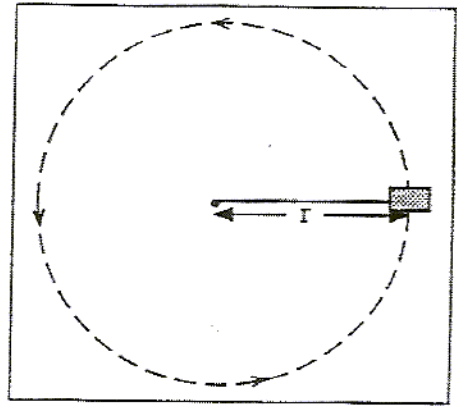
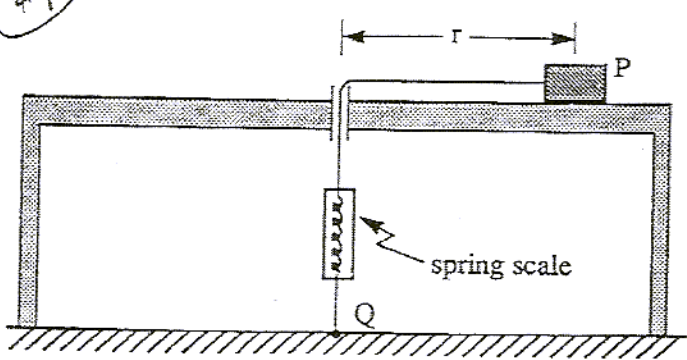


Circular Motion & Gravitation

6/93
 4. A puck P is connected by a cord and a spring scale to point Q, through a frictionless tube set in the centre of a horizontal frictionless table, as shown below. When the puck is set into uniform circular motion with a period of 2.6 s and a radius of 0.16 m, the spring scale reads a tension of 0.24 N.

#1



$$\left. \begin{aligned} F_c &= \frac{mv^2}{r} \\ v &= \frac{2\pi r}{T} \end{aligned} \right\} F_c = \frac{m4\pi^2 r}{T^2} \Rightarrow 0.24 \text{ N} = \frac{m4\pi^2 (0.16)}{(2.6\text{ s})^2} \quad \text{(View from above)}$$

(a) What is the mass of the puck?

$m = 0.26 \text{ kg}$

(b) When the period of rotation is shortened to 2.2 s, the spring stretches to read 0.52 N. What is the new radius of revolution?

$$F_c = \frac{m4\pi^2 r}{T^2} \Rightarrow 0.52 \text{ N} = \frac{(0.26)(4)(\pi^2)(r)}{(2.2)^2} \Rightarrow r = 0.25 \text{ m}$$

6/93
 7. Explain how it is possible to have a centripetal acceleration when an object is travelling at a constant speed in a circle.

#2

The speed is constant, however, the velocity is constantly changing because the direction is changing. Acceleration = change in velocity. \therefore Centripetal acceleration is possible.

11. Which one of the following gives correct units for gravitational field strength?

6/93

- A. kg
- B. N
- C. J/kg
- D. N/kg

#3

See solution to #33

12. Two satellites orbit a planet. One of the satellites has an orbital radius of 2.3×10^6 m and a period of 7.6×10^4 s. The other satellite has an orbital period of 1.3×10^5 s. What is the radius of orbit for this second satellite?

6/93

- A. 1.3×10^6 m
- B. 3.3×10^6 m
- C. 3.9×10^6 m
- D. 5.1×10^6 m

#4

$$\frac{r^3}{T^2} = \frac{r^3}{T^2} \quad \frac{(2.3 \times 10^6)^3}{(7.6 \times 10^4)^2} = \frac{r^3}{(1.3 \times 10^5)^2}$$
$$r = 3.3 \times 10^6 \text{ m}$$

13. A 1.60×10^4 kg satellite orbits a planet in a circle of radius 2.24×10^6 m. Relative to zero at infinity, the gravitational potential energy of this satellite is -5.80×10^9 J. What is the mass of the planet?

5/93

- A. 1.22×10^{22} kg
- B. 1.95×10^{26} kg
- C. 2.73×10^{28} kg
- D. 4.36×10^{22} kg

#5

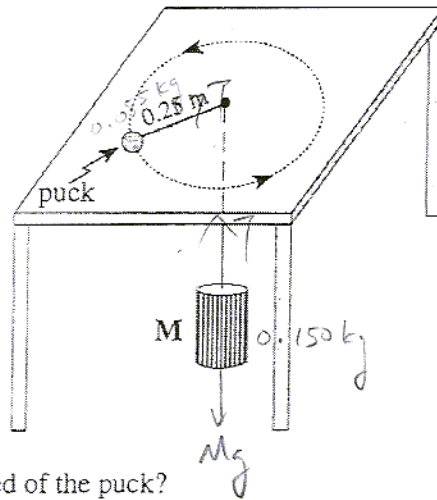
$$E_p = - \frac{GmM}{r}$$
$$-5.80 \times 10^9 \text{ J} = \frac{-6.67 \times 10^{-11} \times 1.6 \times 10^4 \times M}{2.24 \times 10^6}$$

$$M = 1.22 \times 10^{22} \text{ kg}$$

1/94

13. A 0.055 kg puck is attached to a 0.150 kg mass **M** by a cord that passes through a hole in a frictionless table, as shown. The puck travels in a circular path of radius 0.25 m.

#6



What is the speed of the puck?

- A. 0.61 m/s
 B. 0.95 m/s
 C. 1.6 m/s
 D. 2.6 m/s

$$Mg = F_c$$

$$F_c = mac$$

$$Mg = mac$$

$$a_c = \frac{v^2}{r}$$

$$(0.150 \text{ kg})(9.8 \text{ m/s}^2) = (0.055 \text{ kg}) \frac{v^2}{0.25 \text{ m}}$$

$$v^2 = 6.68 \text{ m}^2/\text{s}^2$$

$$v = 2.6 \text{ m/s}$$

$$0.150 \times 9.8 = \frac{mv^2}{r}$$

$$0.150 \times 9.8 = \frac{0.055 v^2}{0.25}$$

1/94 4. A satellite travels in a circular orbit at a height of one Earth radius above the surface of the Earth. What is the satellite's orbital period? (7 marks)

#7
$$T = \frac{2\pi r^{\frac{3}{2}}}{\sqrt{GM}} = \frac{2\pi(2 \times 6.38 \times 10^6)^{\frac{3}{2}}}{\sqrt{(6.67 \times 10^{-11}) \times (5.98 \times 10^{24})}} = 1.4 \times 10^4 \text{ s} \times \frac{\text{min}}{60 \text{ s}} \times \frac{\text{hr}}{60 \text{ min}} = 4 \text{ hr}$$

1/94 12. What is the centripetal acceleration of the Moon in its orbit around the Earth?

- #8
 A. 0 m/s²
 B. $2.7 \times 10^{-3} \text{ m/s}^2$
 C. 1.6 m/s²
 D. 9.8 m/s²

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

$$a_c = \frac{4\pi^2 (3.84 \times 10^8)}{\left(\frac{2\pi (3.84 \times 10^8)^{\frac{3}{2}}}{\sqrt{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}}\right)^2} = 2.7 \times 10^{-3} \text{ m/s}^2$$

1/94 11. 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?

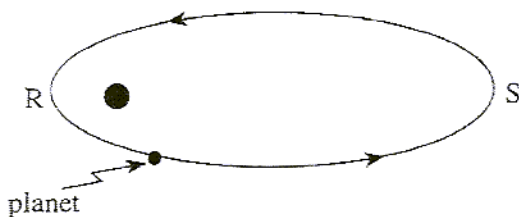
- #9
 A. 0.66 years
 B. 1.5 years
 C. 1.9 years
 D. 3.5 years

$$T = \frac{2\pi r^{\frac{3}{2}}}{\sqrt{GM}} = \frac{2\pi (1.52 \times 1.50 \times 10^{11})^{\frac{3}{2}}}{\sqrt{6.67 \times 10^{-11} \times 1.98 \times 10^{30}}} = 5.95 \times 10^7 \text{ s}$$

$$5.95 \times 10^7 \text{ s} \times \frac{\text{min}}{60 \text{ s}} \times \frac{\text{hr}}{60 \text{ min}} \times \frac{\text{day}}{24 \text{ hr}} \times \frac{\text{yr}}{365 \text{ days}} = 1.9 \text{ yrs}$$

1/94 9. A planet is in orbit as shown in the diagram below.

#10



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.

As orbital radius increases, i.e. from R to S, $P_E = -\frac{GMm}{r}$, therefore there is less negative, and so the potential energy is greater.

1/94 10. The gravitational force of attraction between the Sun and an asteroid travelling in an orbit of radius $4.14 \times 10^{11} \text{ m}$ is $4.62 \times 10^{17} \text{ N}$. What is the mass of the asteroid?

#11

- A. $1.45 \times 10^9 \text{ kg}$
 B. $4.08 \times 10^9 \text{ kg}$
 C. $4.71 \times 10^{16} \text{ kg}$
 D. $6.00 \times 10^{20} \text{ kg}$

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

$$4.62 \times 10^{17} = \frac{6.67 \times 10^{-11} \times m \times 1.98 \times 10^{30}}{(4.14 \times 10^{11})^2}$$

$$m = 6.00 \times 10^{20} \text{ kg}$$

- 6/94 11. A child is riding on a merry-go-round which is rotating at a constant rate. Which of the following describes the child's speed, velocity, and magnitude of acceleration?

#12

	SPEED	VELOCITY	MAGNITUDE OF ACCELERATION
A.	constant	constant	constant
B.	constant	changing	constant
C.	changing	constant	changing
D.	changing	changing	changing

- 6/94 12. A satellite is travelling around the Earth in an orbit of radius 4.47×10^7 m. What is the mass of the satellite if it experiences a gravitational force of 3.00×10^3 N?

#13

$$F = \frac{GMm}{r^2} \quad 3.00 \times 10^3 \text{ N} = \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})m}{(4.47 \times 10^7)^2}$$

$$m = 1.5 \times 10^4 \text{ kg}$$

A. 4.37×10^1 kg
 B. 3.06×10^2 kg
 C. 2.14×10^3 kg
 D. 1.50×10^4 kg

- 6/94 13. A circular space station of radius 120 m is to be rotated so that its astronauts experience an effect similar to that of a gravitational field. If the field is to be 5.0 m/s^2 at this radius, what should be the period of rotation of the space station?

#14

$$F_g = F_c \quad v = 24.49 \text{ m/s}$$

$$m \cdot 5.0 = \frac{mv^2}{r} \quad v = \frac{2\pi r}{T}$$

$$5.0 = \frac{v^2}{120} \quad T = \frac{2\pi r}{v}$$

$$5.0 = \frac{v^2}{120} \quad = \frac{2\pi \cdot 120}{24.49} = 3.1 \times 10^1 \text{ s}$$

A. 3.2×10^{-1} s
 B. 3.1×10^1 s
 C. 5.1×10^3 s
 D. 8.6×10^4 s

- 6/94 14. 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?

#15

$$F_s = F_c \quad v = 15 \text{ m/s}$$

$$15g = \frac{mv^2}{r} \quad v = 8.4 \text{ m/s}$$

$$15 \cdot 9.8 = \frac{15^2}{40} \quad g = \frac{8.4^2}{40} \times \frac{1}{0.574}$$

$$u_s = 0.574 \quad g = 3.1 \text{ m/s}^2$$

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

- 6/94 4. A 900 kg satellite which is travelling at 8600 m/s around a planet of mass 8.1×10^{25} kg has an orbital radius of 7.3×10^7 m. What is the total orbital energy of this satellite relative to infinity?

#16

$$E_p = -\frac{GMm}{r} = -\frac{(6.67 \times 10^{-11})(8.1 \times 10^{25})(900)}{7.3 \times 10^7}$$

$$T_E = \frac{1}{2}P_E = \frac{1}{2} \left(-\frac{GMm}{r} \right) = \frac{1}{2} \left(-\frac{(6.67 \times 10^{-11})(8.1 \times 10^{25})(900)}{7.3 \times 10^7} \right) = -3.33 \times 10^{10} \text{ J}$$

OR $T_E = P_E + K_E = -\frac{GMm}{r} + \frac{1}{2}mv^2 = -3.33 \times 10^{10} \text{ J}$

$F_g = \frac{GMm}{r^2}$ $F_g \propto \frac{1}{r^2}$ given that M, m are constant

1/95

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

#17

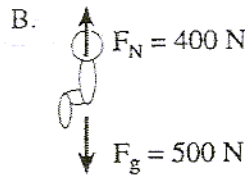
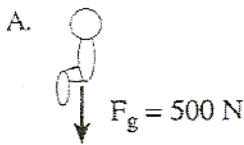
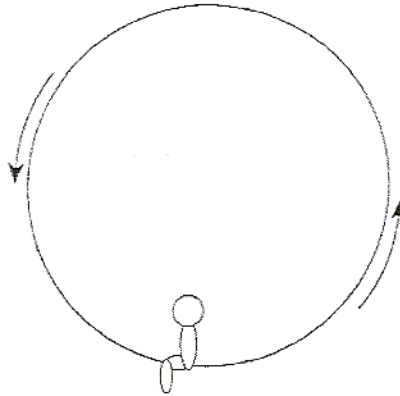
- A. the slope of a graph of gravitational force versus separation distance.
- B. the area under a graph of gravitational force versus separation distance.
- C. the slope of a graph of gravitational potential energy versus separation distance.
- D. the area under a graph of gravitational potential energy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



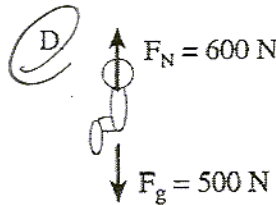
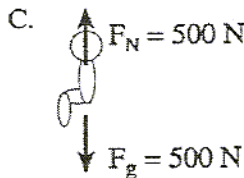
1/95

#18

13. A 500 N child travels in a circular path on a ferris wheel. Which free body diagram best shows the forces which could act on the child as she passes the lowest point?



since it will start to go up, therefore $F_N > F_g$



1/95

14. 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?

#19

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

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

$\frac{GM}{r} = v^2$

$r = \frac{GM}{v^2} = 7.934601665 \text{ m}$

Infinity $KE = PE$

15. 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?

1/95

#20

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

$$PE = -\frac{GMm}{r}$$

$$0 = -\frac{(6.67 \cdot 10^{-11})(1.2 \cdot 10^4)(5.98 \cdot 10^{24})}{6.38 \cdot 10^6}$$

$$= 7.5 \cdot 10^{11} \text{ J}$$

1/95

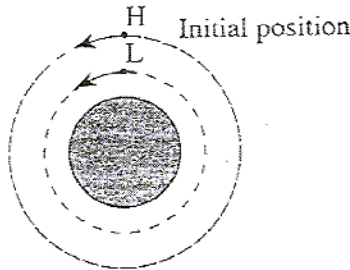
#21

4. a) A satellite is placed in circular orbit at an altitude of 4.8×10^5 m above Earth's surface. What is the satellite's orbital period? (5 marks)

$$\frac{GM}{r^2} = \frac{v^2}{r} \quad \left(\frac{GM_E}{(r_E + 48 \cdot 10^5)} \right) = \frac{v^2}{r}$$

$$v = 7626$$

- b) (i) As shown in the diagram below, two satellites pass over the same point on Earth's surface. Satellite H is in a higher orbit than satellite L.



Which satellite, H or L, completes one orbit first? (Circle one) (1 mark)

- A. satellite H
 B. satellite L

- (ii) Using principles of physics, explain your answer. (3 marks)

Sattelite L orbits closer to the Earth. According to $v = \sqrt{\frac{GM}{r}}$, the sattelite with the smaller orbital radius has a larger velocity and completes its orbit quicker. This is sattelite "L".

6/95 11. Find the gravitational force of attraction between a 75 kg physics student and her 1 500 kg car when their centres are 10 m apart.

#22

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

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

$$= \frac{(6.67 \times 10^{-11})(1500)(75)}{10^2} = 7.50 \times 10^{-8} \text{ N.}$$

6/95 10. A satellite is placed in orbit around the Sun. The orbital radius of the satellite is twice the orbital radius of the Earth. What is the orbital period of this satellite?

#23

- A. 0.50 Earth years
- B. 1.6 Earth years
- C. 2.0 Earth years
- D. 2.8 Earth years

$$T = \frac{4\pi^2 r^{3/2}}{\sqrt{GM}} \quad T \propto r^{3/2}$$

As T is directly proportional to r,

$$[T(2^{3/2})] \times 1 \text{ year} = \text{orbital period}$$

$$2^{3/2} = 2.83 \text{ years.}$$

6/95 9. An object travels along a path at constant speed. There is a constant net force acting on the object that remains perpendicular to the direction of the motion. Describe the path of the object.

#24

A. linear

B. circular



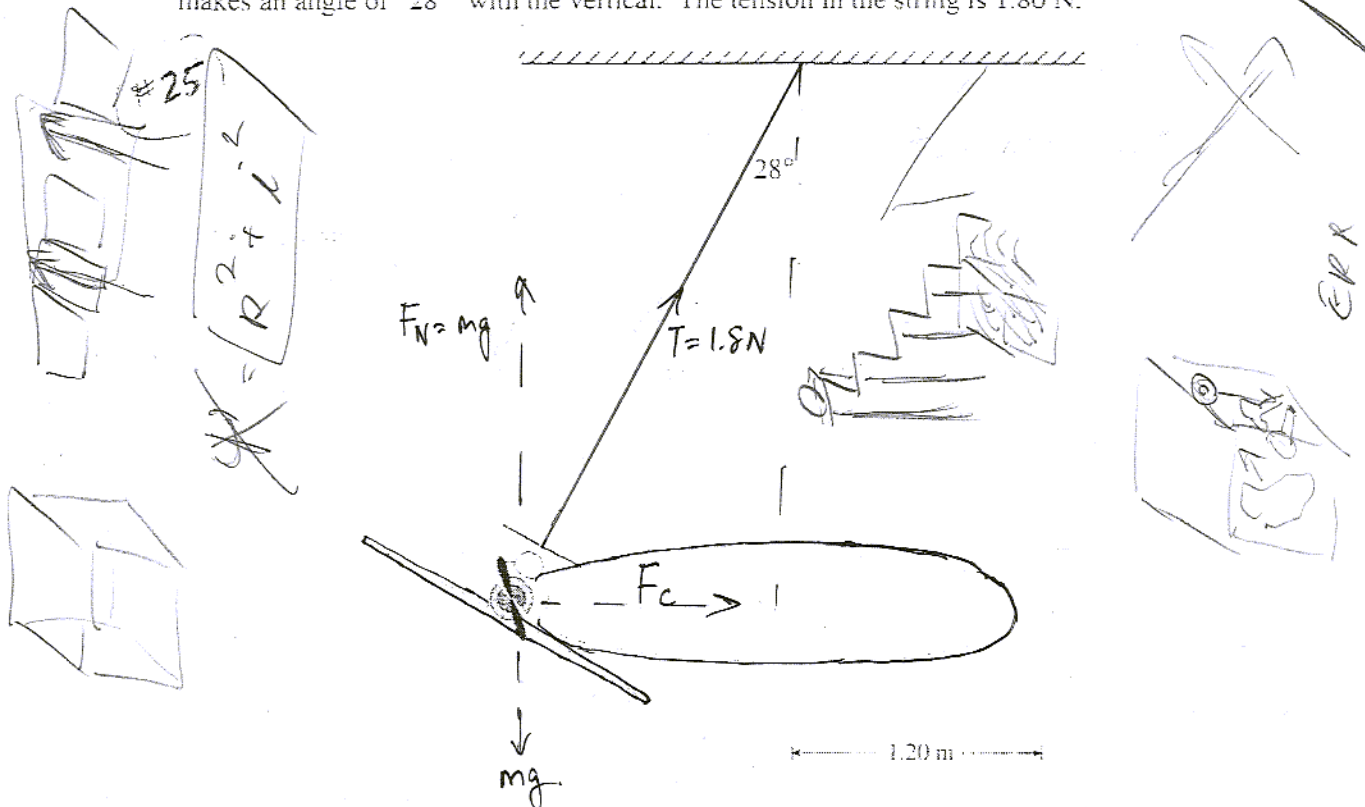
C. elliptical

D. parabolic



[Handwritten notes and scribbles are present in the background of the page, including the word 'circular' written vertically on the left and various calculations and diagrams on the right.]

- 6/95 4. The diagram shows a toy plane flying in a circle of radius 1.20 m, supported by a string which makes an angle of 28° with the vertical. The tension in the string is 1.80 N.



- a) What is the mass of the plane? (3 marks)

$$F_N = mg = 1.8 \cos 28 \quad 9.8 \text{ (m)} = 1.8 \cos 28$$

- b) How long does the plane take to complete one orbit? (4 marks)

$$F_c = \frac{mv^2}{r} = \frac{m \frac{4\pi^2 r}{T^2}}{r} = 1.8 \sin 28$$

$$\frac{(0.16)(4\pi^2(1.2))}{T^2} = 1.8 \sin 28$$

$$T = \sqrt{\frac{7.68}{1.8 \sin 28}} = 3.02 \text{ s}$$

- 6/95 13. 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?

#26

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

$$KE_i + PE_i = KE_f + PE_f$$

$$KE_i - \frac{GmM}{r_i} = 0 - \frac{GmM}{r_f}$$

$$15 \text{ J} = \frac{(6.67 \times 10^{-11})(120 \text{ kg})(M)}{600 \text{ m}} - \frac{(6.67 \times 10^{-11})(120 \text{ kg})(M)}{600 \text{ m} + 300 \text{ m}}$$

$$M = 3.4 \times 10^{12} \text{ kg} \quad \boxed{C}$$

- 6/95 12. A spacecraft of mass m is launched from the surface of a planet of mass M and radius r . Upon which of the variables, m , M and r , does the spacecraft's escape velocity depend?

#27

- A. m and r
 B. M and r
 C. m and M
 D. m , M and r

Escape velocity is derived from the value of

g .

$$g = \frac{GM}{r^2}, \text{ thus the variables affecting the velocity are } M, r.$$

8/95 11. Kepler's third law ($r^3 \propto T^2$) can be derived from the law of

28

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

$$F = \frac{Gm_1m_2}{r^2} \quad \left. \vphantom{\frac{Gm_1m_2}{r^2}} \right\} \rightarrow \text{Used universal gravitation law}$$

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

$$a = \frac{Gm_2}{r^2}$$

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

$$4\pi^2 r^3 = Gm T^2$$

$$\boxed{r^3 \propto T^2}$$

8/95 4. A 1250 kg rocket rests on the surface of the Earth. To what maximum distance from the Earth's centre would the rocket be lifted if 2.5×10^{10} J of work were done on it? (7 marks)

#29

$$W = Fd$$

$$W = \frac{Gm \cdot M_E}{r^2} \cdot d$$

$$d = \frac{2.5 \times 10^{10} \text{ J} (6.38 \times 10^6 \text{ m})^2}{6.67 \times 10^{-11} (1250 \text{ kg})(5.98 \times 10^{24} \text{ kg})} = 2.6 \times 10^6 \text{ m above surface}$$

$\therefore 8.4 \times 10^6 \text{ m from center.}$

8/95 14. A stationary object of mass m is on the surface of a planet of mass M and radius r . Which of the following gives the work required to move the object infinitely far away?

#30

A. $W = \sqrt{\frac{GMm}{r}}$

B. $W = \frac{GMm}{r}$

C. $W = \frac{GMm}{2r}$

D. $W = \frac{GMm}{r^2}$

$$\begin{aligned} W &= \Delta E_p \\ &= E_{p\infty} - E_{p_i} \\ &= 0 - \left(-\frac{GMm}{r}\right) \\ &= \frac{GMm}{r} \end{aligned}$$

8/95 13. 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?

#31

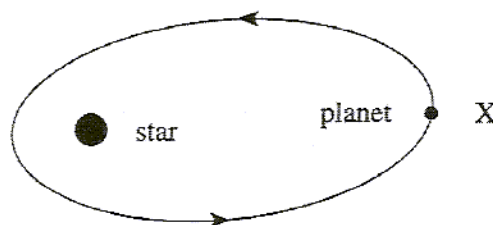
- A. 9.8 N/kg
- B. 4.4×10^4 N/kg
- C. 4.9×10^6 N/kg
- D. 1.2×10^{13} N/kg

$$F_g = mg = \frac{GmM}{r^2}$$

$$g = \frac{(6.67 \times 10^{-11})(4.8 \times 10^{31})}{(2.7 \times 10^8)^2} = 4.4 \times 10^4 \text{ N/kg}$$

8/95 12. A planet travels in an elliptical path around a star as shown.

#32



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

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

$$ma = \frac{GmM}{r^2}$$

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

$$a \propto \frac{1}{r^2}$$

\therefore least when r is greatest

$$a \propto v^2$$

\therefore velocity least when acceleration is least

6/96 3. Gravitational field strength is measured in

#33

A. $N = kg \cdot m/s^2$

B. $N/C = \frac{kg \cdot m}{s^2 \cdot C}$

C. $N/kg = \frac{kg \cdot m}{s^2 \cdot kg} = m/s^2 \leftarrow$ this is the unit for g

D. $N \cdot m^2 / kg^2$

- 6/96 14. A 1500 kg spaceship circles a planet once every 4.0×10^5 s with an orbital radius of 3.6×10^7 m. What is the mass of this planet?

#34

- A. 2.0×10^{11} kg
 B. 1.2×10^{12} kg
 C. 1.7×10^{23} kg
 D. 2.6×10^{26} kg

$$T = 4.0 \times 10^5 \text{ s} \quad v = \frac{2\pi r}{T} = \frac{2\pi(3.6 \times 10^7 \text{ m})}{4.0 \times 10^5 \text{ s}} = 565.5 \text{ m/s}$$

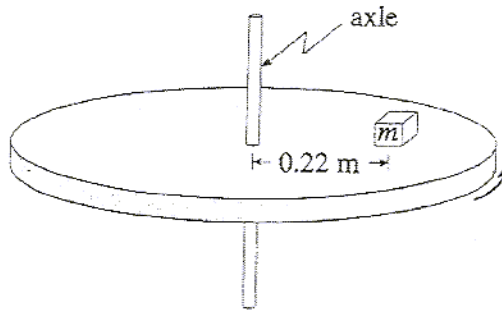
$$m = 1500 \text{ kg}$$

$$M = \frac{(565 \text{ m/s})^2 (3.6 \times 10^7 \text{ m})}{(6.67 \times 10^{-11})} = 1.7 \times 10^{23} \text{ kg}$$

$$\frac{GM}{r} = v^2 \quad M = \frac{v^2 r}{G}$$

- 6/96 13. An object of mass m is on a horizontal rotating platform. The mass is located 0.22 m from the axle and makes one revolution every 0.74 s.

#35



The friction force needed to keep the mass from sliding is 13 N. What is the object's mass?

- A. 0.82 kg
 B. 1.3 kg
 C. 2.7 kg
 D. 5.2 kg

$$r = 0.22 \text{ m} \quad T = 0.74 \text{ s}$$

$$F_c = mv^2$$

$$m = \frac{F_c r}{v^2}$$

$$v = \frac{2\pi r}{T}$$

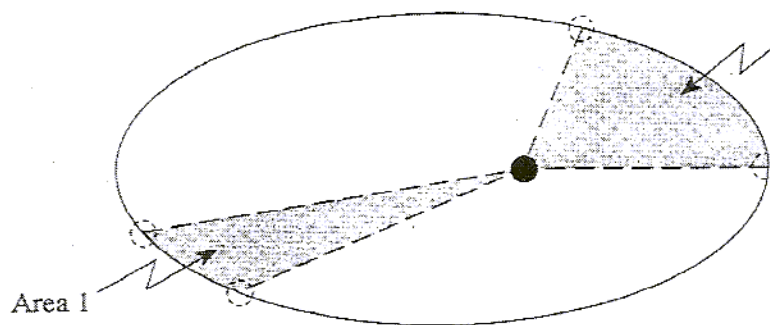
$$v = \frac{2\pi(0.22 \text{ m})}{0.74 \text{ s}} = 1.87 \text{ m/s}$$

$$m = 0.82 \text{ kg}$$

$$m = \frac{13 \text{ N} \cdot 0.22 \text{ m}}{(1.87 \text{ m/s})^2}$$

- 6/96 12. The diagram below shows the path of a planet orbiting a central mass.

#36



Area 2
 According to Kepler's Law, the answer is A.

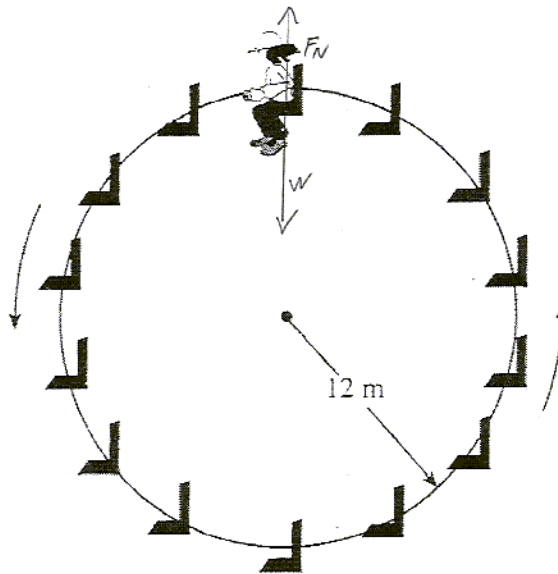
The two areas are swept out in equal intervals of time. How does Area 1 compare to Area 2?

- A. Area 1 is equal to Area 2.
 B. Area 1 is less than Area 2.
 C. Area 1 is greater than Area 2.
 D. Insufficient information is given to compare the two areas.

6/96

4. A 35 kg child rides a ferris wheel of radius 12 m. The child moves in a vertical circle at a constant speed and completes one rotation every 9.0 s.

37



$$W = mg = (35 \text{ kg})(9.8 \text{ m/s}^2) = 343 \text{ N}$$

$$F_c = \frac{mv^2}{r} = \frac{m(2\pi r/T)^2}{r} = \frac{m4\pi^2 r}{T^2} = \frac{(35 \text{ kg})(4\pi^2)(12 \text{ m})}{(9.0 \text{ s})^2} = 205 \text{ N}$$

- a) As the child travels over the top, what is the magnitude of the force that the seat exerts on the child? $F_N = W - F_c = 343 \text{ N} - 205 \text{ N} = 138 \text{ N}$ (5 marks)

- b) How does the magnitude of the child's acceleration at the top of the ride compare to her acceleration at the bottom?

The child's acceleration at the top is: (circle one)

(1 mark)

- i) less than at the bottom.
 ii) greater than at the bottom.
 (iii) the same as at the bottom.

Ac is constant since its uniform circular motion

Explain your choice using principles of physics.

(3 marks)

In uniform circular motion, $a_c = \frac{F_c}{m}$. Since centripetal force F_c and m are both constant, a_c is the same at all points of motion.

6/96

15. 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?

38

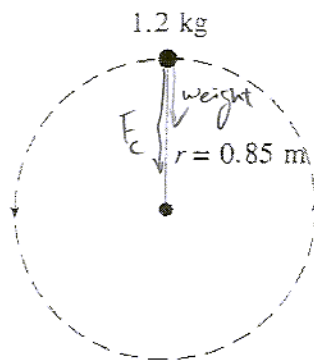
	MASS OF PLANET	MASS OF OBJECT	RADIUS OF PLANET
A.	Yes	Yes	Yes
B.	Yes	Yes	No
(C)	Yes	No	Yes
D.	No	Yes	Yes

Object mass does not matter because object mass is not included in the escape velocity equation $v = \sqrt{\frac{2GM}{r}}$

* Escape velocity has recently been dropped from the Physics 12 curriculum and therefore will not appear in the physics 12 provincial Exam.

8/96 11. A 1.2 kg mass on the end of a string is rotated in a vertical circle of radius 0.85 m.

#39



If the speed of the mass at the top of the circle is 3.6 m/s, what is the tension in the string at this location?

- A. 6.5 N
- B. 12 N
- C. 18 N
- D. 30 N

$$F_c - \text{Weight} = \text{Tension}$$

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

$$= \frac{(1.2)(3.6)^2}{0.85} = 18.3 \text{ N}$$

$$\text{Weight} = mg$$

$$= (1.2)(9.8)$$

$$= 11.8 \text{ N}$$

$$\text{Tension} = 18.3 \text{ N} - 11.8 \text{ N}$$

$$= 6.5 \text{ N}$$

- 8/96 4. A 4.2×10^3 kg spacecraft orbits a 5.6×10^{26} kg planet. If it takes the spacecraft 8.9×10^4 s to complete one orbit, how far is it from the planet's centre? (7 marks)

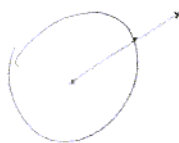
#40

$$\frac{GMm}{r^2} = \frac{m4\pi^2 r}{T^2} \quad r = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = 2.0 \times 10^8 \text{ m}$$

- 8/96 14. A person is on a horizontal rotating platform at a distance of 4.3 m from its centre. This person experiences a centripetal acceleration of 5.6 m/s^2 . What centripetal acceleration is experienced by another person who is at a distance of 2.5 m from the centre of the platform?

#41

- A. 2.3 m/s^2
 B. 3.3 m/s^2
 C. 5.6 m/s^2
 D. 9.6 m/s^2



$$a = r\omega^2$$

$$5.6 = 4.3 \times \omega^2$$

$$\omega^2 = \frac{5.6}{4.3}$$

$$a = r\omega^2 = 2.5 \times \frac{5.6}{4.3} = 3.3 \text{ m/s}^2$$

- 8/96 13. 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?

#42

- A. $-2.4 \times 10^{11} \text{ J}$
 B. $-8.4 \times 10^9 \text{ J}$
 C. $8.4 \times 10^9 \text{ J}$
 D. $2.4 \times 10^{11} \text{ J}$

$$E_p = -\frac{Gm_1m_2}{r} = \frac{-6.7 \times 10^{-11} \times 7.2 \times 10^2 \times 5.98 \times 10^{24}}{3.4 \times 10^7} = -8.4 \times 10^9 \text{ J}$$

- 8/96 12. 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?

#43

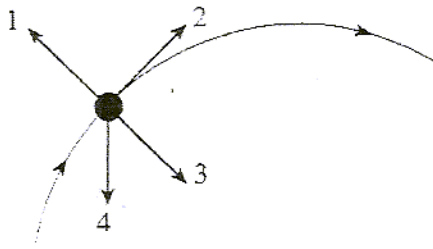
- A. 0.54 m/s^2
 B. 3.3 m/s^2
 C. 4.0 m/s^2
 D. 9.8 m/s^2

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

$$g = \frac{GM}{r^2} = 3.257$$

8/96 10. An object moves at a constant speed along a circular path as shown.

344



Which vector best represents the centripetal acceleration of the object at this point?

- A. 1
- B. 2
- C. 3
- D. 4

$V =$

- 1/97 15. A space shuttle orbits the earth at an altitude where the acceleration due to gravity is 8.70 m/s^2 . What is the shuttle's speed at this altitude?

- A. $2.65 \times 10^3 \text{ m/s}$
 B. $7.45 \times 10^3 \text{ m/s}$
 C. $7.68 \times 10^3 \text{ m/s}$
 D. $7.91 \times 10^3 \text{ m/s}$

$$F = \frac{G m_1 m_2}{r^2}$$

$$mg = \frac{G m_1 m_2}{r^2}$$

$$8.7 \text{ m/s}^2 = \frac{6.67 \times 10^{-11} (5.98 \times 10^{24} \text{ kg})}{r^2}$$

$$r = 6.77 \times 10^6 \text{ m}$$

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

$$v^2 = ar$$

$$= 8.7 \text{ m/s}^2 (6.77 \times 10^6 \text{ m})$$

$$= 5.89 \times 10^7 \text{ m}^2/\text{s}^2$$

$$v = 7.68 \times 10^3 \text{ m/s}$$

- 1/97 4. The moon Deimos orbits the planet Mars at an orbital radius of $2.34 \times 10^7 \text{ m}$ with an orbital period of $1.08 \times 10^5 \text{ s}$. What is the mass of Mars? (7 marks)

$$F = \frac{G m_1 m_2}{r^2}$$

$$mg = \frac{G m_1 m_2}{r^2}$$

$$\frac{4\pi^2 r}{T^2} = \frac{G m_2}{r^2}$$

$$m_2 = \frac{4\pi^2 r^3}{G T^2} = \frac{4\pi^2 (\cancel{1.08 \times 10^5}) (2.34 \times 10^7 \text{ m})^3}{(6.67 \times 10^{-11}) (1.08 \times 10^5 \text{ s})^2}$$

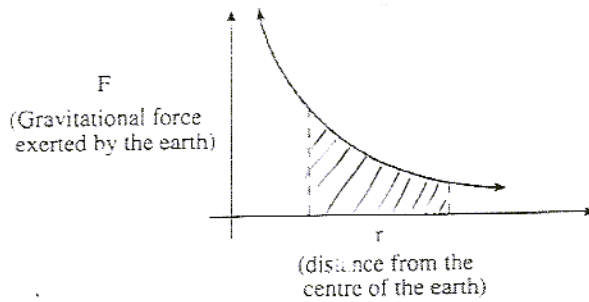
$$= 6.5 \times 10^{23} \text{ kg}$$

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

1/97

11. The shaded area shown in the diagram represents

#47



$$\begin{aligned} W &= Fd \\ &= F_g \cdot r \\ &= \text{Area} \end{aligned}$$

- A. the gravitational field strength near the earth.
 B. the escape velocity from the surface of the earth.
 C. the centripetal acceleration of an object orbiting the earth.
 (D) the work required to move an object in the earth's gravitational field.

1/97

12. What is the magnitude of the centripetal acceleration of the earth as it orbits the sun?

#48

- A. $3.4 \times 10^{-18} \text{ m/s}^2$
 B. $1.8 \times 10^{-8} \text{ m/s}^2$
 (C) $5.9 \times 10^{-3} \text{ m/s}^2$
 D. 9.8 m/s^2

$$a_c = \frac{v^2}{r} = \frac{\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4\pi^2 r}{T^2}$$

$$a_c = \frac{4\pi^2 \times 1.50 \times 10^{11}}{(365 \times 24 \times 60 \times 60)^2} = 5.9 \times 10^{-3} \text{ m/s}^2$$

1/97

13. A certain planet with a radius of $7.0 \times 10^7 \text{ m}$ has an escape velocity of $6.0 \times 10^4 \text{ m/s}$. What is the mass of this planet?

#49

- A. $6.6 \times 10^{25} \text{ kg}$
 B. $1.9 \times 10^{27} \text{ kg}$
 C. $3.8 \times 10^{27} \text{ kg}$
 D. $1.3 \times 10^{35} \text{ kg}$

$$E_k = E_p$$

$$\frac{1}{2}mv^2 = \frac{Gm_1m_2}{r^2} \cdot r$$

$$\frac{1}{2}(6E^4 \text{ m/s})^2 = \frac{6.67E^{-11} \text{ m}_2}{(7E^7 \text{ m})}$$

$$m_2 = 1.9E^{27} \text{ kg}$$

1/97

14. Mars orbits the sun at 1.52 times Earth's orbital radius. What is the orbital period of Mars in Earth years?

#50

- A. 1.23 years
 B. 1.52 years
 (C) 1.87 years
 D. 2.31 years

$$T = \frac{2\pi r^{\frac{3}{2}}}{\sqrt{GM}} = \frac{2\pi (1.52 \times 1.50 \times 10^{11})^{\frac{3}{2}}}{\sqrt{(6.67 \times 10^{-11}) \times 1.98 \times 10^{30}}}$$

$$5.95 \times 10^7 \text{ s} \times \frac{\text{min}}{60\text{s}} \times \frac{\text{hr}}{60\text{min}} \times \frac{\text{day}}{24\text{hr}} \times \frac{\text{yr}}{365\text{days}}$$

$$= 1.87 \text{ years}$$

6/97

4. a) The space shuttle orbits the Earth in a circular path where the gravitational field strength is 8.68 N/kg . What is the shuttle's orbital radius? (5 marks)

$$g = \frac{GM}{r^2} = 8.68 \text{ N/kg} \quad r = \sqrt{\frac{(6.67 \times 10^{-11}) \times (5.98 \times 10^{24})}{8.68}} = 6.78 \times 10^6 \text{ m}$$

- b) A space station that has 10 times the mass of the shuttle in a) orbits Earth at the same altitude. How does the orbital speed of the space station compare to that of the shuttle?

(Check one response.)

(1 mark)

- The space station's speed is less than the shuttle's speed.
 The space station's speed is the same as the shuttle's speed.
 The space station's speed is greater than the shuttle's speed.

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

(3 marks)

Orbital velocity $v = \sqrt{\frac{GM}{r}}$, which is independent on the mass of the object m . Since m is not taken into account, the v is therefore the same for all m .

6/97 12. Which of the following statements best applies to an object moving with uniform circular motion?

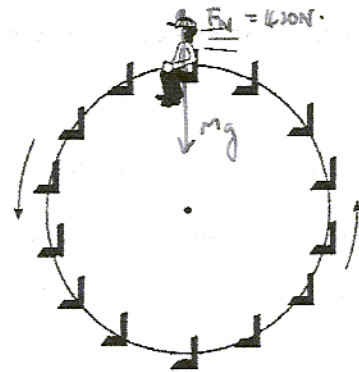
#52

- A. Acceleration is zero.
- B. Acceleration is directed outward.
- C. Acceleration is tangent to the path.
- D. Magnitude of acceleration is constant.

Acc. is not zero as direction is always changing.
 Centripetal Acc. is always directed inward.
 Centripetal Acc. is not tangential to path, but is directed to the middle.
 $a = \frac{v^2}{r}$, as v and r are constant, a is therefore constant.

6/97 10. Hans, whose mass is 50 kg, rides on a ferris wheel in a circular path at constant speed. When he is at the top of the wheel, the seat exerts an upward force of 420 N on Hans.

#53



What is the centripetal force on Hans at the top of the wheel?

- A. 70 N
- B. 420 N
- C. 490 N
- D. 910 N

$$F_c = mg - 420N$$

$$= (50)(9.8) - 420$$

$$= 70N$$

6/97 11. A satellite orbits the Earth with a speed of 5.2×10^3 m/s. What is the satellite's distance from the centre of the Earth?

#54

- A. 2.8×10^6 m
- B. 1.5×10^7 m
- C. 3.0×10^7 m
- D. 7.2×10^7 m

$$v = 5.2 \times 10^3 \text{ m/s} = \sqrt{\frac{GM}{r}}$$

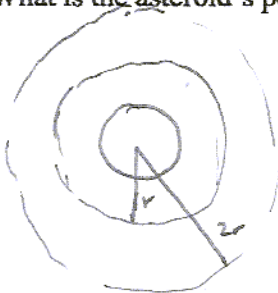
$$\frac{GM}{r} = v^2$$

$$r = \frac{GM}{v^2} = 1.48 \times 10^7 \text{ m}$$

6/97 13. A satellite orbits the Sun with a period of 220 days. An asteroid orbits the Sun with twice the orbital radius of the satellite. What is the asteroid's period?

#55

- A. 110 days
- B. 220 days
- C. 440 days
- D. 620 days



Using proportionality,

$$(220)(2^{3/2}) = 622.25 \text{ days.}$$

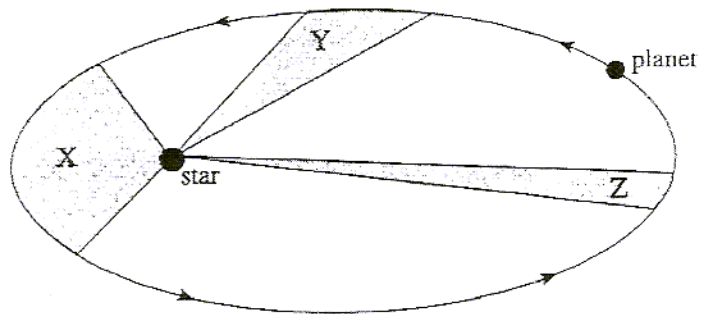
$$\frac{GM}{r^2} = \frac{4\pi^2 v^2}{T^2}$$

$$GM T^2 = 4\pi^2 r^3$$

$T \propto r^{3/2}$

10. A planet travels in an elliptical path around a star. The areas X, Y and Z were swept out in equal time intervals.

8/97
#56



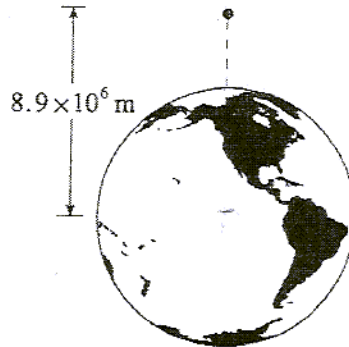
Which of the following describes the relationship between the areas?

- A. Area X is greater than area Z.
- B. Area X is equal to the sum of areas Y and Z.
- C. Area X is less than area Z.
- D. Area X is equal to area Y which is equal to area Z.

↑ According to Kepler's Law of Planetary Motion

8/97 13. A stationary 25 kg object is released from a position 8.9×10^6 m from the centre of the earth.

#57



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

$$0.5mv^2 = \Delta PE = \left(\frac{(6.67 \cdot 10^{-11})(5.98 \cdot 10^{24})(25)}{6.38 \cdot 10^6} - \frac{(6.67 \cdot 10^{-11})(5.98 \cdot 10^{24})(25)}{(8.9 \cdot 10^6)} \right) \cdot 2 = 6.0 \cdot 10^3 \text{ m/s}$$

97 14. 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)?

#58

- A. 9.0×10^3 s
- B. 1.3×10^4 s
- (C) 1.8×10^4 s
- D. 2.4×10^4 s

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

$$T = \frac{2\pi r^{3/2}}{\sqrt{GM}}$$

$$\frac{g \cdot r^2}{G} = M = 5.99 \cdot 10^{27}$$

8/97 11. A 1200 kg car is travelling at 25 m/s on a horizontal surface in a circular path of radius 85 m. What is the net force acting on this car?

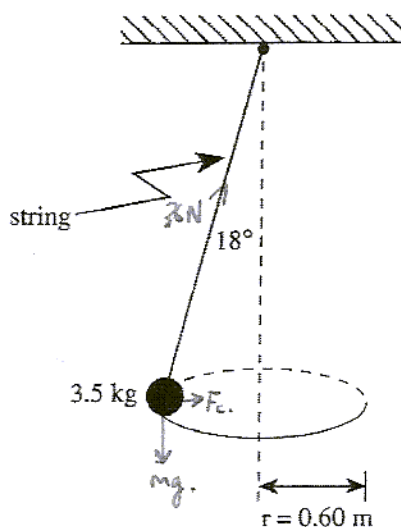
#59

- A. 0 N
- (B) 8.8×10^3 N
- C. 1.2×10^4 N
- D. 3.8×10^5 N

$$\Sigma F = \frac{mv^2}{r} = 8.8 \times 10^3 \text{ N}$$

- 8/97 4. A 3.5 kg object is suspended by a string and moves in a horizontal circle of radius 0.60 m. The tension in the string is 36 N.

#60

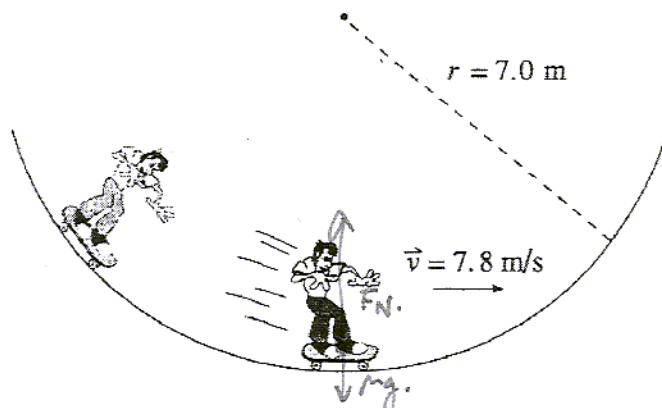


- a) What is the magnitude of the net force on the object? (3 marks)
 $F_{net} = F_c = T \sin 18 = 36 \sin 18 = 11.1 \text{ N.}$
- b) What is the period of revolution of the object? (4 marks)

$$F_c = \frac{mv^2}{r} = \frac{v^2}{T^2} r, \quad T = 2.73 \text{ s.}$$

- 8/97 12. A 61 kg skateboarder is moving down a ramp with a 7.0 m radius of curvature. At the bottom of this ramp he reaches a speed of 7.8 m/s.

#61



What upward force acts on the skateboarder at the bottom of the ramp?

- A. $7.0 \times 10^1 \text{ N}$
 B. $5.3 \times 10^2 \text{ N}$
 C. $6.0 \times 10^2 \text{ N}$
 D. $1.1 \times 10^3 \text{ N}$

$$F_c = F_N - mg.$$

$$\frac{mv^2}{r} = F_N - (61)(9.8).$$

$$F_N = \frac{(61)(7.8^2)}{7} + (61)(9.8)$$

$$= 1.13 \times 10^3 \text{ N.}$$

Circular Motion & Gravitation

1 <u>0.26 Kg 0.25 m</u>	31 <u>B</u>	
2 <u>See text</u>	32 <u>A</u>	
3 <u>d</u>	33 <u>C</u>	
4 <u>B</u>	34 <u>C</u>	
5 <u>A</u>	35 <u>A</u>	
6 <u>d</u>	36 <u>A</u>	
7 <u>4 hours</u>	37 <u>138 N iii</u>	
8 <u>B</u>	38 <u>A</u>	
9 <u>C</u>	39 <u>A</u>	
10 <u>C</u>	40 <u>2×10^6 m</u>	
11 <u>d</u>	41 <u>B</u>	
12 <u>B</u>	42 <u>B</u>	
13 <u>d</u>	43 <u>B</u>	
14 <u>B</u>	44 <u>C</u>	
15 <u>B</u>	45 <u>C</u>	
16 <u>3.4×10^{16} Joules</u>	46 <u>6.5×10^{23} Kg</u>	
17 <u>B</u>	47 <u>d</u>	
18 <u>d</u>	48 <u>C</u>	
19 <u>B</u>	49 <u>B</u>	
20 <u>C</u>	50 <u>C</u>	
21 <u>94 min (B)</u>	51 <u>6.79×10^6 m SAME</u>	
22 <u>A</u>	52 <u>d</u>	
23 <u>d</u>	53 <u>A</u>	
24 <u>B</u>	54 <u>B</u>	
25 <u>0.16 Kg 3 sec</u>	55 <u>d</u>	
26 <u>C</u>	56 <u>d</u>	
27 <u>B</u>	57 <u>A</u>	
28 <u>B</u>	58 <u>C</u>	
29 <u>9.4×10^6 m</u>	59 <u>B</u>	
30 <u>B</u>	60 <u>11.1 N 2.7 sec</u>	

61 d