{3}$

C 9

D $\frac{1}{9}$

E 1

Q3: An asteroid with a mass of 3, 500 kg moves from a position 40, 000 km away from the center of mass of Earth to a position 22, 000 km away. What is the change in the gravitational potential energy between the asteroid and Earth? Use a value of 5.97×10^{24} kg for the mass of Earth. Give your answer to 3 significant figures.

A -2.85×10^{10} J

B -3.48×10^{10} J

C 9.82×10^{10} J

D 6.33×10^{10} J

E 7.74×10^{10} J

Q4: Two astronauts are trying to land a spacecraft on the Moon. The spacecraft is initially at rest at a position 4 km above the surface of the Moon, and the mass of the spacecraft and the two astronauts is 2, 900 kg. The spacecraft is allowed to fall under the effect of gravity until it is 500 m above the surface of the Moon, when its thrusters are engaged. What is the speed of the spacecraft just before the thrusters are engaged? Use a value of 1, 740 km for the radius of the Moon and a value of 7.34×10^{22} kg for the mass of the Moon. Give your answer to 3 significant figures.

A 131 m/s

B 2, 380 m/s

C 3, 360 m/s

D 75.1 m/s

E 106 m/s

Q5: An asteroid is heading straight for Earth. When it is a distance of 40,000 km away from the surface of Earth, it has a velocity of 55 m/s straight toward Earth. The asteroid has a mass of 16,000 kg. Ignoring the effect of any resistance as the asteroid moves through Earth's atmosphere, what would the speed of the asteroid be just before it hits the Earth's surface? Use a value of 5.97×10^{24} kg for the mass of Earth and a value of 6,370 km for the radius of Earth. Give your answer to 3 significant figures.

A 4.46 km/s

B 8.43 km/s

C 5.19 km/s

D 11.9 km/s

E 10.4 km/s

Q6: Which of the following formulas correctly shows the relation between the magnitude of the gravitational potential energy between two massive objects, E, and the distance between their centers of mass, r?

A $E \propto \frac{1}{r^3}$

B $E \propto \frac{1}{r}$

C $E \propto r$

D $E \propto \frac{1}{r^2}$

E $E \propto r^2$

Q7: A satellite orbiting Earth has a mass of $1,500$ kg. Earth has a mass of 5.97×10^{24} kg. If the gravitational potential energy of the Earth-and-satellite system is -49.8 GJ, what is the satellite's orbital radius? Give your answer to 3 significant figures.

A $12,000$ km

B $835,000$ km

C $24,000$ km

D $3,460$ km

E 8.00 km

Q8: Fill in the blanks: An asteroid is in space near a planet. As the distance between the centers of mass of the planet and the asteroid decreases, the gravitational potential energy between the two objects ___. As the distance between the centers of mass of the planet and the asteroid increases, the gravitational potential energy between the two objects ___.

A stays the same, stays the same

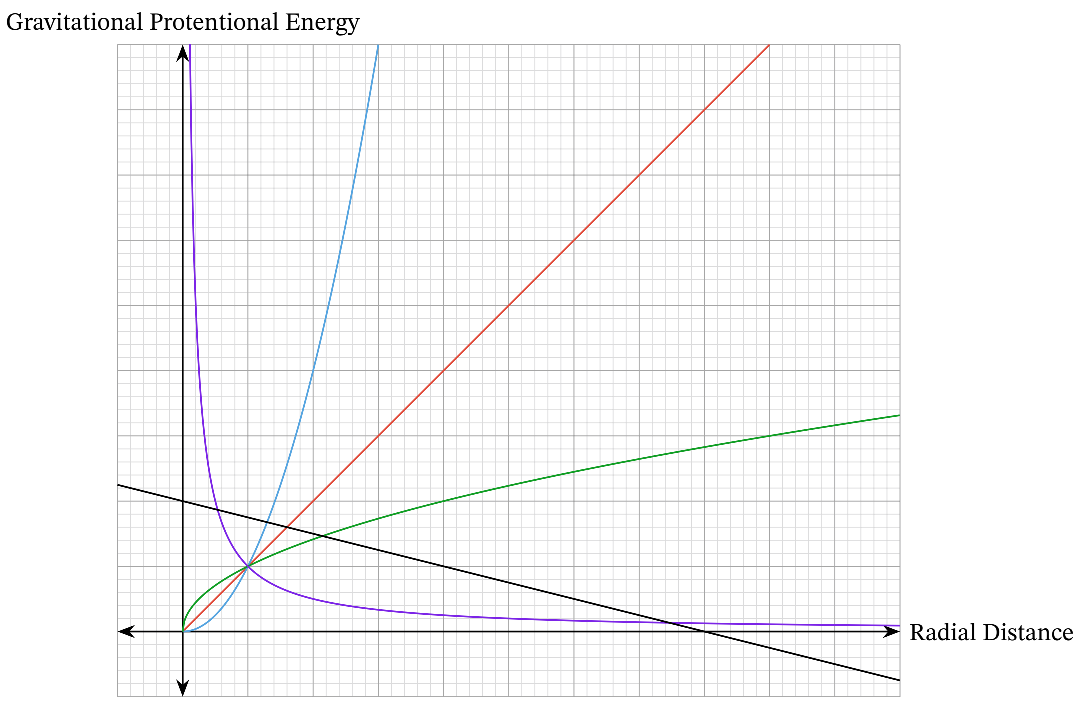
B increases, decreases

C decreases, increases

D decreases, decreases

E increases, increases

Q9: Which of the lines shown on the graph shows how the magnitude of the gravitational potential energy between two massive objects varies with the radial distance between their centers of mass?



- A The red line
- B The black line
- C The purple line
- D The blue line
- E The green line

Q10: A spacecraft sent to investigate a comet moves from a position 10.0 km away from the comet's center of mass to the surface of the comet, 2.10 km away from its center of mass. The spacecraft has a mass of 1,890 kg and the comet has a mass of 8.78×10^{12} kg. If all of the gravitational potential energy lost by the spacecraft is converted into kinetic energy of the spacecraft, what is the kinetic energy of the spacecraft just before it reaches the surface of the comet? Use a value of 6.67×10^{-11} $m^3/kg \cdot s^2$ for the universal gravitational constant. Give your answer to 3 significant figures.

A 140 J

B 111 J

C 527 J

D 638 J

E 416 J

Q11: Phobos is the largest of Mars's two moons. Its mass is 1.07×10^{16} kg, and it orbits Mars at a distance of 9,380 km. Mars has a mass of 6.42×10^{23} kg. What is the value (including the sign) of the gravitational potential energy of the Phobos-and-Mars system? Use a value of 6.67×10^{-11} $m^3/kg \cdot s^2$ for the universal gravitational constant. Give your answer to 3 significant figures.

A -4.30×10^{30} J

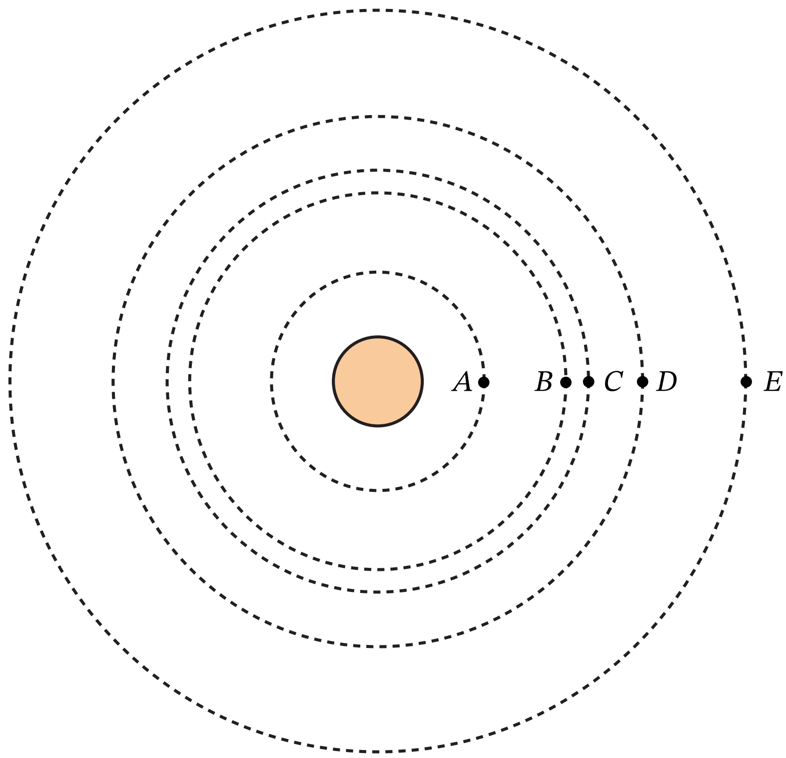
B -4.88×10^{22} J

C 4.88×10^{22} J

D 4.30×10^{30} J

E 2.21×10^{11} J

Q12: The diagram shows a planet and five points at different radii away from the center of mass of the planet.



If an object with mass m were moved from point E to point B, the gravitational potential energy between the object and the planet would ___.

- A Increase
- B Decrease
- C Stay the same

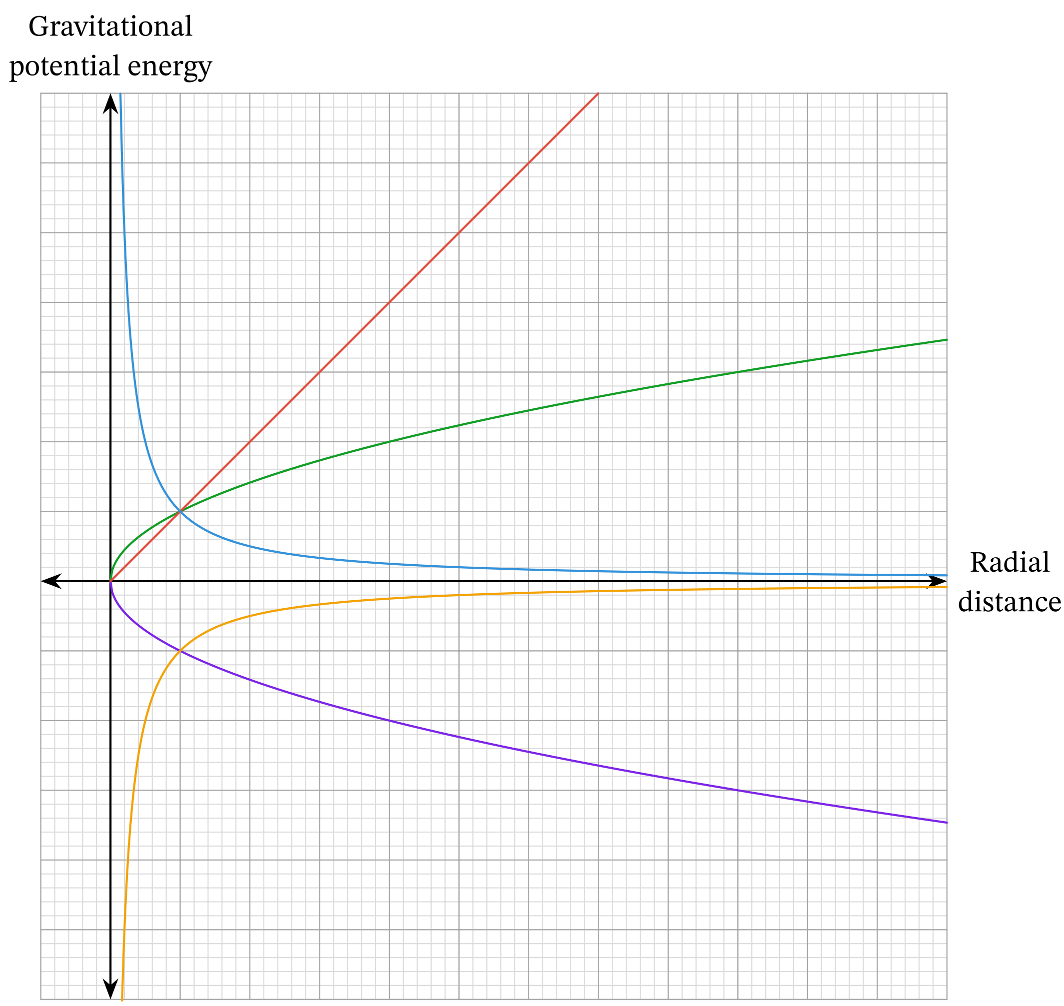
If an object with mass m were moved from point B to point C, the gravitational potential energy between the object and the planet would ___.

A Decrease

B Increase

C Stay the same

Q13: Which of the lines shown on the graph shows how the value (including the sign) of the gravitational potential energy between two massive objects varies with the radial distance between their centers of mass?



A The purple line

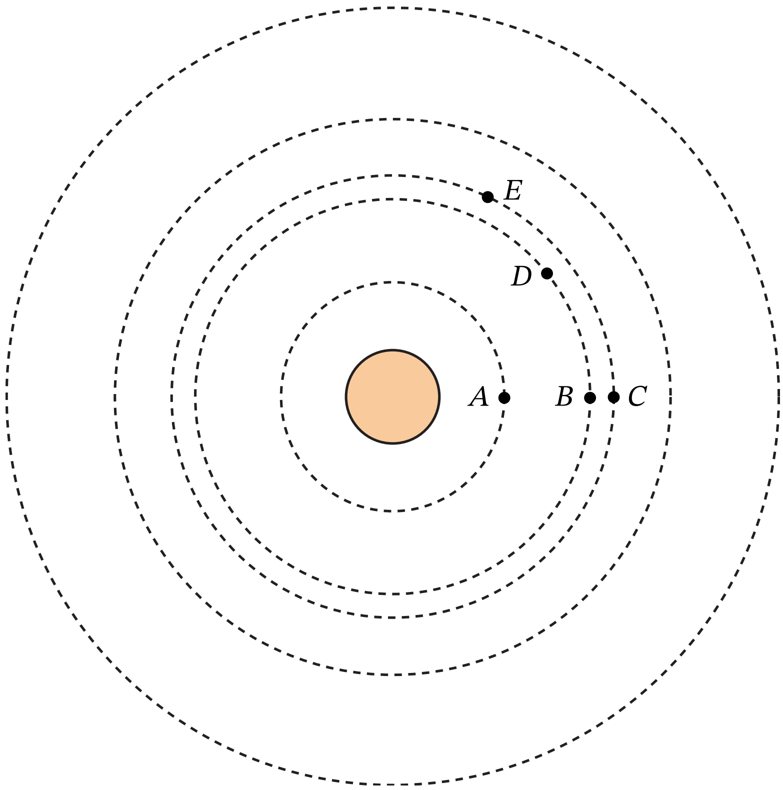
B The blue line

C The green line

D The red line

E The orange line

Q14: The diagram shows a planet and five points at various radii away from its the center of mass.



If an object with mass m were moved from point E to point C along the dashed line that connects the two points, the gravitational potential energy between the object and the planet would ___.

- A Increase
- B Stay the same
- C Decrease

▸ If an object with mass m were moved from point C to point D, the gravitational potential energy between the object and the planet would ___.

A Dtay the same

B Decrease

C Increase

▸ If an object with mass m were moved from point D to point E, the gravitational potential energy between the object and the planet would ___.

A Stay the same

B Increase

C Decrease

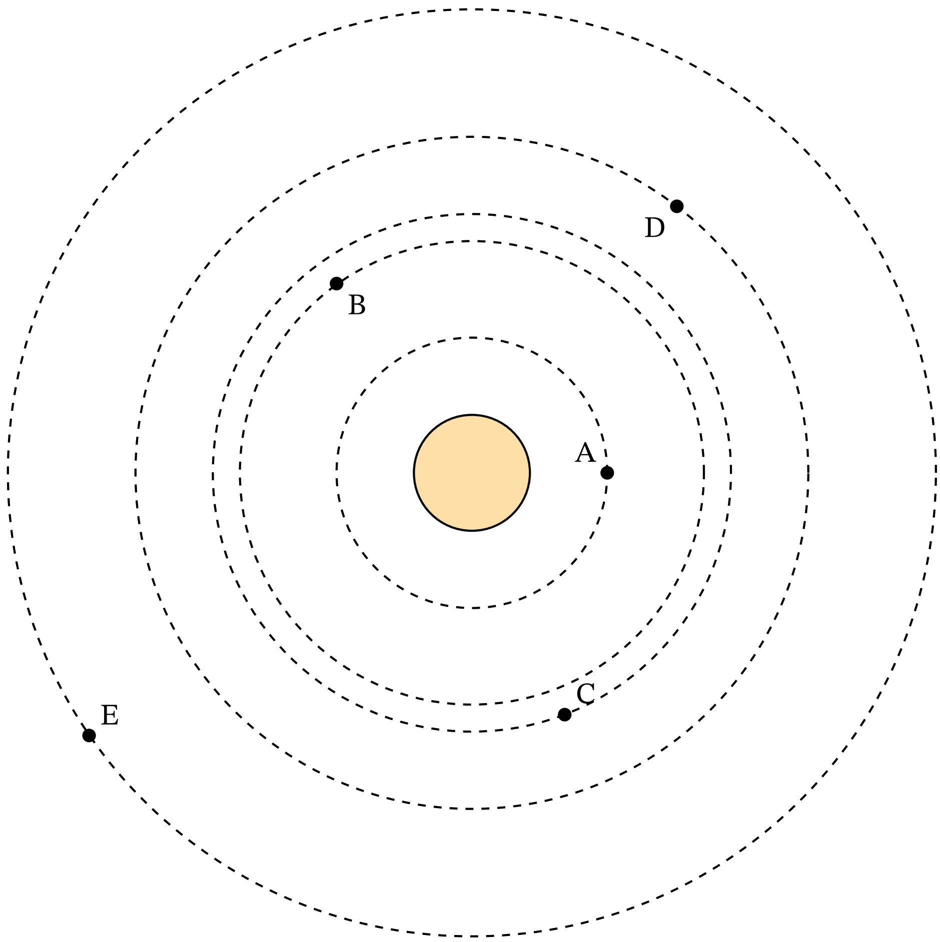
▸ If an object with mass m were moved from point E to point A, the gravitational potential energy between the object and the planet would ___.

A Stay the same

B Decrease

C Increase

Q15: The diagram shows a planet and five points at various radii away from the center of mass of the planet.



If an object with mass m were moved from point A to point B, the difference in the gravitational potential energy between the object and the planet would be ___.

- A: A net decrease
- B: A net increase
- C: Zero

▸ If an object with mass m were moved from point C to point D, the difference in the gravitational potential energy between the object and the planet would be ___.

A A net decrease

B A net increase

C Zero

▸ If an object with mass m were moved from point E to point A, the difference in the gravitational potential energy between the object and the planet would be ___.

A A net increase

B A net decrease

C Zero

Q16: A spacecraft heading toward the Moon to deploy a rover on the surface has a mass of 870 kg. The magnitude of the gravitational potential energy of the spacecraft-and-Moon system is 427 MJ. How far away from the Moon's center of mass is the spacecraft? Use a value of 7.35×10^{22} kg for the mass of the Moon and 6.67×10^{-11} m^3/kg$nagwacdot$s^2 for the universal gravitational constant. Give your answer to 3 significant figures.

A $3,370$ kg

B $2,410$ kg

C $7,890$ kg

D $5,780$ kg

E $9,990$ kg