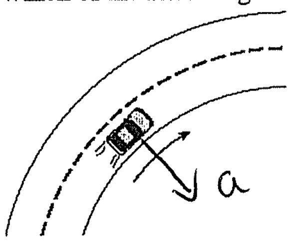
NAME: Key

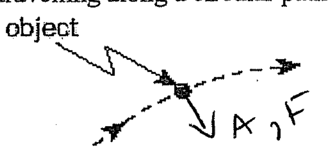
Circular Motion and Gravitation

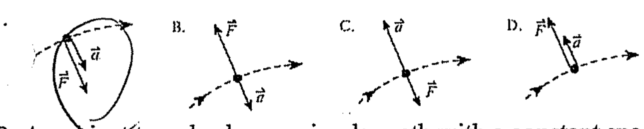
1. A car is moving at a constant speed around a circular curve. Which of the following best describes this situation?



	VELOCITY OF CAR	ACCELERATION OF CAR	NET FORCE ON CAR
A.	↗	↗	↖
B.	↗	↘	↖
(C.)	↗	↘	↘
D.	↘	↘	↘

2. Which vector diagram best represents the acceleration, a, and force, F, for an object travelling along a circular path?



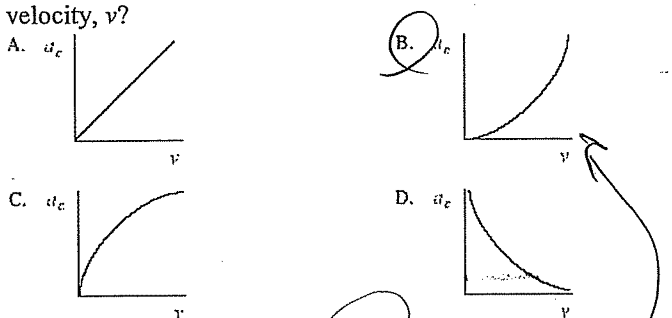


3. An object travels along a circular path with a constant speed v when a force F acts on it. How large a force is required for this object to travel along the same path at twice the speed ($2v$)?

A. 12 F
B. F
C. $2F$
(D.) $4F$

$F = \frac{mv^2}{r}$ $F_{new} = \frac{m(2v)^2}{r} = 4\frac{mv^2}{r} = 4F$

4. In a series of test runs, a car travels around the same circular track at different velocities. Which graph best shows the relationship between its centripetal acceleration, a_c, and its velocity, v?



$a = \frac{v^2}{r}$ quadratic

$v = \frac{d}{t} = \frac{2\pi r}{t} = 2.6 m/s$, $a = \frac{v^2}{r} = 1.4 m/s^2$

5. An athlete runs, at a constant speed, around a circle of radius 5.0 m in 12 s. What are the athlete's speed and acceleration?

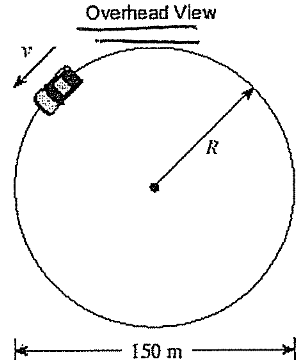
	SPEED	MAGNITUDE OF ACCELERATION
A.	0.42 m/s	$0.22 m/s^2$
B.	0.42 m/s	$1.4 m/s^2$
C.	2.6 m/s	$0.22 m/s^2$
(D.)	2.6 m/s	$1.4 m/s^2$

6. A car travels at 25 m/s along a horizontal curve of radius 450 m. What minimum coefficient of friction is necessary between its tires and the road in order for the car not to skid?

(A.) 0.14
B. 0.54
C. 0.72
D. 1.4

$F_f = F_c$ $\mu mg = \frac{mv^2}{r}$ $\mu = \frac{v^2}{g \cdot r}$

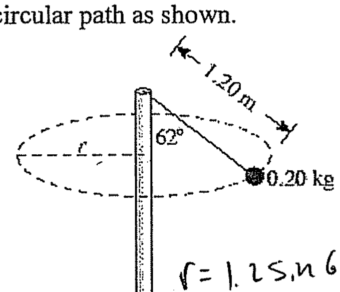
7. What is the maximum speed a car can travel along a level circular path (as shown below) if the coefficient of friction is 0.86?



A. 4 1. m/s
B. 8.0 m/s
(C.) 25 m/s
D. Depends on the mass of the car

$F_f = F_c$ $\mu mg = \frac{mv^2}{r}$ $v^2 = \mu g r$ $r = 75 m$

8. A 0.20 kg object moves at a constant speed in a horizontal circular path as shown.



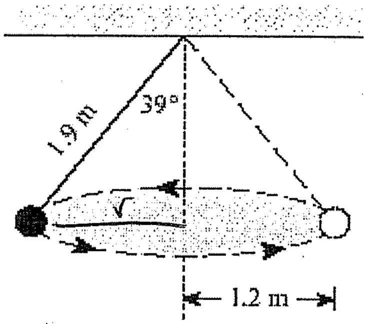
$r = 1.2 \sin 62° = 1.06 m$

$\tan 62° = \frac{mv^2/r}{mg}$ $v^2 = g \cdot r \tan 62°$

What is the speed of this object?

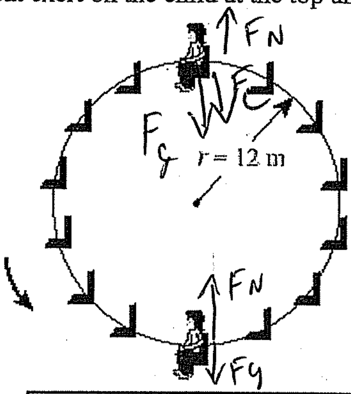
A. 2.3 m/s
B. 3.2 m/s
C. 3. 4 m/s
(D.) 4. 4 m/s

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



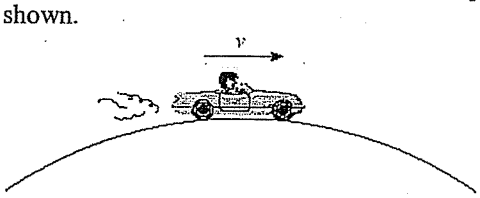
A. 19 N
B. 23 N
C. 24 N
D. 29 N

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

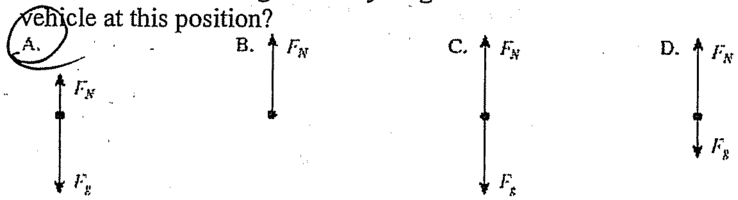


	TOP	BOTTOM
A.	76 N	76 N
B.	430 N	590 N
C.	510 N	510 N
D.	590 N	430 N

11. A vehicle and driver travel at constant speed over the hill as shown.



Which of the following free body diagrams best describes the vehicle at this position?



12. A frictionless 3.0 kg cart rolls down an incline, and then "loops the loop."

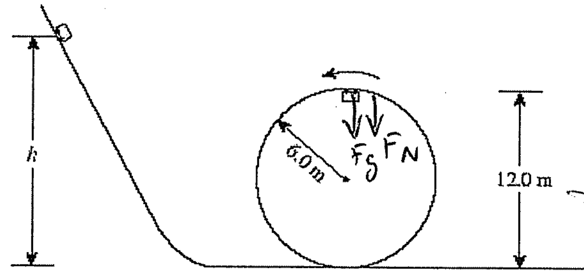


Diagram not to scale

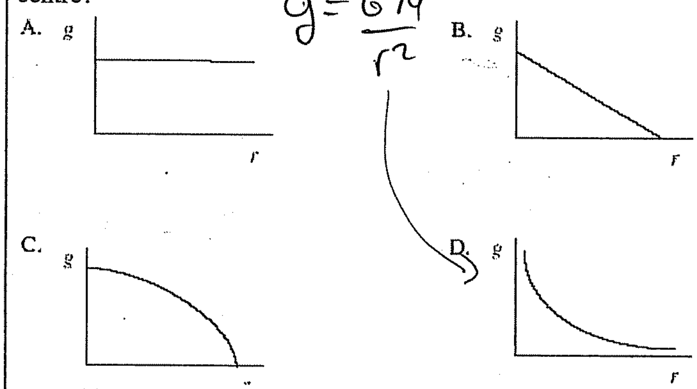
From what minimum height, h, should the cart be released so that it does not fall off the circular track?

A. 12.0 m
B. 15.0 m
C. 18.0 m
D. 24.0 m

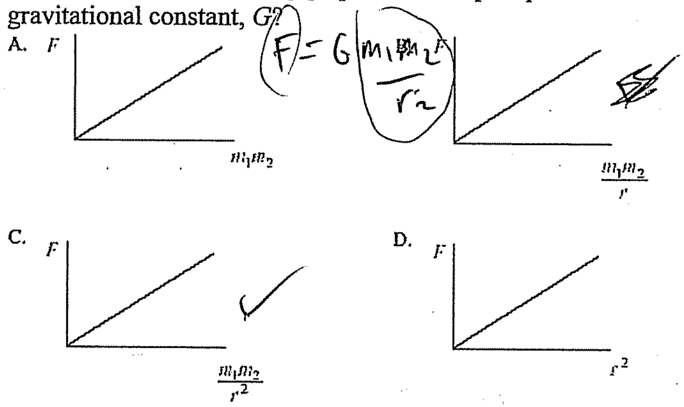
13. Tarzan, of mass 85 kg, holds on to a horizontal vine of length 8.0 m and jumps off a cliff. What is the tension force in the vine as Tarzan passes the lowest point of his circular path?

A. 830 N
B. 1 700 N
C. 2 500 N
D. 6 700 N

14. Which of the following best illustrates how the gravitational field strength of a body varies with distance r from the body's centre?



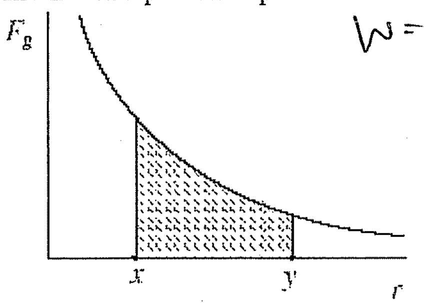
15. Which of the following graphs has a slope equal to the gravitational constant, G?



16. What is the gravitational force exerted on a 63 kg student by her 1400 kg car when their centers are 7.0 m apart?
A. 8.6×10^{11} N
B. 1.9×10^{9} N
C. 1.2×10^{7} N
D. 1.8×10^{3} N

17. A 75 kg astronaut stands on the surface of a planetoid with a mass of 5.8×10^{21} kg and a radius of 7.3×10^{5} m. What is the gravitational field strength at the surface?
A. 0.73 N kg
B. 1.6 N kg
C. 9.8 N kg
D. 54 N kg

18. As an object moves from x to y, the shaded area below the graph of gravitational force versus distance of separation represents



A. the gain in kinetic energy.
B. the energy released into space.
C. the work required to move the object.
D. the average force required to move the object.

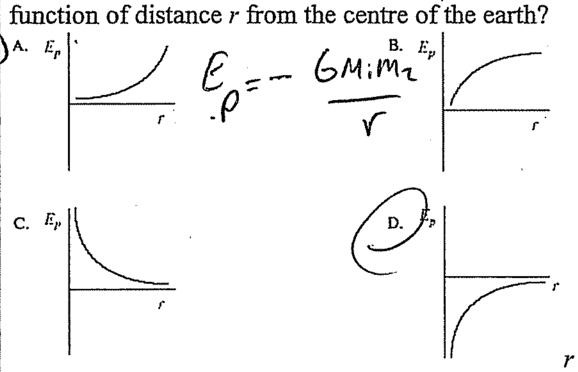
19. What is the change in gravitational potential energy as a 3500 kg object is raised vertically from the surface of the earth to a height of 8.2×10^{5} m?
A. 5.5×10^{7} J
B. 2.5×10^{10} J
C. 2.8×10^{10} J
D. 1.9×10^{11} J

20. How much work must be done to lift a 4.00×10^{4} kg object from Earth's surface to a height of 3.00×10^{5} m?
A. 1.12×10^{11} J
B. 1.18×10^{11} J
C. 2.39×10^{12} J
D. 5.32×10^{13} J

21. What minimum energy is required to raise a 1.7×10^{3} kg vehicle from the surface of the Moon to a height of 5.22×10^{6} m?
A. 1.6×10^{9} J
B. 3.6×10^{9} J
C. 4.8×10^{9} J
D. 1.4×10^{10} J

22. A 3500 kg piece of space debris is brought from an altitude of 2.1×10^{5} m back to the earth's surface. What is the change in potential energy of this space debris?
A. -7.0×10^{9} J
B. -7.2×10^{9} J
C. -2.1×10^{11} J
D. -2.2×10^{11} J

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



24. 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.

25. 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.

26. A satellite orbits the earth with a speed of 7.3×10^{3} m/s. What is the distance from the centre of the earth to this satellite?
A. 2.3×10^{5} m
B. 3.8×10^{6} m
C. 7.5×10^{6} m
D. 1.3×10^{7} m

27. 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

28. 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

$E_{before} = E_{after}$

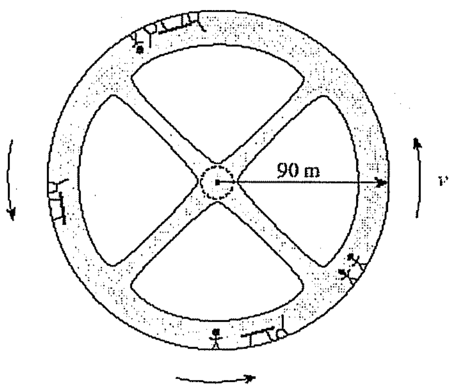
29. At an altitude of 1.3 x10^7 m above the surface of the earth an incoming meteor of mass 1. 0 x10^6 kg has a speed of 6.5 x10^3 m/s. What would be the speed just before impact with the surface of the earth? Ignore air resistance.

A. 9.1x10^3 m/s
B. 1.0 x10^4 m/s
C. 1.1x10^4 m/s
D. 1.7 x10^4 m/s

$E_T = E_k + E_p = E_k + E_p$

$\frac{1}{2}m_1 v_1^2 + \left(-\frac{GM_eM_1}{r_e + 1.3\times10^7}\right) = \frac{1}{2}m_1 v_f^2 + \left(-\frac{GM_eM_1}{r_e}\right)$

30. A space station of radius 90 m is rotating to simulate a gravitational field.



a) What is the period of the space station's rotation so that a 70 kg astronaut will experience a normal force by the outer wall equal to 60% of his weight on the surface of the earth?

$F_N = F_c = .6(F_g)$ $\qquad T = 24.6\ s$

$\frac{m4\pi^2 r}{T^2} = .6\,m(9.8)$

$T^2 = \frac{4\pi^2(90)}{(.6)(9.8)} = 604$

b) What would be the effect experienced by the astronaut if the space station rotated faster so that the period of rotation was decreased? Explain your predicted effect.

Smaller T → larger F_N, Feel heavier

31. A 720 kg communication satellite is in synchronous orbit around the planet Mars. This synchronous orbit matches the period of rotation so that the satellite appears to be stationary over a position on the equator of Mars. What is the orbital radius of this satellite?

Planetary Data for Mars
Mass: 6. 42 x10^{23} kg
Period of rotation: 8.86 x10^4 s

$F_g = F_c$

$\frac{GM_m m_o}{r^2} = \frac{m4\pi^2 r}{T^2}$

$r^3 = \frac{GM_m T^2}{4\pi^2} = 8.5\times10^{21}$

$r = 2.0\times10^7\ m$

32. What minimum energy is required to take a stationary 3.5 x10^3 kg satellite from the surface of the Earth and put it into a circular orbit with a radius of 6.88 x10^6 m and an orbital speed of 7.61x10^3 m/s? (Ignore Earth's rotation.)

$W = \Delta E = E_f - E_o$

$= (E_k + E_p) - (E_p)$

$= \frac{1}{2}M_s v^2 + \left(-\frac{GM_eM_s}{6.88\times10^6}\right) - \left(-\frac{GM_eM_s}{r_e}\right)$

$= 1.01\times10^{11}\ J - 2.03\times10^{11}\ J + 2.19\times10^{11}\ J$

$= 1.17\times10^{11}\ J$

33. An 884 kg satellite in orbit around a planet has a gravitational potential energy of 5. 44 x10^{10} J. The orbital radius of the satellite is 8.52 x10^{6} m and its speed is 7.84 x10^{3} m/s.

What is the mass of the planet?

$$E_p = -\frac{G M_p M_o}{r}$$

~~$r = \frac{-G(8.52\times10^6)(884)}{-5.44\times10^{10}}$~~

$$M_p = \frac{E_p \cdot r}{G M_o}$$

$$M_p = 7.86\times10^{24}$$

b) What is the kinetic energy of the satellite?

$$\frac{1}{2} M_s V^2 = 2.7\times10^{10}\ J$$

34. A spacecraft of mass 470 kg rests on the surface of an asteroid of radius 1 400 m and mass 2.0 ×10^{12} kg. How much energy must be expended so that the spacecraft may rise to a height of 2 800 m above the surface of the asteroid?

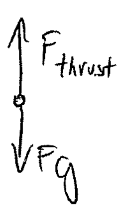
$$\Delta E_p = E_f - E_o$$

$$= -\frac{G M_a M_s}{4200\,m} - -\frac{G M_a M_s}{1400\,m}$$

a) Mars has a mass of 6.37 x 10^{23} kg and a radius of 3.43 x10^{6} m. What is the gravitational field strength on its surface?

$$g = \frac{G M_p}{r_p^2} = 3.61\ N/kg$$

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?



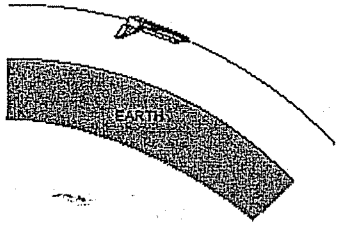
$$F_{net} = F_T - F_g$$

$$F_T = F_{net} + F_g$$

$$= (87.5)(1.2) + (87.5)(3.61)$$

$$= 421\ N$$

36. A space shuttle is placed in a circular orbit at an altitude of 3.00 x 10^5 m **above** Earth's surface.

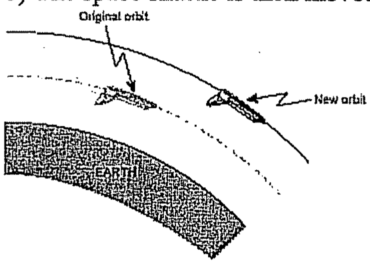


a) What is the shuttle's orbital speed?

$$F_g = F_c$$

$$\frac{G M_e M_s}{(r_e + 3\times10^5)^2} = \frac{M_s v^2}{(r_e + 3\times10^5)} \qquad v^2 = \frac{G M_e}{6.68\times10^6 m}$$

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.
- [x] less than in the lower orbit.
- [ ] the same as in the lower orbit.

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

Velocity is proportional to $\frac{1}{\sqrt{r}}$

37. A 5.0 kg rock dropped near the surface of Mars reaches a speed of 15 m/s in 4.0 s.
a) What is the acceleration due to gravity near the surface of Mars?

$$V_f = V_0 + at$$

$$15 = 0 + a(4)$$

$$a = \frac{15}{4} = 3.75 m/s$$

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

$$g = \frac{G M_m}{r^2} = 3.75 N/kg$$

$$M_m = \frac{(3.75)(3.38\times10^6)^2}{G} = 6.42\times10^{23} kg$$

Answers:

1. C	9. C	17. A	25. B	31. 2.0x10^7 m	36. 7.73x10^3 m/s, less than..., v proportional to √r
2. A	10. B	18. C	26. C	32. 1.17x10^{11} J	37. 3.75 m/s^2, 6.42x10^{23} kg
3. D	11. A	19. B	27. B	33. 7.86x10^{24} kg, 2.7x10^{10} J	
4. B	12. B	20. A	28. A	34. 30 J	
5. D	13. C	21. B	29. C	35. 3.61 N/kg, 421 N	
6. A	14. D	22. A	30. 24.6 s, faster, less T, more Fc, feel heavier		
7. C	15. C	23. D			
8. D	16. C	24. D			