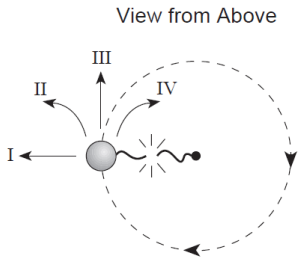
Circular Motion and Gravitation Review

Multiple Choice

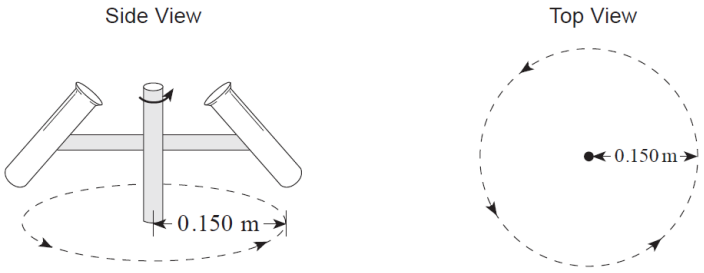
1. A ball attached to a string is swung in a horizontal circle.



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

A. I
B. II
C. III
D. IV

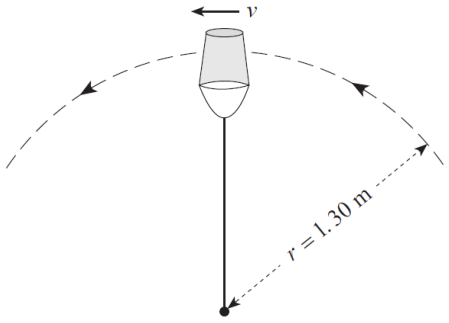
2. A test tube rotates in a centrifuge with a period of 1.20×10^{-3} s. The bottom of the test tube travels in a circular path of radius 0.150 m.



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

A. 9.86×10^{-5} N
B. 2.08×10^{-3} N
C. 8.22×10^{-2} N
D. 4.11×10^{6} N

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

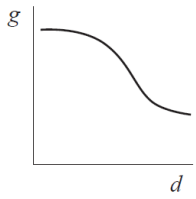


What is the minimum speed, v, at the top of the circle if the water is not to spill from the pail?

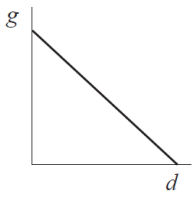
A. 3.6 m/s
B. 6.1 m/s
C. 8.0 m/s
D. 9.8 m/s

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

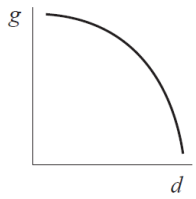
A.



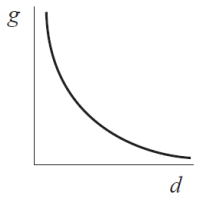
B.



C.



D.



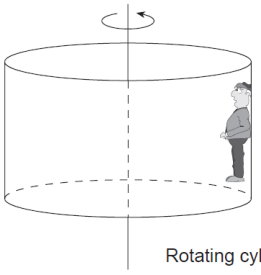
5. *Sputnik I*, Earth's first artificial satellite, had an orbital period of 5 760 s. What was the average orbital radius of *Sputnik's* orbit?

A. 6.38×10^{6} m
B. 6.95×10^{6} m
C. 8.24×10^{6} m
D. 3.84×10^{8} m

6. 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

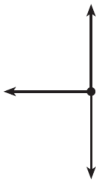
7. In a popular amusement park ride, a large cylinder is set in rotation. The floor then drops away leaving the riders suspended against the wall in a vertical position as shown.



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

A.

B.



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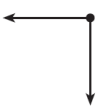
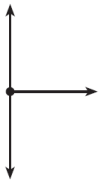


D.



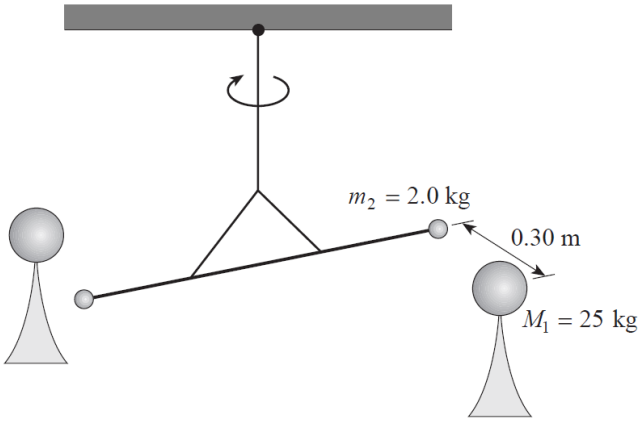
8. A 0.500 kg ball is swung in a horizontal circle of radius 1.20 m with a period of 1.25 s. What is the centripetal force on the ball?

A. 0.384 N
B. 15.2 N
C. 18.9 N
D. 30.3 N

9. 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

10. 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?

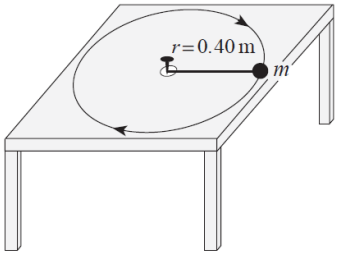


A. 1.1×10^{-8} N
B. 1.9×10^{-8} N
C. 2.2×10^{-8} N
D. 3.7×10^{-8} N

11. A car travels at a uniform speed through a level circular curve in the road. Which of the following correctly describes the magnitude of the acceleration, velocity and force acting on the car?

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

12. 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 2.1 s.



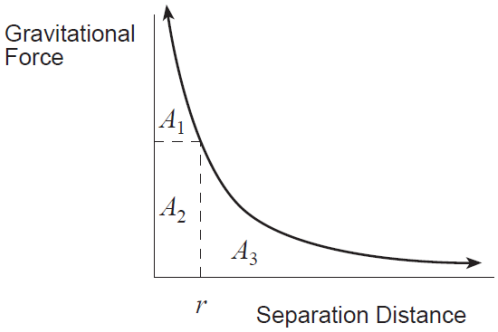
What is the maximum mass of the object?

A. 0.57 kg
B. 0.64 kg
C. 1.8 kg
D. 3.6 kg

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

A. 640 N
B. 3 500 N
C. 4 100 N
D. 4 700 N

14. 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

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

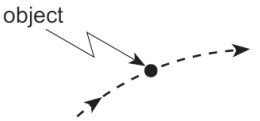
What is the mass of this satellite?

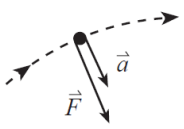
A. 23 kg
B. 650 kg
C. 910 kg
D. 1 200 kg

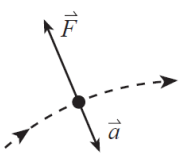
16. A 1 570 kg satellite orbits a planet in a circle of radius 5.94×10^6 m. Relative to zero at infinity the gravitational potential energy of this satellite is -9.32×10^{11} J. What is the mass of the planet?

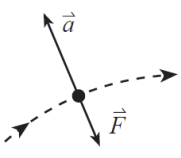
A. 5.29×10^{25} kg
B. 8.31×10^{28} kg
C. 3.14×10^{31} kg
D. 4.93×10^{34} kg

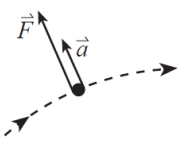
17. Which vector diagram best represents the acceleration, $\vec{a}$, and force, $\vec{F}$, for an object travelling along a circular path?



A.


B.


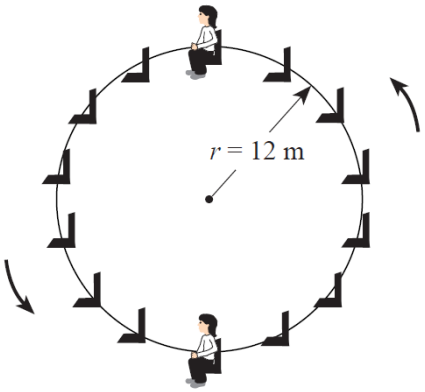
C.


D.


18. 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. $4F$

19. 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?

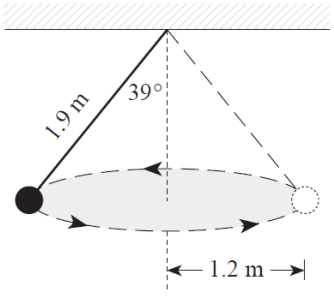


	TOP	BOTTOM
A.	76 N	76 N
B.	430 N	590 N
C.	510 N	510 N
D.	590 N	430 N

20. The equation $E_p = mgh$, in which g is $9.8\ \text{m/s}^2$, 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.

21. 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?

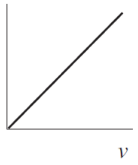


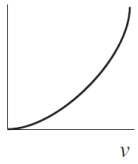
A. 19 N
B. 23 N
C. 24 N
D. 29 N

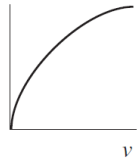
22. A car travels at 25 m/s along a horizontal curve of radius 450 m. What minimum coefficient of friction is necessary between its tires and the road in order for the car not to skid?

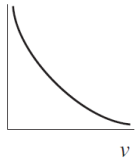
A. 0.14
B. 0.54
C. 0.72
D. 1.4

23. 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. 

B. 

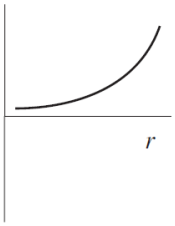
C. 

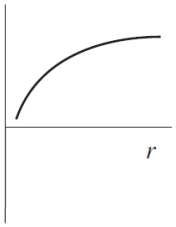
D. 

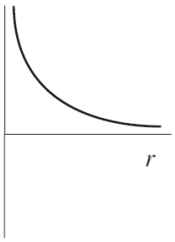
24. Tarzan, of mass 85 kg, holds on to a horizontal vine of length 8.0 m and jumps off a cliff. What is the tension force in the vine as Tarzan passes the lowest point of his circular path?

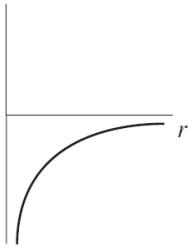
A. 830 N
B. 1 700 N
C. 2 500 N
D. 6 700 N

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

A. 

B. 

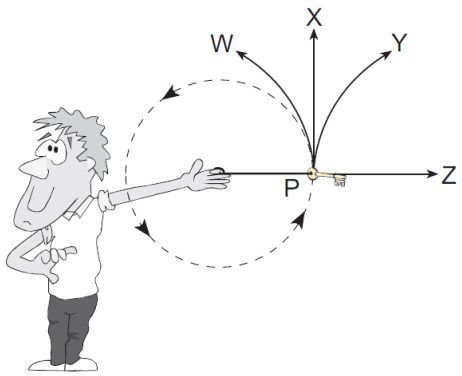
C. 

D. 

26. 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

27. The diagram shows a student "twirling" a car key in a circular path on the end of a string.



If the string snaps at P, which path will the keys follow?

A. W
B. X
C. Y
D. Z

28. 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

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

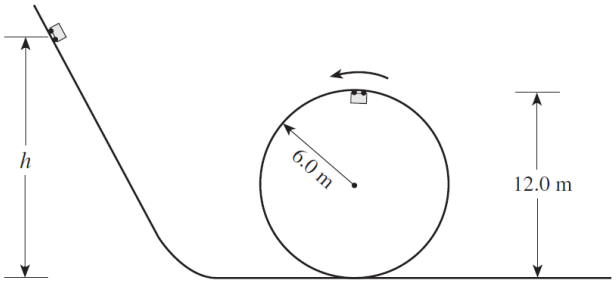
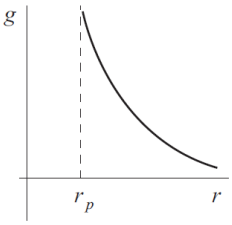


Diagram not to scale.

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

30. Which graph best shows how the gravitational field strength, g, varies with the distance, r, from the centre of a planet? (r_p is the radius of the planet.)

A.


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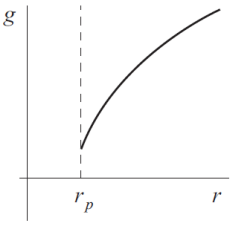
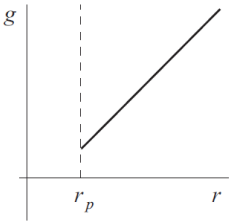


C.


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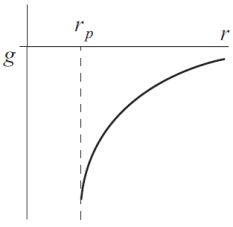


31. A satellite is in a stable circular orbit around the earth. Another satellite in a stable circular orbit at a greater altitude must have

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.

32. 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

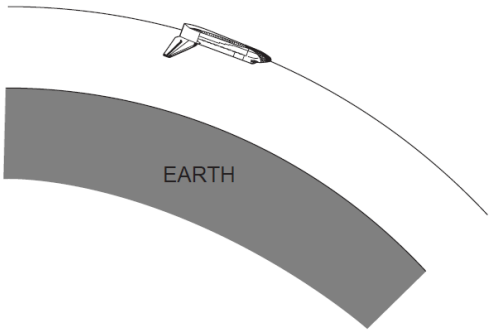
Written Response

1. 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? **(2 marks)**

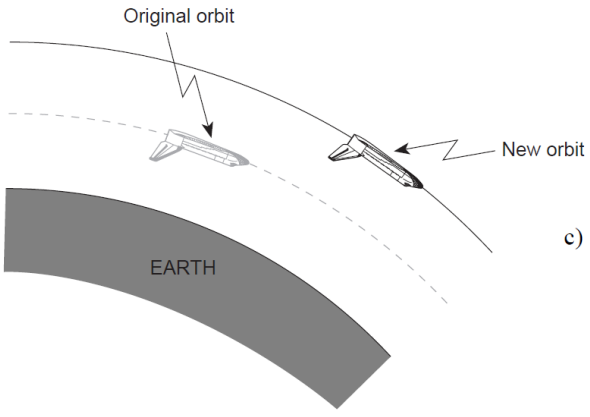
b) Mars has an average radius of 3.38×10^6 m. What is the mass of Mars? **(5 marks)**

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



a) What is the shuttle's orbital speed? **(5 marks)**

b) The space shuttle is then moved to a higher orbit in order to capture a satellite.



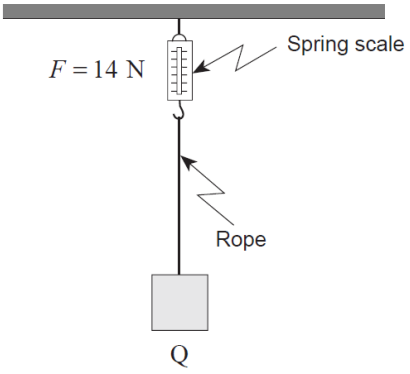
c) Using principles of physics, explain your answer to b).

The shuttle's speed in this new higher orbit will have to be

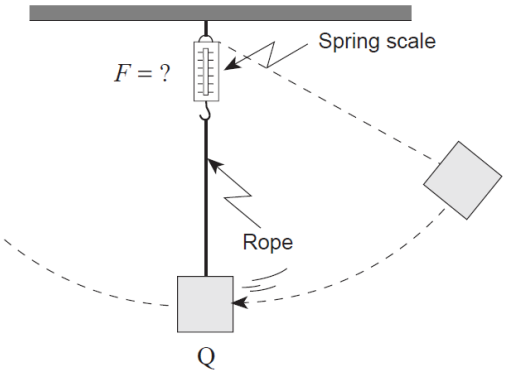
- ❒ greater than in the lower orbit.
- ❒ less than in the lower orbit.
- ❒ the same as in the lower orbit.

(Check one response.) **(1 mark)**

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

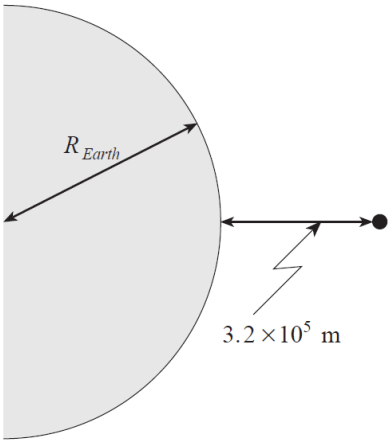


The mass is pulled to the side and then released as shown in Diagram 2.



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. **(4 marks)**

4. A 4.00×10^3 kg object is lifted from the earth's surface to an altitude of 3.2×10^5 m. How much work does this require? **(7 marks)**



(Diagram not to scale.)

5. An 884 kg satellite in orbit around a planet has a gravitational potential energy of -5.44×10^{10} J.

The orbital radius of the satellite is 8.52×10^{6} m and its speed is 7.84×10^{3} m/s.

a) What is the mass of the planet? **(3 marks)**

b) What is the kinetic energy of the satellite? **(2 marks)**

c) What is the total energy of the satellite? **(2 marks)**

6. 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? **(7 marks)**

Answers

MC

1. C
2. C
3. A
4. D
5. B
6. C
7. B
8. B
9. D
10. D
11. A
12. C
13. D
14. D
15. D
16. A
17. A
18. D
19. B
20. D
21. C
22. A
23. B
24. C
25. D
26. A
27. B
28. D
29. B
30. A
31. B
32. A

WR

1.

$a = \frac{\Delta v}{\Delta t}$ ← **1 mark**

$= \frac{15}{4.0}$ ← **½ mark**

$= 3.8$ m/s^2 ← **½ mark**

OR

$d = v_{ave} \times t$

$= 7.5\times4 = 30$ m ← **½ mark**

$v^2 = v_0{}^2 + 2ad$ ← **1 mark**

$15^2 = 2(a)(30)$

$a = 3.8$ m/s^2 ← **½ mark**

b) Mars has an average radius of 3.38×10^{6} m. What is the mass of Mars?

$F_g = \frac{GMm}{R^2}$ ← **1 mark**

$\cancel{m}g = \frac{GM\cancel{m}}{R^2}$ ← **1 mark**

$\therefore M = \frac{gR^2}{G}$ ← **1 mark**

$= \frac{3.8\times\left(3.38\times10^{6}\right)^2}{6.67\times10^{-11}}$ ← **1 mark**

$= 6.5\times10^{23}$ kg ← **1 mark**

2.

a) What is the shuttle's orbital speed? **(5 marks)**

$F_c = F_g$ ← **1 mark**

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

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

$v = \sqrt{\frac{GM}{R}}$ ← **2 marks**

$= \sqrt{\frac{6.67\times10^{-11}\times5.98\times10^{24}}{6.68\times10^{6}}}$ ← **1 mark**

$v = 7.73\times10^{3}\ \text{m/s}$ ← **1 mark**

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.

Using principles of physics, explain your answer to b). **(3 marks)**

As the space shuttle moves further away from the earth's centre the force of gravity acting on the shuttle decreases. Since the centripetal force is provided by the force of gravity, it must decrease as well. ← 2 marks

The smaller centripetal force generates a smaller centripetal acceleration ← 1 mark which in turn requires a smaller orbital velocity.

3. 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. **(4 marks)**

The reading will be greater than 14 N. (by $\frac{mv^2}{r}$) ← 1 mark

Initially, the net force is zero, so the spring scale reads the weight of the mass. When moving, there is a net (centripetal) force provided by the spring scale (tension in the rope) which exceeds the weight (force of gravity) of the mass so that the mass goes in a vertical circle. ← 3 marks

4.

$R_1 = 6.38\times10^{6}\ \text{m}$

$R_2 = 6.38\times10^{6}\ \text{m} + 3.2\times10^{5}\ \text{m}$

$= 6.70\times10^{6}\ \text{m}$ ← **1 mark**

$W = \Delta E$ ← **1 mark**

$\Delta Ep = Ep_2 - Ep_1$

$= \frac{-GMm}{R_2} - \left(-\frac{GMm}{R_1}\right)$ ← **1 mark**

$= \frac{-6.67\times10^{-11}\cdot5.98\times10^{24}\cdot4.00\times10^{3}}{6.70\times10^{6}} - \frac{-6.67\times10^{-11}\cdot5.98\times10^{24}\cdot4.00\times10^{3}}{6.38\times10^{6}}$ ← **2 marks**

$= -2.38\times10^{11}\ \text{J} - \left(-2.50\times10^{11}\ \text{J}\right)$ ← **1 mark**

$\Delta Ep = 1.2\times10^{10}\ \text{J}$ ← **1 mark**

5.

a) What is the mass of the planet?

$$E_p = -\frac{GMm}{r} \qquad \leftarrow \textbf{1 mark}$$

$$-5.44\times10^{10} = -\frac{6.67\times10^{-11}\times M\times 884}{8.52\times10^{6}} \qquad \leftarrow \textbf{1}\tfrac{\textbf{1}}{\textbf{2}}\ \textbf{mark}$$

$$M = 7.86\times10^{24}\ \text{kg} \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

b) What is the kinetic energy of the satellite?

$$E_k = \frac{1}{2}mv^2 \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

$$= \frac{1}{2}(884)\left(7.84\times10^{3}\right)^2 \qquad \leftarrow \textbf{1 mark}$$

$$= 2.72\times10^{10}\ \text{J} \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

c) What is the total energy of the satellite?

$$E_T = E_k + E_p \qquad \leftarrow \textbf{1 mark}$$

$$= 2.72\times10^{10} + \left(-5.44\times10^{10}\right) \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

$$= -2.72\times10^{10}\ \text{J} \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

6.

$$\Delta E = E_p' - E_p \qquad \leftarrow \textbf{2 marks}$$

$$= \left(-G\frac{Mm}{r'}\right) - \left(-\frac{GMm}{r}\right) \qquad \leftarrow \textbf{2 marks}$$

$$= \left(-\frac{6.67\times10^{-11}\times2.0\times10^{12}\times470}{(1\,400+2\,800)}\right) - \left(-\frac{6.67\times10^{-11}\times2.0\times10^{12}\times470}{1\,400}\right) \qquad \leftarrow \textbf{2 marks}$$

$$= (-14.9) - (-44.8)$$

$$= 29.9\ \text{J}$$

$$= 30\ \text{J} \qquad \leftarrow \textbf{1 mark}$$