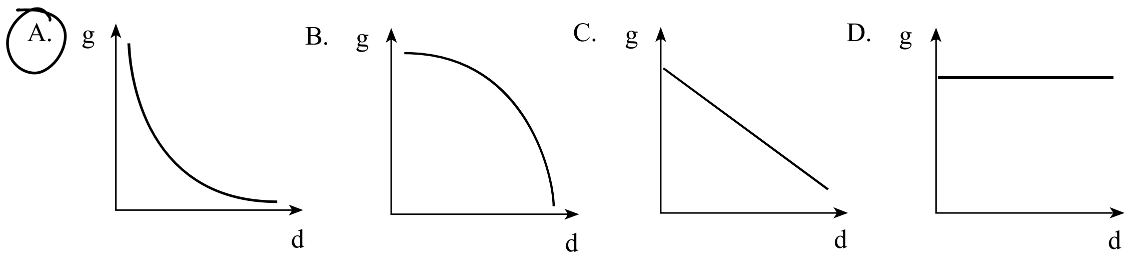
$g = \frac{Gm}{r^2} \quad \therefore g \propto \frac{1}{r^2}$

1. Which of the following graphs shows how the gravitational field of a body varies with distance from its centre? (Assume d is greater than the radius of the body.)

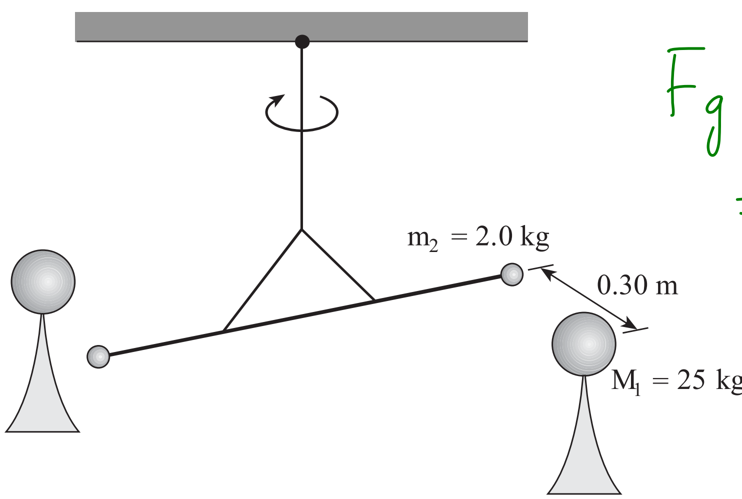


2. A rock drops from a very high altitude towards the surface of the moon. Which of the following is correct about the changes that occur in the rock's mass and weight?

	MASS	WEIGHT
A.	decreases	decreases
B.	decreases	increases
C.	remains constant	decreases
D.	remains constant	increases

mass = always constant
weight depends on g

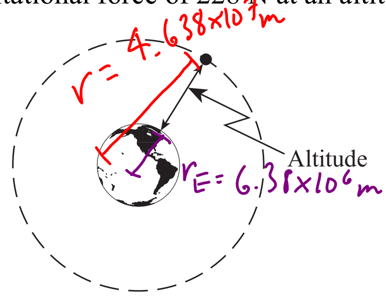
3. Cavendish's historic experiment is set up as shown to determine the force between two identical sets of masses. What would be the net force of attraction between one set of masses?



$F_g = \frac{Gm_1m_2}{r^2}$
$= 3.7 \times 10^{-8}$ N

A. 1.1×10^{-8} N
B. 1.9×10^{-8} N
C. 2.2×10^{-8} N
D. 3.7×10^{-8} N

4. A satellite experiences a gravitational force of 228 N at an altitude of 4.0×10^{7} m above Earth.



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

$$m_2 = \frac{F_g r^2}{Gm_1}$$

$$= 1200 \text{ kg}$$

What is the mass of this satellite?

A. 23 kg
B. 650 kg
C. 910 kg
D. 1 200 kg

5. Oberon is a satellite of the planet Uranus. It has an orbital radius of 5.83×10^{8} m and an orbital period of 1.16×10^{6} s. What is the mass of Uranus?

A. 2.6×10^{8} kg
B. 5.9×10^{14} kg
C. 1.5×10^{17} kg
D. 8.7×10^{25} kg

$$F_g = F_c$$

$$\cancel{m}g = \cancel{m}a_c$$

$$g = a_c$$

$$\frac{Gm}{r^2} = \frac{4\pi^2 r}{T^2}$$

$$m = \frac{4\pi^2 r^3}{GT^2} = 8.72 \times 10^{25} \text{ kg}$$

6. An object travels along a circular path with a constant speed v when a force F acts on it. How large a force is required for this object to travel along the same path at twice the speed (2v)?

A. $\frac{1}{2}$F
B. F
C. 2F
D. 4F

$$F_c = \frac{mv^2}{r}$$

$$\therefore F_c \propto v^2$$

$$\therefore 2v \Rightarrow 4F$$

or

$$F_1 = \frac{mv^2}{r}$$

$$F_2 = \frac{m(2v)^2}{r}$$

$$F_2 = 4\left(\frac{mv^2}{r}\right) \quad \therefore F_2 = 4F_1$$

7. Find the gravitational force of attraction between a 75 kg physics student and her 1500 kg car when their centres are 10 m apart.

A. 7.5×10^{-8} N
B. 7.5×10^{-7} N
C. 740 N
D. 1.5×10^{3} N

$$F_g = \frac{Gm_1m_2}{r^2} = 7.50 \times 10^{-8} \text{ N}$$

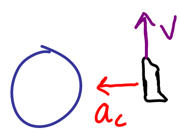
8. A certain planet has a mass of 3.3×10^{23} kg and a radius of 2.6×10^{6} m. What is the acceleration due to gravity on the surface of this planet?

A. $0.54\ \text{m/s}^2$
B. $3.3\ \text{m/s}^2$
C. $4.0\ \text{m/s}^2$
D. $9.8\ \text{m/s}^2$

$$g = \frac{Gm}{r^2} = \frac{(6.67\times10^{-11})(3.3\times10^{23})}{(2.6\times10^{6})^2}$$
$$= 3.3\ \text{m/s}^2$$

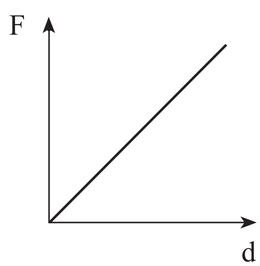
9. A space shuttle orbits the earth at an altitude where the acceleration due to gravity is $8.70\ \text{m/s}^2$. What is the shuttle's speed at this altitude?

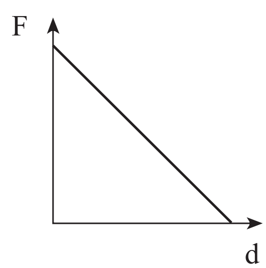
A. 2.65×10^{3} m/s
B. 7.45×10^{3} m/s
C. 7.68×10^{3} m/s
D. 7.91×10^{3} m/s

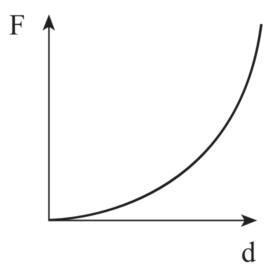


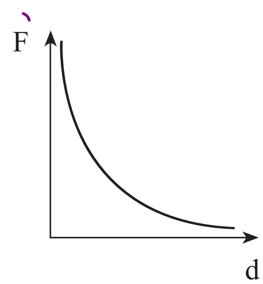
$$a_c = g \qquad g = \frac{Gm}{r^2}$$
$$\frac{v^2}{r} = g \qquad r = \sqrt{\frac{Gm}{g}}$$
$$v = \sqrt{rg} \qquad = 6.771\times10^{6}\ \text{m}$$
$$= 7680\ \text{m/s}$$

10. Which of the following graphs shows how the gravitational force varies with the distance of separation between two objects?

A.


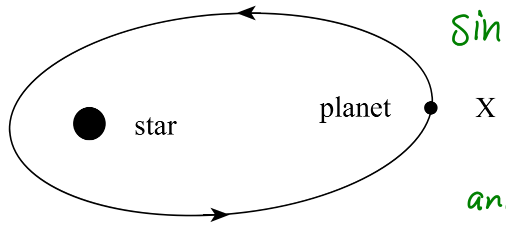
B.


C.


D.


$$F_g = \frac{Gm_1m_2}{r^2}$$
same as "d"
$$\therefore F_g \propto \frac{1}{r^2}$$

11. A planet travels in an elliptical path around a star as shown.



since r is at a maximum $v = \sqrt{\frac{Gm}{r}}$ is minimum

and $a_c = g = \frac{Gm}{r^2}$ is minimum

Describe the magnitude of the velocity and the acceleration of the planet at X.

	MAGNITUDE OF VELOCITY	MAGNITUDE OF ACCELERATION
A.	least	least
B.	least	greatest
C.	greatest	least
D.	greatest	greatest

12. What is the gravitational field strength at the surface of a star of mass 4.8×10^{31} kg and radius 2.7×10^{8} m?

$g = \frac{Gm}{r^2} = 44\,000$ N/kg

A. 9.8 N/kg
B. 4.4×10^{4} N/kg
C. 4.9×10^{6} N/kg
D. 1.2×10^{13} N/kg

13. A satellite's orbit is maintained by a

A. normal force.
B. frictional force.
C. centrifugal force.
D. gravitational force.

14. Kepler's third law $(r^3 \propto T^2)$ can be derived from the law of

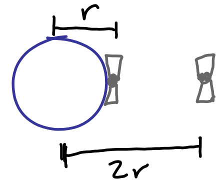
A. inertia.
B. universal gravitation.
C. conservation of energy.
D. conservation of momentum.

DON'T DO!!!

but the answer is...

15. A planet of radius 7.0×10^{7} m has a gravitational field strength of 68 N/kg at its surface. What is the period of a satellite orbiting this planet at a radius of 1.4×10^{8} m (twice the planet's radius)?

A. 9.0×10^{3} s
B. 1.3×10^{4} s
C. 1.8×10^{4} s
D. 2.4×10^{4} s



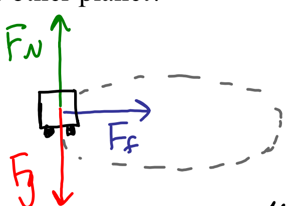
$g = a_c \quad g = \frac{4\pi^2 r}{T^2}$

$T = \sqrt{\frac{4\pi^2 r}{g}} = \sqrt{\frac{4\pi^2(1.4\times10^8)}{17}} = 18030\text{ s}$

$g_1 = \frac{Gm}{r^2} = 68\text{ N/kg} \quad g_2 = \frac{Gm}{(2r)^2} = \frac{Gm}{4r^2} = \frac{1}{4}(68) = 17\text{ N/kg}$

16. On Earth, the maximum speed without skidding for a car on a level circular curved track of radius 40 m is 15 m/s. This car and track are then transported to another planet for the Indy Galactic 500. The maximum speed without skidding is now 8.4 m/s. What is the value of the acceleration due to gravity on this other planet?

A. 1.8 m/s^2
B. 3.1 m/s^2
C. 4.3 m/s^2
D. 5.5 m/s^2



Earth

$F_c = F_f$

$\frac{\cancel{m}v^2}{r} = \mu \cancel{m} g$

$\mu = \frac{v^2}{rg} = 0.574$

Planet X

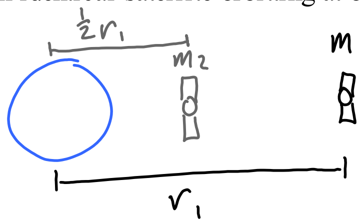
$F_c = F_f$

$\frac{\cancel{m}v^2}{r} = \mu \cancel{m} g$

$g = \frac{v^2}{r\mu} = 3.07\text{ m/s}^2$

17. A satellite travels around a planet at 9.0×10^{3} m/s with an orbital radius of 7.4×10^{6} m. What would be the speed of an identical satellite orbitting at one half this radius?

A. 4.5×10^{3} m/s
B. 9.0×10^{3} m/s
C. 1.3×10^{4} m/s
D. 1.8×10^{4} m/s



m_1

$a_{c_1} = g_1$

$\frac{v_1^2}{\cancel{r_1}} = \frac{Gm}{r_1^{\cancel{2}}}$

$v_1 = \sqrt{\frac{Gm}{r_1}}$

m_2

$a_{c_2} = g_2$

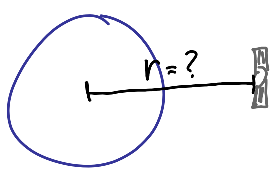
$\frac{v_2^2}{\cancel{\frac{1}{2}r_1}} = \frac{Gm}{(\frac{1}{2}r_1)^{\cancel{2}}}$

$v_2 = \sqrt{\frac{Gm}{\frac{1}{2}r_1}} = \sqrt{2}\sqrt{\frac{Gm}{r_1}}$

$= 1.3\times10^4\text{ m/s} = \sqrt{2}(9.0\times10^3)$

18. A satellite orbits a planet of mass 4.0×10^{25} kg at a velocity of 5.8×10^{3} m/s. What is the radius of this orbit?

A. 6.4×10^{6} m
B. 7.9×10^{7} m
C. 1.6×10^{8} m
D. 1.2×10^{19} m



$a_c = g$

$\frac{v^2}{\cancel{r}} = \frac{Gm}{r^{\cancel{2}}}$

$r = \frac{Gm}{v^2} = \frac{(6.67\times10^{-11})(4.0\times10^{25})}{(5.8\times10^3)^2}$

$= 7.93\times10^7\text{ m}$

19. The orbital radius of Mars around the Sun is 1.52 times that of Earth's orbital radius. In Earth years, what is the period of revolution for Mars in this orbit?

A. 0.66 years
B. 1.5 years
C. 1.9 years
D. 3.5 years

Earth

$a_c = g$

$\frac{4\pi^2 r_1}{T_1^2} = \frac{Gm}{r_1^2}$

$T_1 = \sqrt{\frac{4\pi^2 r_1^3}{Gm}} = 1 \text{ year}$

Mars

$T_2 = \sqrt{\frac{4\pi^2 (1.52 r_1)^3}{Gm}} = 1.89\sqrt{\frac{4\pi^2 r_1^3}{Gm}}$

$= 1.89(1 \text{ year})$

20. What is the centripetal acceleration of the Moon in its orbit around the Earth?

A. 0 m/s^2
B. $2.7 \times 10^{-3} \text{ m/s}^2$
C. 1.6 m/s^2
D. 9.8 m/s^2

$g = \frac{Gm_E}{r^2}$

$= \frac{(6.67\times10^{-11})(5.98\times10^{24})}{(3.84\times10^{8})^2} = 2.70\times10^{-3} \text{ m/s}^2$

21. The equation $E_p = mgh$, in which g is 9.8 m/s^2, can not be used for calculating the gravitational potential energy of an orbiting Earth satellite because

A. the Earth is rotating.
B. of the influence of other astronomical bodies.
C. the Earth's gravity disappears above the atmosphere.
D. the Earth's gravitational field strength varies with distance.

22. A 1570 kg satellite orbits a planet in a circle of radius 5.94×10^6 m. Relative to zero at infinity the gravitational potential energy of this satellite is -9.32×10^{11} J. What is the mass of the planet?

A. 5.29×10^{25} kg
B. 8.31×10^{28} kg
C. 3.14×10^{31} kg
D. 4.93×10^{34} kg

$E_p = -\frac{Gm_1 m_2}{r}$

$m = -\frac{E_p \cdot r}{Gm_2} = \frac{-(-9.32\times10^{11})(5.94\times10^{6})}{(6.67\times10^{-11})(1570)}$

$= 5.29\times10^{25} \text{ kg}$

23. Relative to zero at infinity, what is the gravitational potential energy of a 7.2×10^2 kg satellite that is at a distance of 3.4×10^7 m from earth's centre?

A. -2.4×10^{11} J
B. -8.4×10^{9} J
C. 8.4×10^{9} J
D. 2.4×10^{11} J

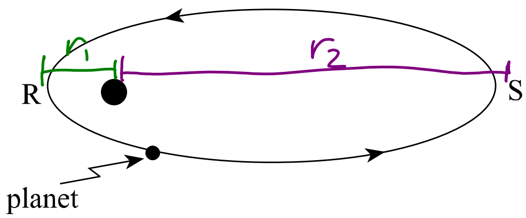
$E_p = -\frac{Gm_1 m_2}{r} = \frac{-(6.67\times10^{-11})(5.98\times10^{24})(7.2\times10^{2})}{3.4\times10^{7}}$

$= -8.45\times10^{9} \text{ J}$

24. A planet is in orbit as shown in the diagram below.

$r_1 < r_2$

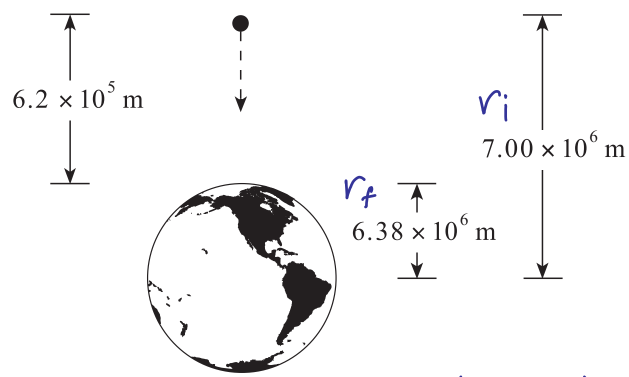
$\therefore E_{p_1} < E_{p_2}$



The planet's gravitational potential energy will

A. be constant throughout its orbit.
B. always be equal to its kinetic energy.
C. increase as the planet goes from point R to point S.
D. decrease as the planet goes from point R to point S.

25. A 450 kg piece of space debris initially at rest falls from an altitude of 6.2×10^5 m above the earth's surface. What is its kinetic energy just before impact with the surface? (Ignore air resistance.)

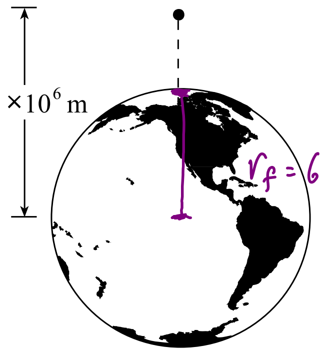


A. 2.5×10^9 J
B. 2.7×10^9 J
C. 2.6×10^{10} J
D. 2.9×10^{11} J

$$\Delta E_p = E_{pf} - E_{pi} = \left(-\frac{Gm_1m_2}{r_f}\right) - \left(-\frac{Gm_1m_2}{r_i}\right)$$
$$= -2.49 \times 10^9 \text{ J}$$

$$\Delta E_k = -\Delta E_p = 2.49 \times 10^9 \text{ J}$$

26. A stationary 25 kg object is released from a position 8.9×10^6 m from the centre of the earth.



$$\Delta E_p = Gm_1m_2\left(\frac{1}{r_i} - \frac{1}{r_f}\right)$$
$$= -4.425 \times 10^8 \text{ J}$$

What is the speed of the object just before impact? Ignore air resistance.

A. 6.0×10^3 m/s
B. 7.0×10^3 m/s
C. 1.3×10^4 m/s
D. 1.8×10^4 m/s

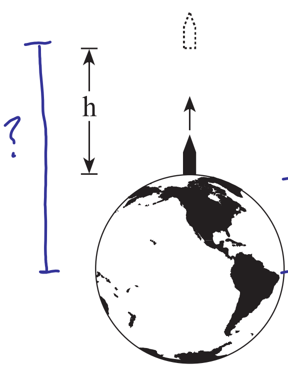
$$\Delta E_k = -\Delta E_p = 4.425 \times 10^8$$

$$\Delta E_k = E_{kf} - \cancel{E_{ki}}^{\,0}$$

$$E_{kf} = \frac{1}{2}mv_f^2$$

$$v_f = \sqrt{\frac{2E_k}{m}} = 5950 \text{ m/s}$$

27. A 5.2×10^4 kg rocket is initially at rest on the surface of the earth. If 3.0×10^{11} J of work is done on this rocket, what maximum altitude h will the rocket reach? (Assume the rocket's mass does not change.)



A. 5.9×10^5 m
B. 6.5×10^5 m
C. 5.8×10^6 m
D. 6.9×10^7 m

$$W = \Delta E_p = 3.0 \times 10^{11} \text{ J}$$

$$\Delta E_p = E_{pf} - E_{pi}$$

$$E_{pf} = E_{pi} + \Delta E_p = -\frac{Gm_1m_2}{r_i} + \Delta E_p = -2.95 \times 10^{12} \text{ J}$$

$$E_{pf} = -\frac{Gm_1m_2}{r_f} \qquad r_f = -\frac{Gm_1m_2}{E_{pf}} = \frac{-(6.67 \times 10^{-11})(5.98 \times 10^{24})(5.2 \times 10^4)}{-2.95 \times 10^{12}}$$

$$= 7.03 \times 10^6 \text{ m}$$

$$h = r_f - r_i = 6.48 \times 10^5 \text{ m}$$

28. A 620 kg satellite orbits the earth where the acceleration due to gravity is $0.233\ \text{m/s}^2$. What is the kinetic energy of this orbiting satellite?

A. -5.98×10^9 J
B. -2.99×10^9 J
C. 2.99×10^9 J
D. 5.98×10^9 J

$g = \frac{Gm}{r^2}$

$r = \sqrt{\frac{Gm}{g}} = \sqrt{\frac{(6.67\times10^{-11})(5.98\times10^{24})}{0.233}}$

$= 4.137\times10^7\ m$

$a_c = g$

$\frac{v^2}{r} = g \qquad v = \sqrt{rg} = 3105\ m/s$

$E_k = \frac{1}{2}mv^2 = \underline{2.99\times10^9\ J}$

29. What minimum kinetic energy would a spacecraft of mass 1.2×10^4 kg need at the surface of the Earth so that it could escape to infinity?

A. 1.1×10^4 J
B. 1.2×10^5 J
C. 7.5×10^{11} J
D. An infinite amount

$r = \infty$
$E_{pf} = 0$
$E_{kf} = 0$

$E_{pi} = -\frac{Gm_1m_2}{r}$
$E_{ki} = ?$

$\Delta E_p = -\Delta E_k$

$\cancel{E_{pf}}^{0} - E_{pi} = -(\cancel{E_{kf}}^{0} - E_{ki})$

$-E_{pi} = E_{ki}$

$E_{ki} = -\left(-\frac{Gm_1m_2}{r_i}\right) = 7.50\times10^{11}\ J$

30. An object is located on the surface of a planet. The work required to remove this object from the planet's gravitational field depends on which combination of the following three variables: mass of the planet, mass of the object, and radius of the planet?

	MASS OF PLANET	MASS OF OBJECT	RADIUS OF PLANET
A.	Yes	Yes	Yes
B.	Yes	Yes	No
C.	Yes	No	Yes
D.	No	Yes	Yes

$W = \Delta E_p$

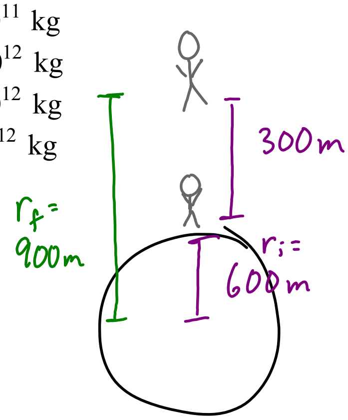
$= E_{pf} - E_{pi}$

$= Gm_1m_2\left(\frac{1}{r_i} - \frac{1}{r_f}\right)$

planet object radius of planet

31. A 120 kg astronaut stands on the surface of an asteroid of radius 600 m. The astronaut leaves the surface with 15 J of kinetic energy and reaches a maximum height of 300 m above the surface. What is the mass of the asteroid?

A. 5.6×10^{11} kg
B. 2.2×10^{12} kg
C. 3.4×10^{12} kg
D. 5.1×10^{12} kg



$\Delta E_k = -15\ J$

$\Delta E_p = 15\ J$

$\Delta E_p = Gm_1m_2\left(\frac{1}{r_i} - \frac{1}{r_f}\right)$

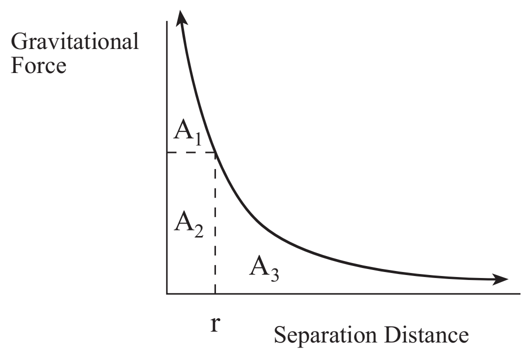
$m_1 = \frac{\Delta E_p}{Gm_2\left(\frac{1}{r_i} - \frac{1}{r_f}\right)} = 3.37\times10^{12}\ kg$

32. The work required to move an object in a planet's gravitational field can be determined graphically by calculating

A. the slope of a graph of gravitational force versus separation distance.
B. the area under a graph of gravitational force versus separation distance.
C. the slope of a graph of gravitational potential energy versus separation distance.
D. the area under a graph of gravitational potential energy versus separation distance.

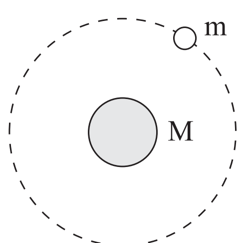
Work = $F \cdot d$ = Area

33. Which of the indicated areas of the graph represent the work needed to send an object from separation distance r to infinity?



A. $A_1 + A_2$
B. A_2
C. $A_2 + A_3$
D. A_3

34. Which of the following is a correct expression for the total energy of the orbiting satellite shown below?



$$E_T = E_K + E_P$$
$$= \frac{1}{2}mv^2 + \left(-\frac{Gm_1m_2}{r}\right)$$

A. $E_T = -G\dfrac{Mm}{r}$

B. $E_T = G\dfrac{Mm}{r}$

C. $E_T = \dfrac{1}{2}mv^2 + mgr$

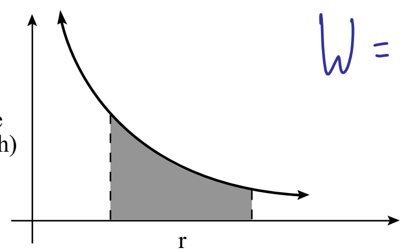
D. $E_T = \dfrac{1}{2}mv^2 + \left(-G\dfrac{Mm}{r}\right)$

35. A satellite orbits the earth with a kinetic energy of 2.0×10^{10} J . Its gravitational potential energy in this orbit is -4.0×10^{10} J. What is the total energy of the satellite?

A. -6.0×10^{10} J
B. -2.0×10^{10} J
C. 2.0×10^{10} J
D. 6.0×10^{10} J

$E_T = E_k + E_p$
$= -2.0 \times 10^{10}$ J

36. The shaded area shown in the diagram represents



$W = F \cdot d = \text{Area}$

A. the gravitational field strength near the earth.
B. the gain in kenitic energy.
C. the centripetal acceleration of an object orbiting the earth.
D. the work required to move an object in the earth's gravitational field.

37. A 2.0×10^3 kg satellite is in a circular orbit around the earth. The satellite has a speed of 3.6×10^3 m/s at an orbital radius of 3.1×10^7 m. What is the total energy of this orbiting satellite?

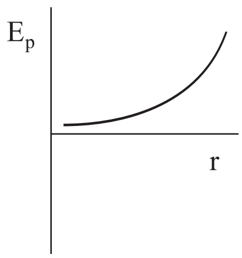
A. -2.6×10^{10} J
B. -1.3×10^{10} J
C. 1.3×10^{10} J
D. 3.9×10^{10} J

$E_T = E_k + E_p = 1.296 \times 10^{10} - 2.573 \times 10^{10}$
$= \underline{\underline{-1.3 \times 10^{10} \text{ J}}}$

$E_k = \frac{1}{2} m v^2$
$= \frac{1}{2}(2.0 \times 10^3)(3.6 \times 10^3)^2$
$= 1.296 \times 10^{10}$ J

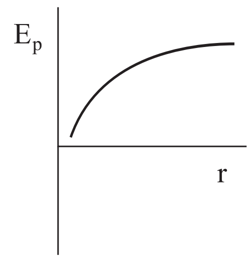
$E_p = -\frac{G m_1 m_2}{r}$
$= -\frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})(2.0 \times 10^3)}{3.1 \times 10^7}$
$= -2.573 \times 10^{10}$ J

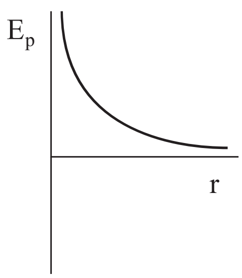
38. Which graph shows gravitational potential energy plotted as a function of distance r from the centre of the earth?

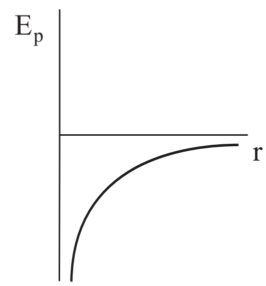
A.


$E_p = -\frac{Gm_1m_2}{r}$

$E_p \propto -\frac{1}{r}$

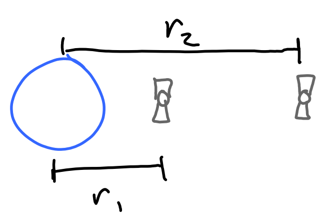
B.


C.


D.


39. A satellite is in a stable circular orbit around the earth. Another satellite in a stable circular orbit at a greater altitude must have

A. a smaller speed and a shorter period.
B. a smaller speed and a longer period.
C. a greater speed and a shorter period.
D. a greater speed and a longer period.



40. Which of the following could represent the kinetic energy, the gravitational potential energy and the total energy for an orbiting satellite in a stable circular orbit?

	KINETIC ENERGY	GRAVITATIONAL POTENTIAL ENERGY	TOTAL ENERGY
A.	40 000 J	- 80 000 J	- 40 000 J
B.	40 000 J	40 000 J	80 000 J
C.	-80 000 J	-40 000 J	-120 000 J
D.	80 000 J	- 40 000 J	40 000 J

since $r < \infty$ $E_p < 0$

satellite is in orbit $\therefore E_T < 0$

E_k always ≥ 0

$\therefore E_p < E_T$ (both negative)