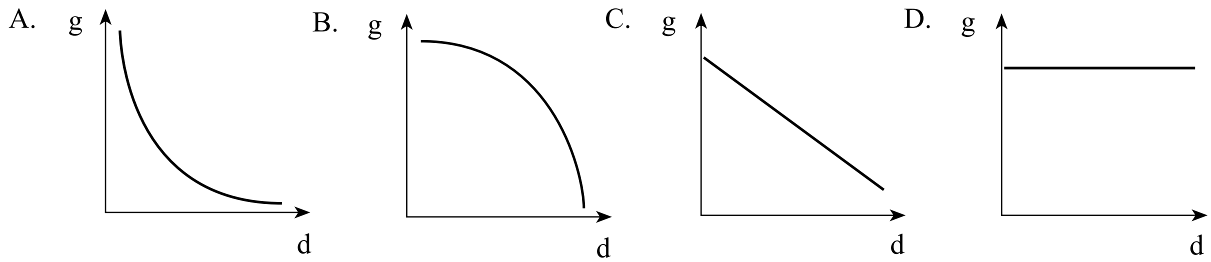
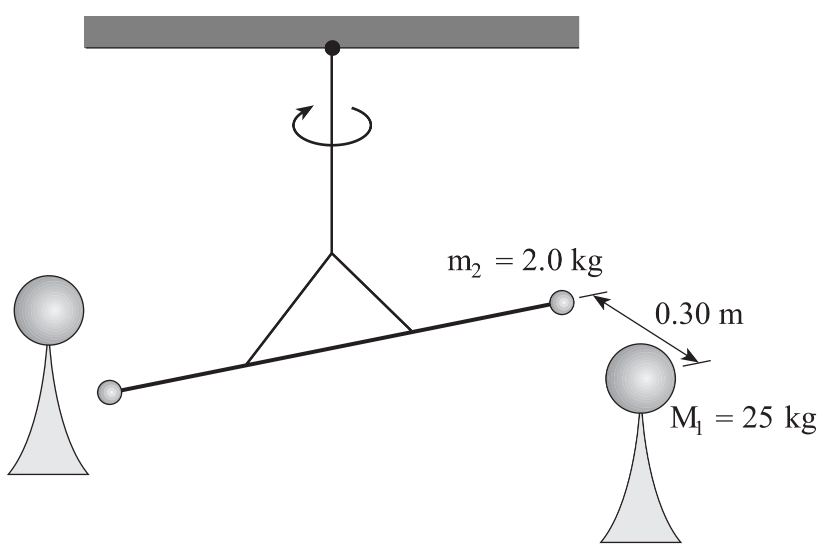
1. Which of the following graphs shows how the gravitational field of a body varies with distance from its centre? (Assume d is greater than the radius of the body.)



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

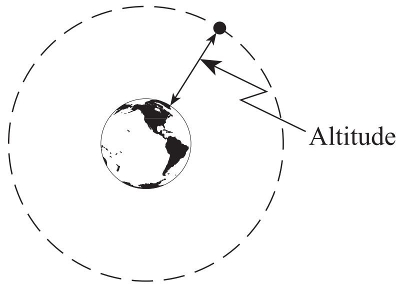
	MASS	WEIGHT
A.	decreases	decreases
B.	decreases	increases
C.	remains constant	decreases
D.	remains constant	increases

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



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

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



What is the mass of this satellite?

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

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

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

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

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

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

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

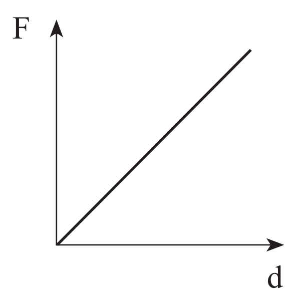
8. A certain planet has a mass of 3.3×10^{23} kg and a radius of 2.6×10^{6} m. What is the acceleration due to gravity on the surface of this planet?

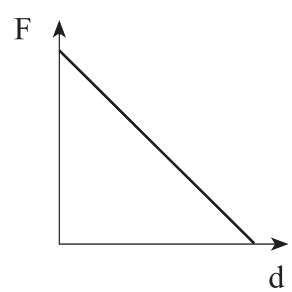
A. 0.54 m/s^2
B. 3.3 m/s^2
C. 4.0 m/s^2
D. 9.8 m/s^2

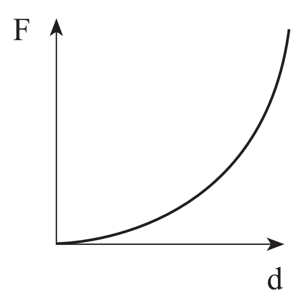
9. A space shuttle orbits the earth at an altitude where the acceleration due to gravity is 8.70 m/s^2. What is the shuttle's speed at this altitude?

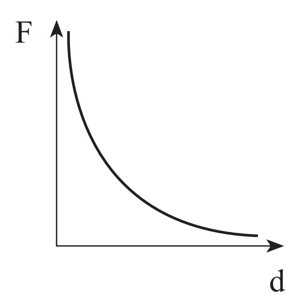
A. 2.65×10^{3} m/s
B. 7.45×10^{3} m/s
C. 7.68×10^{3} m/s
D. 7.91×10^{3} m/s

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

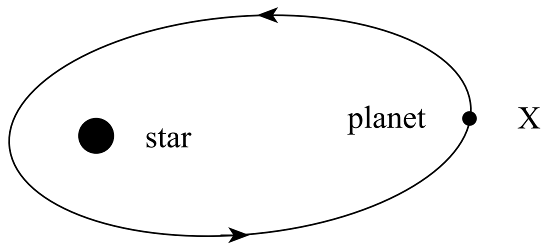
A.


B.


C.


D.


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



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

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

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

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

13. A satellite's orbit is maintained by a

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

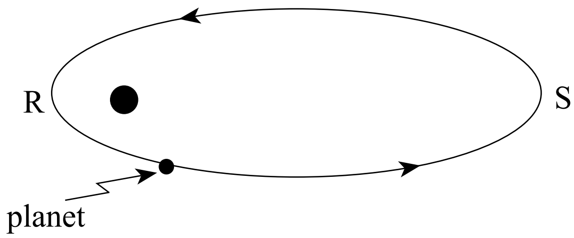
22. A 1570 kg satellite orbits a planet in a circle of radius 5.94×10^{6} m. Relative to zero at infinity the gravitational potential energy of this satellite is -9.32×10^{11} J. What is the mass of the planet?

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

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

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

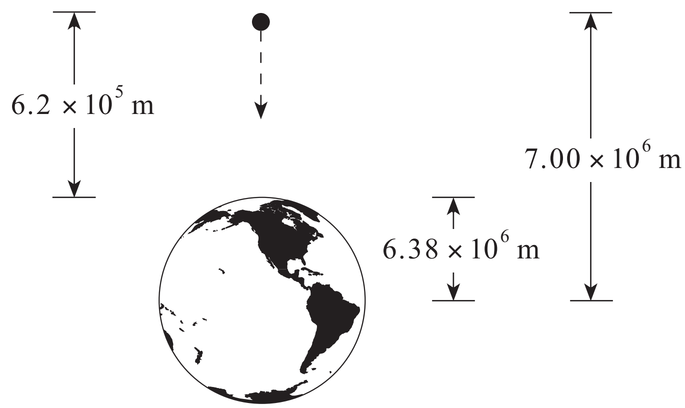
24. A planet is in orbit as shown in the diagram below.



The planet's gravitational potential energy will

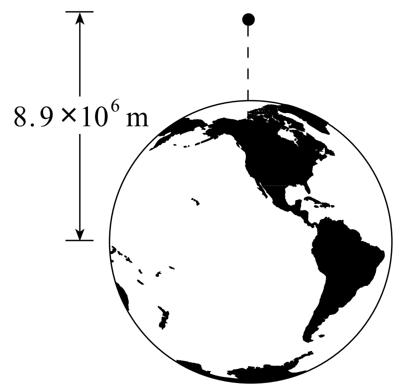
A. be constant throughout its orbit.
B. always be equal to its kinetic energy.
C. increase as the planet goes from point R to point S.
D. decrease as the planet goes from point R to point S.

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



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

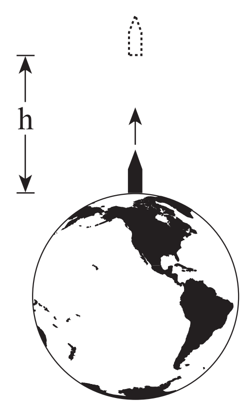
26. A stationary 25 kg object is released from a position 8.9×10^6 m from the centre of the earth.



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

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



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

28. A 620 kg satellite orbits the earth where the acceleration due to gravity is 0.233 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

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

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

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

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

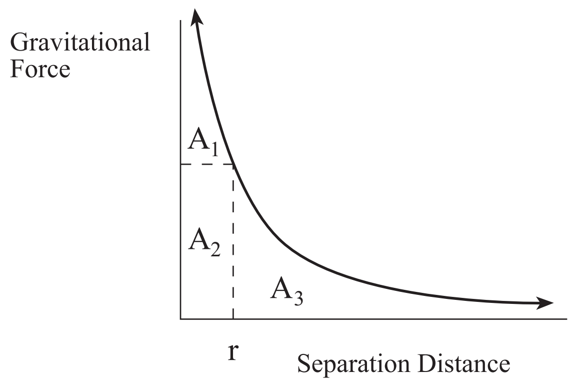
31. A 120 kg astronaut stands on the surface of an asteroid of radius 600 m. The astronaut leaves the surface with 15 J of kinetic energy and reaches a maximum height of 300 m above the surface. What is the mass of the asteroid?

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

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

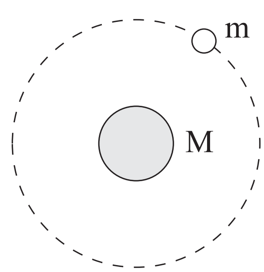
A. the slope of a graph of gravitational force versus separation distance.
B. the area under a graph of gravitational force versus separation distance.
C. the slope of a graph of gravitational potential energy versus separation distance.
D. the area under a graph of gravitational potential energy versus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

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



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

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



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

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

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

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

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

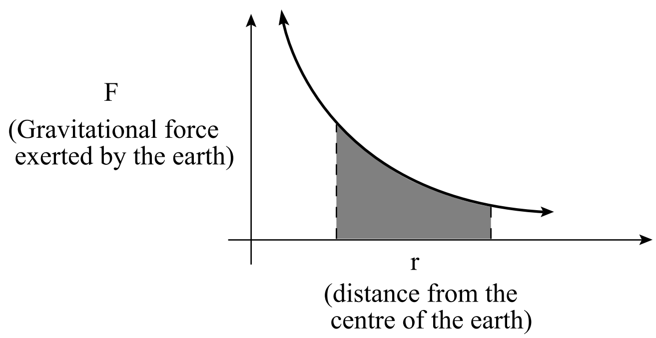
A. -6.0 10^{10} J

B. -2.0 10^{10} J

C. 2.0 10^{10} J

D. 6.0 10^{10} J

36. The shaded area shown in the diagram represents



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

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

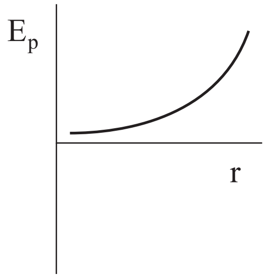
A. -2.6×10^{10} J

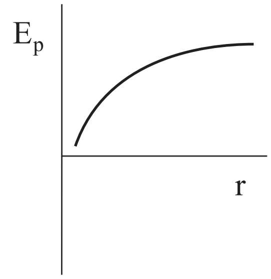
B. -1.3×10^{10} J

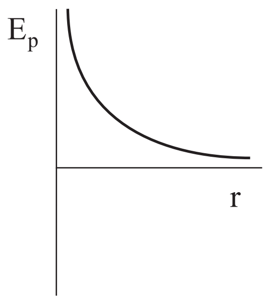
C. 1.3×10^{10} J

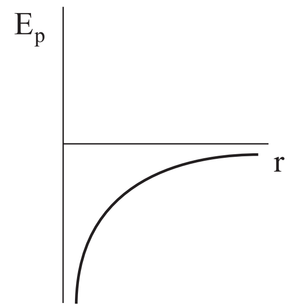
D. 3.9×10^{10} J

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

A. 

B. 

C. 

D. 

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

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

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

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

1. A $4.2 \quad 10^{3}$ kg spacecraft orbits a $5.6 \quad 10^{26}$ kg planet. If it takes the spacecraft $8.9 \quad 10^{4}$ s to complete one orbit, how far is it from the planet's centre? **(7 marks)**

2. a) The space shuttle orbits the Earth in a circular path where the gravitational field strength is $8.68\ \mathrm{N/kg}$. What is the shuttle's orbital radius? **(5 marks)**

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)**

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3. 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)**

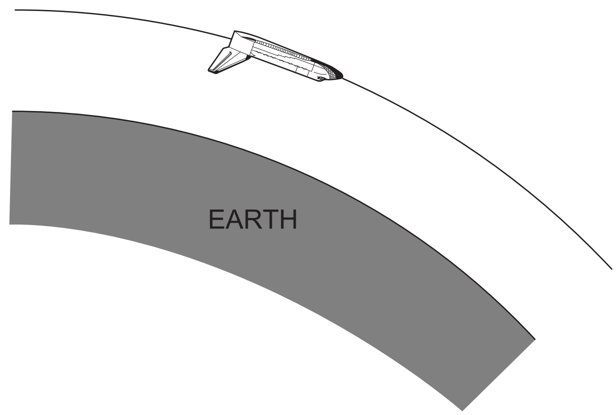
c) What is the total energy of the satellite? **(2 marks)**

4. 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)**

5. a) Mars has a mass of $6.37 \quad 10^{23}$ kg and a radius of $3.43 \quad 10^{6}$ m. What is the gravitational field strength on its surface? **(4 marks)**

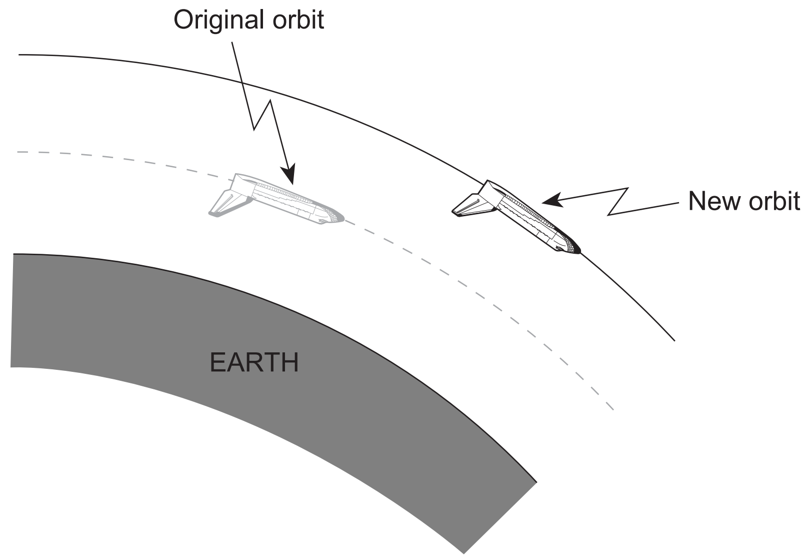
b) What thrust force must the rocket engine of a Martian lander exert if the 87.5 kg spacecraft is to accelerate upwards at $1.20\ \text{m/s}^2$ as it leaves the surface of Mars? **(3 marks)**

6. 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.



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)**

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

7. A 650 kg satellite in circular orbit around Earth has an orbital period of $1.5 \quad 10^4$ s.

a) What is the satellite's orbital radius? **(5 marks)**

b) What is the gravitational potential energy of this satellite? **(2 marks)**

8. A 1 200 kg space probe is in a circular orbit around the Sun. The orbital radius is $7.0 \quad 10^{9}$ m.

a) What is the orbital speed of this satellite? **(5 marks)**

b) If the Sun collapsed to one-tenth its present radius without a change to its mass, the space probe's orbital radius will

- ☐ increase.
- ☐ decrease.
- ☐ stay the same.

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

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

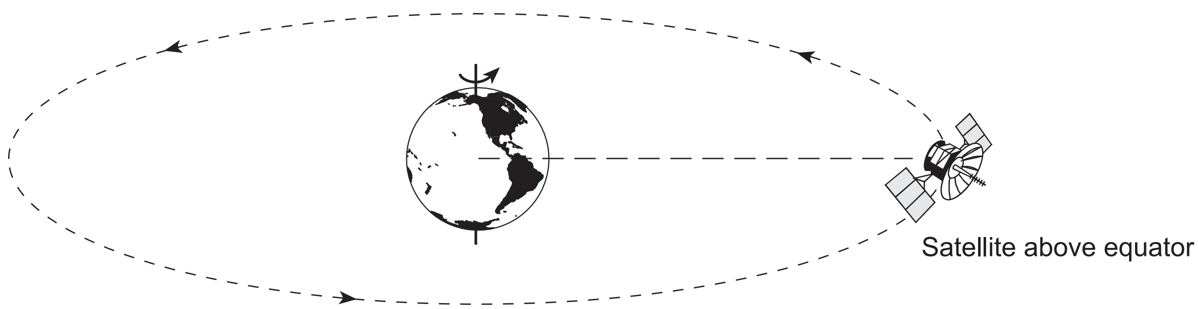
9. What minimum energy is required to take a stationary 3.5×10^3 kg satellite from the surface of the Earth and put it into a circular orbit with a radius of 6.88×10^6 m and an orbital speed of 7.61×10^3 m/s? (Ignore Earth's rotation.) **(7 marks)**

10. A 720 kg communication satellite is in a geosynchronous orbit around the planet Mars.

What is the orbital radius of this satellite? **(7 marks)**

Planetary Data for Mars
Mass: 6.42×10^{23} kg
Period of rotation: 8.86×10^{4} s

11. Geostationary satellites appear to remain stationary to an observer on Earth. Such satellites are placed in orbit far above the equator.



Using principles of physics, explain why such satellites all have the same orbital radius.

(4 marks)