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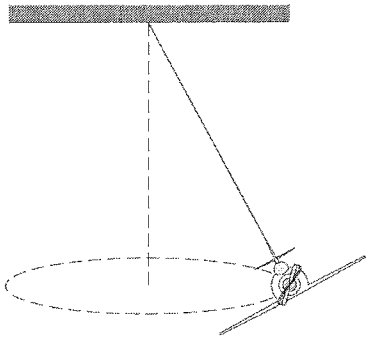
Name: _____

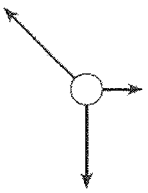
# Circular Motion and Universal Gravitation Review Package

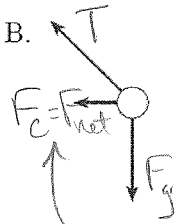
Key

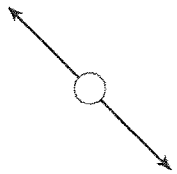
1. A small toy airplane suspended as shown below flies in a circular path.

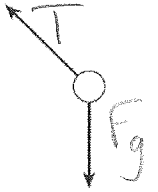


Which of the following free body diagrams best describes the forces acting on the airplane at the position shown?

A. 

B. 


C. 

D. 


this is the total of T + $F_g$

$F_c = \frac{m 4\pi^2 R}{T^2}$

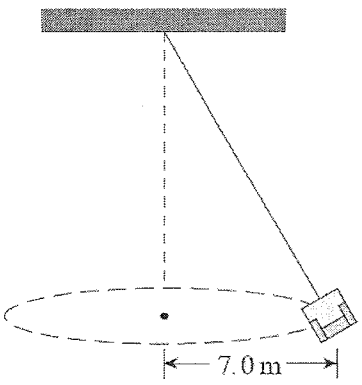
$= \frac{(1.5\text{kg})\,4\pi^2 (4\text{m})}{(3\text{s})^2}$

2. A 1.5 kg object is in uniform circular motion with a period of 3.0 s. If the radius of the path is 4.0 m, what is the centripetal force on the object?

$= 26\text{ N}$

3. An empty 12 kg swing-type ride at the fairgrounds has a kinetic energy of 480 J.

What is the centripetal force on the empty seat?




$E_k = \frac{1}{2}mv^2$

$480\text{J} = \frac{1}{2}(12)v^2$

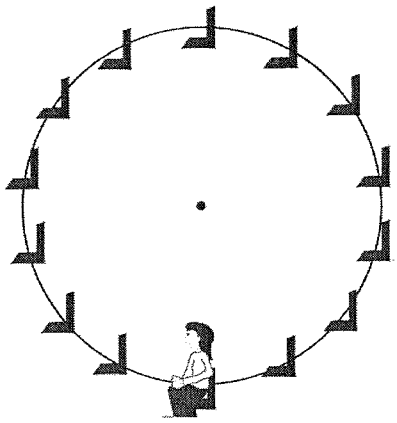
$v = 8.944\text{ m/s}$

$F_c = \frac{mv^2}{R} = \frac{(12\text{kg})(8.944\text{ m/s})^2}{7\text{m}}$

$= 137\text{ N}$

$= 1.4 \times 10^2\text{ N}$

4. A 75 kg person rides a Ferris wheel which is rotating uniformly. The centripetal force on the person is 45 N.



Top


$T = -F_N$

$F_N = -690$

$= 690\,N$

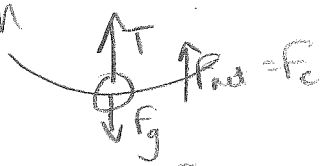
$F_c = T + F_g$

$T = F_c - F_g$

$= 45N - 75(9.8)$

$= -690\,N$

Bottom




$F_c = T - F_g$

$T = F_c + F_g$

$= 45N + 75(9.8)$

$= 780N$

$= 7.8 \times 10^2\,N$ ✓

What force does the seat exert on the rider at the top and at the bottom of the ride?

T

$T = F_N = 690N = 6.9 \times 10^2\,N$ ✓

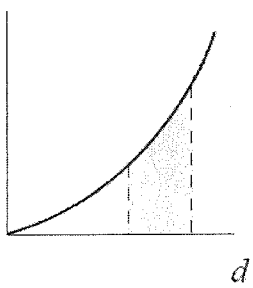
5. Which of the following illustrates the work required to move an object in a gravitational field?

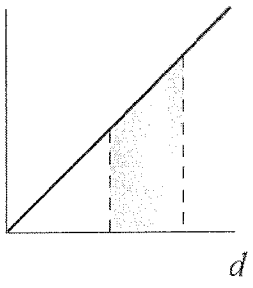
$\Delta E = Fd$

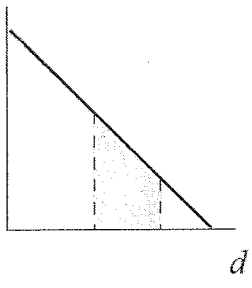
$F = \frac{GMm}{R^2}$

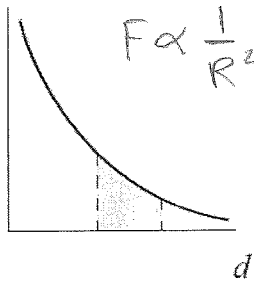
$F \propto \frac{1}{R^2}$

$\therefore E \propto \frac{1}{R^2}$

A. 


B. 


C. 


(D) 


$F \propto \frac{1}{R^2}$ ✓

6. A 1 500 kg satellite orbits the earth at 2 500 m/s. What is the satellite's centripetal acceleration?

(A) 0.098 m/s$^2$

B. 0.98 m/s$^2$

C. 9.8 m/s$^2$

D. $1.5 \times 10^2$ m/s$^2$

$a_c = \frac{V^2}{R}$

$= \frac{(2500\,m/s)^2}{6.38 \times 10^7\,m}$

$= 0.098\,m/s^2$

need r:

$F_c = F_g$

$\frac{mV^2}{R} = \frac{GMm}{R^2}$

$R = \frac{GM}{V^2}$

$= 6.38185 \times 10^7\,m$

$F_c = F_g$

$\frac{mv^2}{R} = \frac{GMm}{R^2}$

$v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{(6.67\times10^{-11})(5.98\times10^{24})}{(1.3\times10^{7}\ m)}} = 5.5\times10^{3}\ m/s$ from centre

7. A 1 500 kg satellite travels around the earth in a stable orbit with a radius of $1.3\times10^{7}$ m.
   a. What is the speed of the satellite in orbit?

   b. The satellite is then moved to a new orbit with twice the radius of the first orbit. The speed in this orbit is

   ☐ the same as
   ☒ less than ✓
   ☐ more than

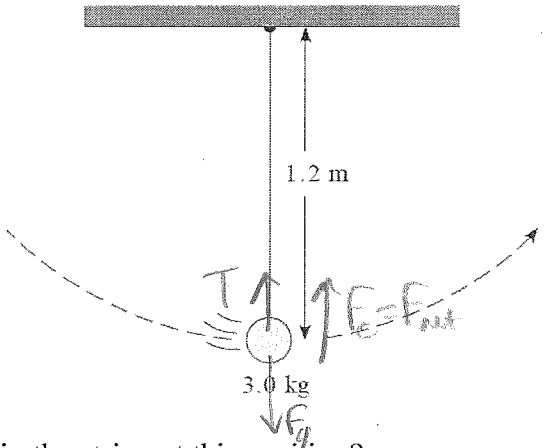
   $v = \sqrt{\frac{GM}{2R}} = \frac{1}{\sqrt{2}}\sqrt{\frac{GM}{R}}$ ✓

   as R increases, v decreases

   the speed of the first orbit.

   c. Using principles of physics, explain your answer to b).

8. A 1.2 m long pendulum reaches a speed of 4.0 m/s at the bottom of its swing.




$F_c = T - F_g$

$T = F_c + F_g$

$= \frac{mv^2}{R} + mg$

$= \frac{(3)(4)^2}{1.2} + 3(9.8)$

$= 69\ N$ ✓

T

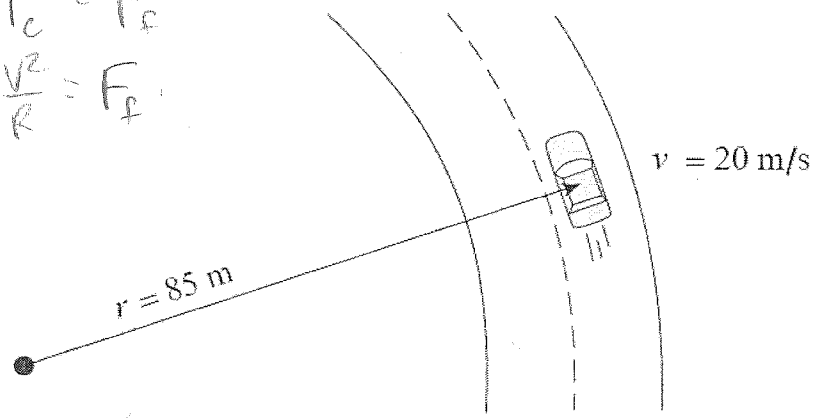
What is the tension in the string at this position?

9. A 1 200 kg car rounds a flat circular section of road at 20 m/s as shown in the diagram.

The coefficient of friction between the car tires and the road surface is 0.65. What minimum friction force is required for the car to follow this curve?

$F_c = F_f$

$\frac{mv^2}{R} = F_f$




$F_f = \frac{(1200)(20)^2}{85\ m}$

$= 5.6\times10^{3}\ N$ ✓

10. A satellite's orbit is maintained by

A. normal force.
B. frictional force.
C. centrifugal force.
(D.) gravitational force. ✓

$E_T = E_k + E_p = \frac{1}{2}mv^2 + \frac{GMm}{R} = -4.4\times10^{9}\ J$ ✓

$V: F_c = F_g$

$\frac{mv^2}{R} = \frac{GMm}{R^2} \rightarrow v = 7670\ m/s$

11. What is the gravitational field strength on the surface of a planetoid with a mass of $7.4\times10^{22}$ kg and a radius of $1.7\times10^{6}$ m? $g = \frac{GM_m}{R^2} = 1.7\ N/kg$ ✓

12. A 1 500 kg satellite is in a stable orbit at an altitude of $4.0\times10^{5}$ m above Earth's surface. What is the satellite's total energy in this orbit?

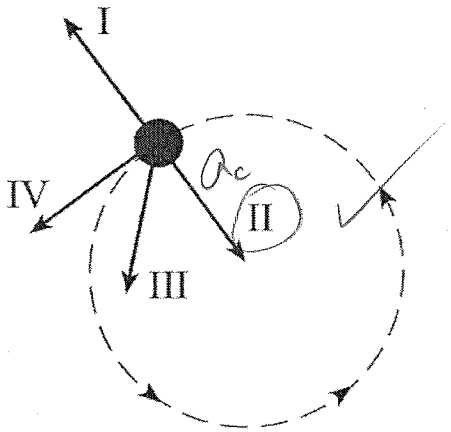
$F_c = F_g$

$ma_c = \frac{GMm}{R^2}$

13. The moon Titan orbits the planet Saturn with a period of $1.4\times10^{6}$ s. the average radius of this orbit is $1.2\times10^{9}$ m.
    a. What is Titan's centripetal acceleration? $a_c = \frac{4\pi^2 R}{T^2} = 0.02417\ m/s^2 = 2.4\times10^{-2}\ m/s^2$
    b. Calculate Saturn's mass.

$\rightarrow M = 5.2\times10^{26}\ kg$ ✓

14. A satellite moves in a circular path at a constant speed. Which vector in the diagram below best represents the satellite's acceleration?




15. A 2.5 kg object moves at a constant speed of 8.0 m/s in a 5.0 m radius circle. What is the object's acceleration? $a_c = \frac{v^2}{R} = \frac{8^2}{5} = 13\ m/s^2$ ✓

16. What is the magnitude of Earth's centripetal acceleration as it orbits the Sun?

$a_c = \frac{4\pi^2 R}{T^2} = \frac{4\pi^2 (1.5\times10^{11}\ m)}{(365\times24\times3600)^2} = 5.9\times10^{-3}\ m/s^2$ ✓

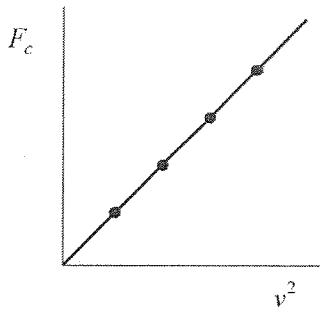
17. A satellite orbits Earth at a velocity of $3.1\times10^{3}$ m/s. What is the radius of this orbit?

$F_c = F_g$

$\frac{mv^2}{R} = \frac{GMm}{R^2}$

$R = \frac{GM}{v^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24}\ kg)}{(3.1\times10^{3}\ m/s)^2} = 4.2\times10^{7}\ m$

18. A student plots a graph of centripetal force $F_c$ versus the square of velocity $v^2$ for an object in uniform circular motion.




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

$F_c = \left(\frac{m}{R}\right)v^2$

What is the slope of this graph?

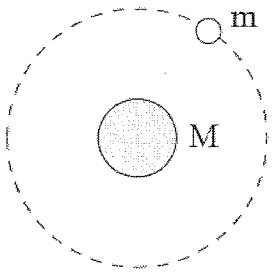
A. $\frac{m}{r}$ ✓

B. $\frac{r}{m}$

C. $\frac{4\pi^2 r}{T^2}$

D. $\frac{T^2}{4\pi^2 r}$

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




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

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

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

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

$E_K + E_P$

omit

20. An electron orbits the nucleus of an atom with velocity $v$. if this electron were to orbit the same nucleus with twice the previous orbital radius, its orbital velocity would now be

A. $\frac{v}{2}$

B. $\frac{v}{\sqrt{2}}$ ✓

C. $v$

D. $2v$

next unit

$F_c = F_e$

$\frac{mv^2}{R} = \frac{kQQ}{R^2}$

$v = \sqrt{\frac{kQ}{mR}}$

$v_2 = \frac{1}{\sqrt{2}}\sqrt{\frac{kQ}{mR}}$

$F_c = F_g$

$\frac{mv^2}{R} = \frac{GMm}{R^2}$

$v = 3.1\times10^3\ m/s$

21. A 1500kg satellite travels in a stable circular orbit around the earth. The orbit radius is $4.2\times10^7$ m. What is the satellite's kinetic energy?

$E_k = \frac{1}{2}mv^2 = 7.1\times10^9\ J$ ✓

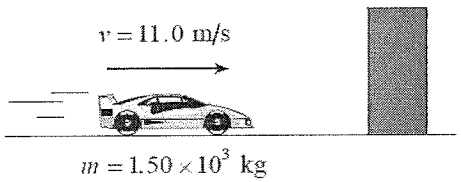
previous unit

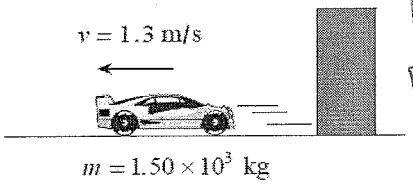
22. What is the minimum work done when a 65kg student climbs an 8.0m-high stairway in 12s?

$W = Fd = mgh = (65kg)(9.8N/kg)(8m) = 5.1\times10^3\ J$ ✓

(do anyway)

23. A $1.50\times10^3$ kg car travelling at 11.0m/s collides with a wall as shown.




$imp = \Delta p$

$Ft = p_f - p_i$

$F = \frac{1.3(1.5\times10^3) - -11(1.5\times10^3)}{1.7}$

$= +1.1\times10^4\ N$ [left] ✓

The car rebounds off the wall with a speed of 1.3m/s. If collision lasts for 1.7s, what force does the wall apply to the car during the collision?

24. A 1500kg car travelling at 25m/s collides with a 2500kg van stopped at traffic light. As a result of the collision the two vehicles become entangled. With what initial speed will the entangled mass ~~over~~ move off, and is the collision elastic or inelastic?

$E_{k_1} \neq E_{k_2}$ ✓

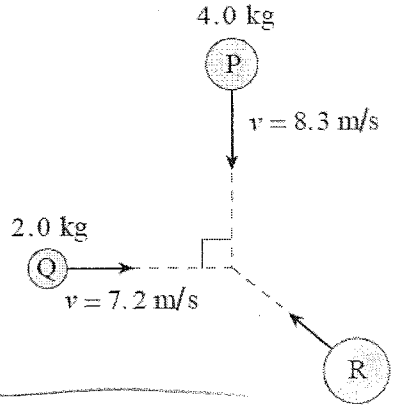
$p_1 + p_2 = p_{12}$

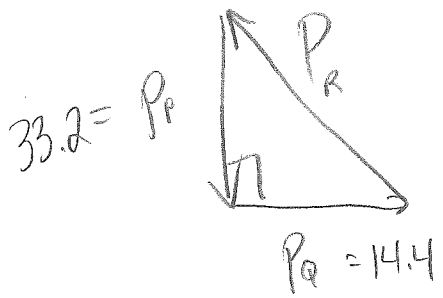
$1500\cdot25 + 2500(0) = 4000\,v_{12}$

$v_{12} = 9.4\ m/s$ ✓

25. Three objects travel as shown.

What is the magnitude of the momentum of the object R so that the combined masses remains stationary after they collide?



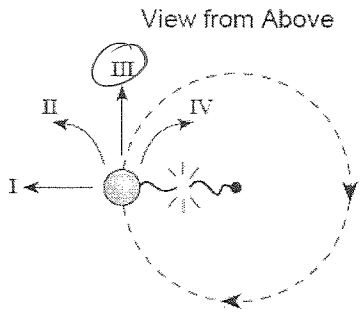

$p_R = \sqrt{33.2^2 + 14.4^2}$

$= 36\ kgm/s$ ✓

2nd day of review

uniform circular motion

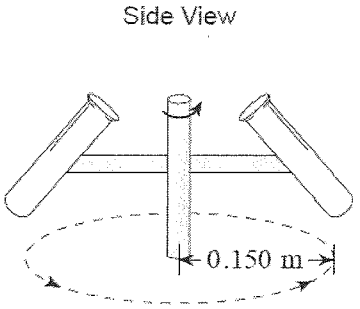
26. A ball attached to a string is swing in a horizontal circle.

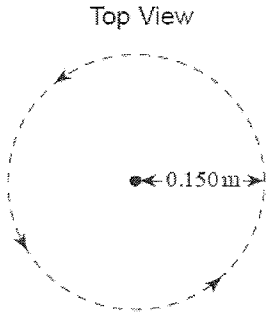



III ✓

Which path will the ball follow at the instant the string breaks?

27. A test tube in a centrifuge with a period of $1.20 \times 10^{-3}$s. The bottom of the test tube travels in a circular path of radius 0.150m.



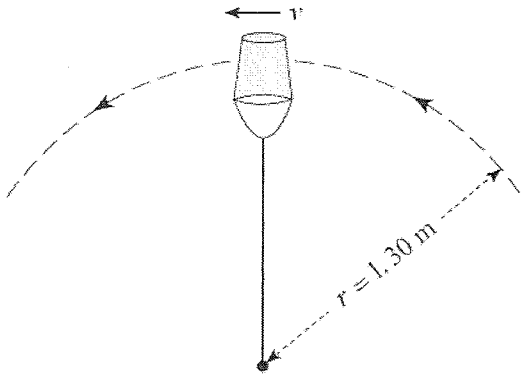

$F_c = \frac{m 4\pi^2 R}{T^2}$

$\frac{(2\times10^{-8})4\pi^2(0.15)}{(1.2\times10^{-3})^2}$

$= 8.22\times10^{-2}$N ✓

What is the centripetal force on a $2.00 \times 10^{-8}$kg amoeba at the bottom of the tube?

28. A physics student swings a 5.0kg pail of water in a vertical circle of radius 1.3m.




orbit so: $F_g = F_c$

$mg = m\frac{v^2}{R}$

$v = \sqrt{gR}$

$= \sqrt{9.8(1.3)}$

$= 3.6$m/s ✓

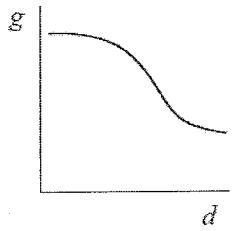
What is the minimum speed, v, at the top of the circle if the water is not to spill from the pail?

29. Which of the following is a correct graph for gravitational field strength, g, versus distance, d?

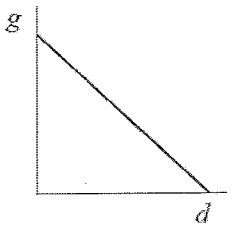
$mg = \frac{GMm}{R^2}$

$g \propto \frac{1}{R^2}$

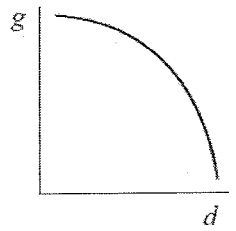
A.



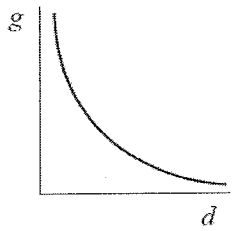

B.




C.




(D.) ✓




$F_c = F_g$

$\frac{m4\pi^2R}{T^2} = \frac{GMm}{R^2}$

30. Sputnik I, earth's first artificial satellite had an orbital period of 5760s. What was the average orbital radius of Sputnik's orbit?

$R = \sqrt[3]{\frac{T^2GM_\oplus}{4\pi^2}} = 6.95 \times 10^6 m$ ✓

$F_c = F_g$

$ma_c = \frac{GMm}{R^2} \rightarrow R = 4.1375 \times 10^7 m$, $a_c = \frac{v^2}{R} \rightarrow v = 3.105 \times 10^3 m/s$, $E_k = \frac{1}{2}mv^2 = 2.99 \times 10^9 J$ ✓

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

$a = \frac{\Delta v}{t}$

$= \frac{15}{4} = 3.8 m/s^2$ ✓

32. A 5.0kg rock dropped near the surface of Mars reaches a speed of 15m/s in 4.0s.

a) What is the acceleration due to gravity near the surface of Mars?

b) Mars has an average radius of 3.38x10$^6$m. What is the mass of Mars?

$mg = \frac{GMm}{R^2}$

$M = 6.4 \times 10^{23} kg$

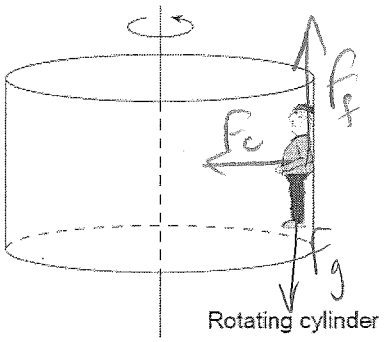
33. A 0.500kg ball is swung in a horizontal circle of radius 1.20m with a period of 1.25s. What is the centripetal force on the ball?

$F_c = m\frac{4\pi^2R}{T^2} = \frac{(0.5)4\pi^2(1.2)}{(1.25)^2} = 15.2 N$ ✓

34. A rock drops from a very high altitude toward 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 ✓ |

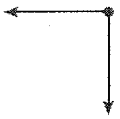
35. In a popular amusement park ride, a large cylinder is set in rotation. The floor then drops away leaving the rides suspended against the wall in vertical position as shown.

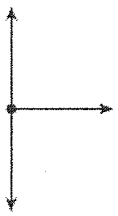



Which of the following is the correct free-body diagram for the person at the position shown?

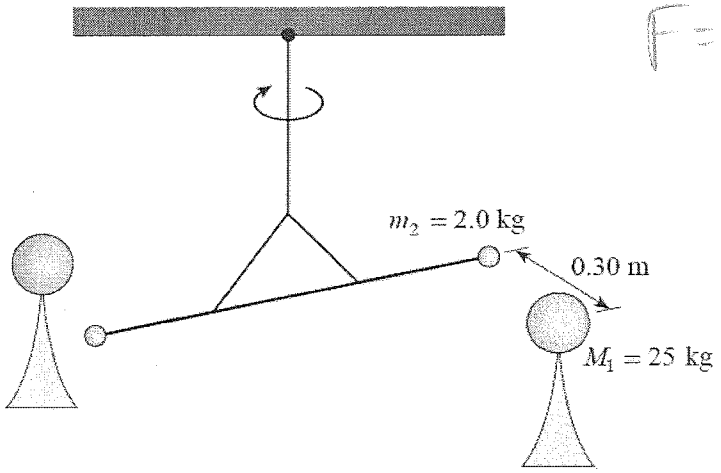
A. 

B. 

C. 

D. 

36. 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?




$F = \frac{GMm}{R^2}$

$= \frac{(6.67\times10^{-11})(2)(25)}{0.3^2}$

$= 3.7\times10^{-8}$ N ✓

37. A 1570 kg satellite orbits a planet in a circle of radius $5.94\times10^6$ m. Relative to zero at infinity the gravitational potential energy of this satellite is $-9.32\times10^{11}$ J. what is the mass of the planet?

$E_p = \frac{-GMm}{R}$

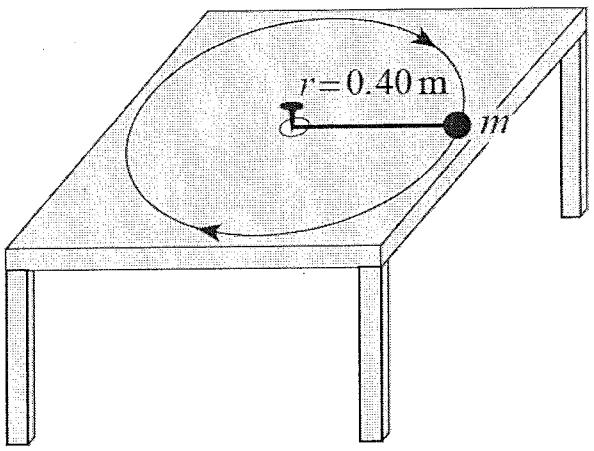
$M = \frac{-RE_p}{Gm} = 5.29\times10^{25}$ Kg ✓

38. An object is attached to a string that can withstand a maximum tension force of 6.3 N. The object travels in a circular path of radius 0.40 m with a period of 2.1s.

$F_c = \frac{m4\pi^2 R}{T^2}$

$m = \frac{F_c T^2}{R 4\pi^2}$

$= 1.8\ kg$ ✓





What is the maximum mass of the object?

$F_c = T - F_g$

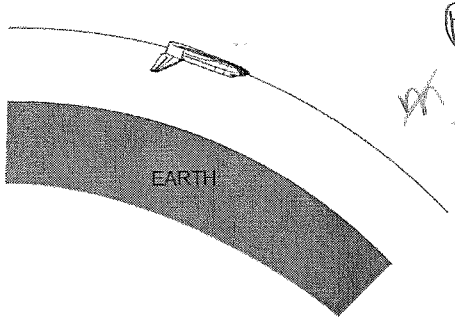
$T = F_c + F_g$

39. A 65 kg pilot in a stunt plane performs a vertical loop with a 700 m radius. The plane reaches a speed of 210m/s at the bottom of the loop. What is the upward force on the pilot at the bottom of the loop?

T

$= \frac{mv^2}{R} + mg = 4.7 \times 10^3\ N$ ✓

40. A space shuttle is placed in a circular orbit at an altitude of $3.00 \times 10^5$ m above Earth's surface. $+R_\oplus$




$F_c = F_g$

$\frac{mv^2}{R} = \frac{GMm}{R^2}$

$v = \sqrt{\frac{GM}{R}}$ ← $3\times10^5 + 6.38\times10^6$

$= 7.73 \times 10^3\ m/s$ ✓

a) What is the shuttle's orbital speed?

b) The space shuttle is then moved to a higher orbit in order to capture a satellite. The shuttle's speed in this new higher orbit will have to be

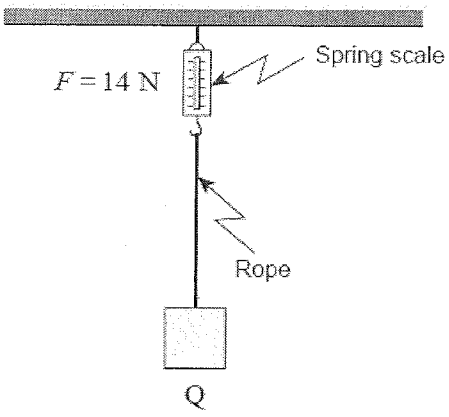
- ☐ greater than in the lower orbit.
- ☒ less than in the lower orbit.
- ☐ the same as in the lower orbit.

c) Using principles of physics, explain your answer to b).

$v \propto \frac{1}{\sqrt{R}}$ as R increases, v decreases

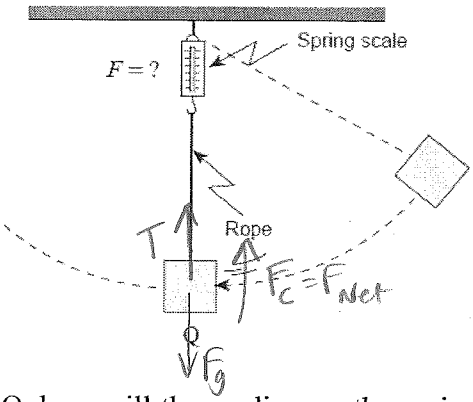
✓

41. A mass is suspended by a string attached to a spring scale that initially reads 14 N as shown in Diagram 1.




T = $F_g$ here
since $F_{net}$ (= $F_c$) = 0

The mass is pulled to the side and then released as shown in Diagram 2.




Spring scale will read higher since now must support $F_g$ (14N) and $F_c$

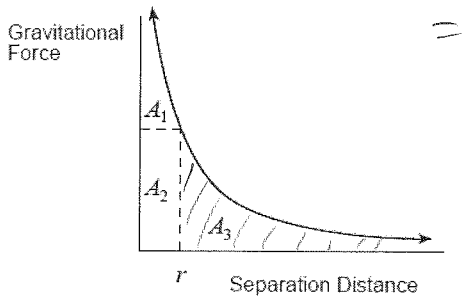
$F_c = T - F_g$ ✓

$T = F_c + F_g$ here

As the mass passes point Q, how will the reading on the spring scale compare to the previous value of 14 N? Using principles of physics, explain your answer.

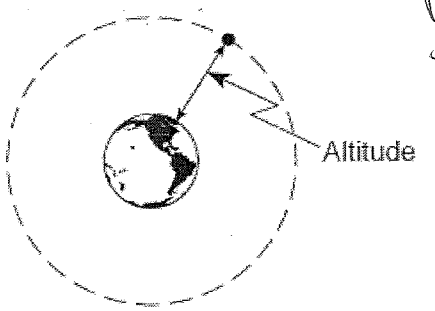
42. Which of the indicated areas of the graph represent the work needed to send an object from separation distance *r* to infinity?

= Fd
= Area




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

43. A satellite experiences a gravitational force of 228 N at an altitude of $4.0 \times 10^7$ m above Earth. What is the mass of this satellite?




$F_g = \frac{GMm}{R^2}$

$m = \frac{F_g R^2}{GM}$

$= \frac{228(4\times10^7 + 6.38\times10^6)^2}{(6.67\times10^{-11})(5.98\times10^{24})}$

$= 1230\ \text{kg} = 1.2\times10^3\ \text{kg}$ ✓

44. A $4.00 \times 10^3$ kg object is lifted from the earth's surface to an altitude of $3.2 \times 10^5$ m. How much work does this require?

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

$= -\frac{GMm}{R_f} + \frac{GMm}{R_i}$

$= -GMm\left(\frac{1}{R_f} - \frac{1}{R_i}\right)$

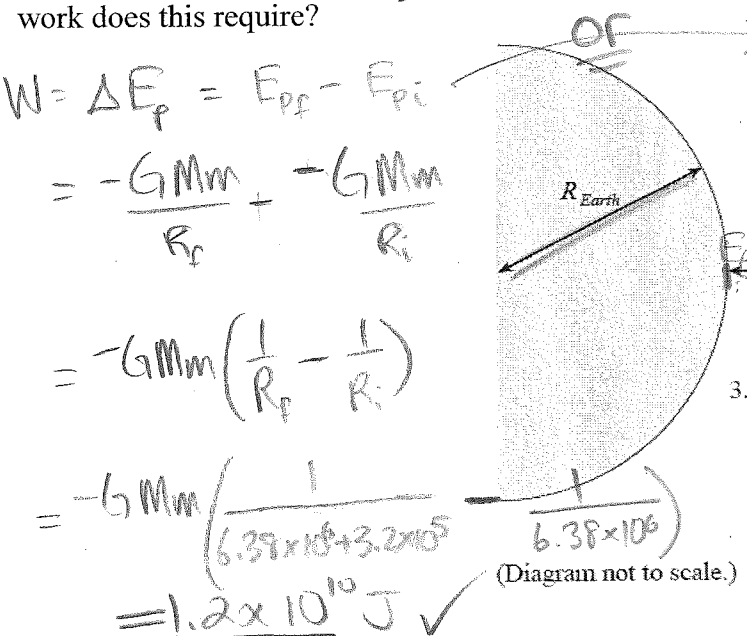
$= -GMm\left(\frac{1}{6.38\times10^6 + 3.2\times10^5} - \frac{1}{6.38\times10^6}\right)$

$= 1.2\times10^{10}\ \text{J}$ ✓

or $\rightarrow -\frac{GMm}{r_f} - \frac{GMm}{r_i}$

$= -\frac{GMm}{6.38\times10^6 + 3.2\times10^5} - \frac{GMm}{6.38\times10^6}$

$= 1.2\times10^{10}\ \text{J}$




(Diagram not to scale.)

45. 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.) $4F$ ✓

$F_{c1} = \frac{mv^2}{R}$

$F_{c2} = \frac{m(2v)^2}{R} = 4\frac{mv^2}{R} = 4F_{c1}$

46. The equation $E_p = mgh$, in which $g$ is 9.8m/s$^2$, cannot 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. ✓

$-101$

$F_c = \frac{m4\pi^2 R}{T^2} = \frac{52(4)\pi^2 12}{18^2} = 76.03\ N$

$F_g = mg = 52(9.8) = 509.6\ N$

47. The diagram shows a 52kg child riding on a Ferris wheel of radius 12m and period 18s. what force (normal force) does the seat exert on the child at the top and bottom of the ride?

$T = -F_N$

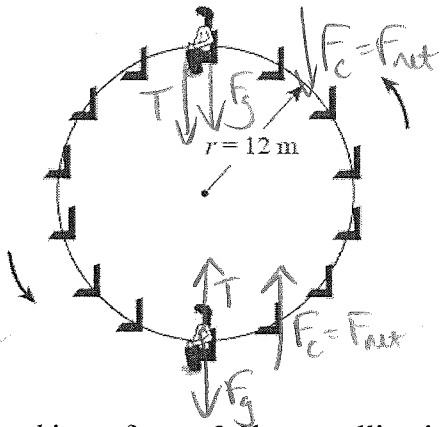
Top: $F_c = T + F_g$

$T = F_c - F_g$

$= 76.03 - 509.6$

$= -434\ N$

$F_N = 4.3\times10^2\ N$ ✓




Bottom: $(T = F_N)$

$F_c = T - F_g$

$T = F_c + F_g$

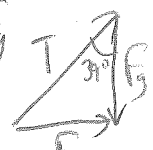
$= 76.03 + 509.6$

$= 5.9\times10^2\ N$ ✓

$= F_N$

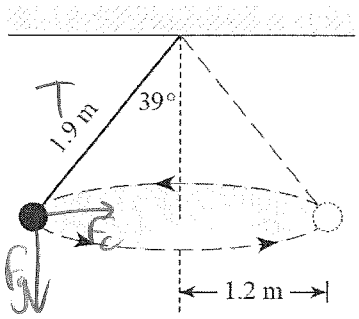
48. The diagram below shows an object of mass 3.0kg travelling in a circular path of radius 1.2m while suspended by a piece of string of length 1.9m. What is the centripetal force on the mass?

$F_c = T + F_g$




$\cos\theta = \frac{F_g}{T}$

$T = 37.83\ N$




$\tan\theta = \frac{F_c}{F_g}$

$F_c = 24\ N$ ✓

19b)


$F_{net} = ma = T - F_g$

$T = ma + F_g$

$= 421\ N$ ✓

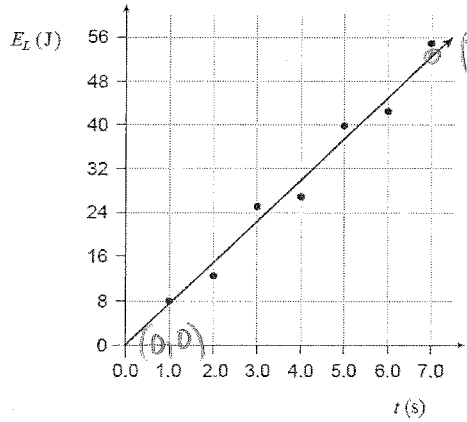
49. Mars has a mass of $6.37\times10^{23}$ kg and a radius of $3.43\times10^6$ m.

a) What is the gravitational field strength on its surface? $g = \frac{GM}{R^2} = 3.61\ N/kg$ ✓

b) What thrust force must the rocket engine of a Martian lander exert if the 87.5 kg spacecraft is to accelerate upwards at 1.20 m/s$^2$ as it leaves the surface of Mars?

50. The graph shows the light energy $E_L$ emitted by a light bulb versus time $t$.

previous unit




a) Find the power output of the bulb. $P = \frac{W}{t} = \text{slope} = \frac{49}{7} = 7W$ ✓

b) If the bulb is 20% efficient, find the power delivered to the bulb.

$\%\,eff = \frac{P_{out}}{P_{in}}$

$P_{in} = \frac{7W}{0.2} = 35W$ ✓