HSC Physics – Module 5: Advanced Mechanics – Motion in Gravitational Fields Short Answer Question Solutions 1

1. $V = \sqrt{\frac{GM}{R}} = \frac{\sqrt{6.67\times10^{-11}\times6.0\times10^{24}}}{(6400+260)\times10^{3}} = 7751.78\ ms^{-1} = 7.\frac{75km}{s}\ or\ 7800\ m/s$

- use the correct equation 1
- correct numerical value 1
- 3 sig fig 1

2. $\frac{R^3}{T^2} = \frac{GM}{4\pi^2}$

$R = ^3\sqrt{\frac{6.67\times10^{-11}\times6\times10^{24}(14\times60\times60)^2}{4\pi^2}}$

$= 29529.73\ km$

$= 29.5\times10^3 km$

- correct equation 1
- correct numerical value + unit 1

3. a) Satellite is accelerating towards the central planet, with the gravitational force acting on it at 90° to its direction of motion.

Criteria	Marks
States direction of gravitational force or acceleration in relation to its velocity	1

b) Weight is experienced when our body is in contact with the ground (or any surface) which exerts an upward force on us (pushes on us in the opposite direction to the gravitational force). In orbiting the Earth in a satellite, all parts of out body accelerate at the same right as the satellite towards the Earth due to gravitational force, and no contact forces are exerted on us. Thus, there is no sensation of weight.

Criteria	Marks
Explains sensation of weight and lack of weight in satellite due to common acceleration	2
Explains sensation of weight OR lack of weight in satellite in satellite due to common acceleration	1

c) It will have the same orbital velocity as the first satellite.

$\frac{GMm}{r^2} = \frac{mv^2}{r}$, where m=mass of the satellite, M=mass of the planet, r=radius of the orbit, $v = \left(\frac{GM}{r}\right)^{\frac{1}{2}}$

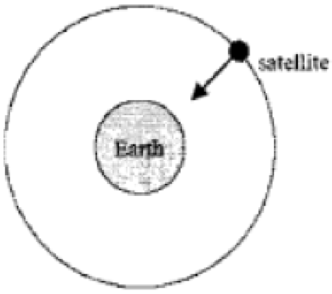
Orbital velocity depends on the Mass the planet

Criteria	Marks
Provides correct answer and equations to justify it will have the same orbital velocity	2
Provides correct answer OR provides equation to justify same orbital velocity	1
Provides incorrect answer and equation	0

4. a)

Marking Criteria	Marks
Provides the correct force name AND correct vector addition to the diagram.	1

Centripetal force or gravitational force



b)

Marking Criteria	Marks
Provides the correct answer	2
Provides correct formula or other method but makes numerical or one substitution error in calculating answer	1

$a = GM_E/r^2 = 6.67 \times 10^{-11} \times 6 \times 1024 \div [(6280 + 20000) \times 10^3]^2 = 0.58 \text{ ms}^{-2}$

5.

Marking Criteria	Marks
States direction of gravitational force or acceleration in relation to its velocity.	1

Satellite is accelerating towards the centre, it has gravitational force acting on it at 90° to its direction of motion, therefore undergoes uniform circular motion.

OR

The satellite undergoes centripetal acceleration as its direction is constantly changing.

b)

Marking Criteria	Marks
Explains sensation of weight and lack of weight in satellite due to common acceleration.	2
Explains sensation of weight OR lack of weight in satellite due to common acceleration	1

Weight is experienced when our body is in contact with the ground (or other surface) which pushes on us in the opposite direction to the gravitational force. In space circling the Earth or in 'freefall' all parts of our body accelerate at the same rate as the satellite towards Earth due to the gravitational force and no contact forces are exerted on us, hence no sensation of weight.

c)

Marking Criteria	Marks
Provides correct answer and provides equation to justify same orbital speed.	2
Provides correct answer OR provides equation to justify same orbital speed.	1

Same orbital speed.
$GMm/r^2 = mv^2/r$
Since mass of satellite m cancels, orbital speed is independent of mass of the satellite. Therefore, speed will be the same for all satellites at the same radius.
(OR use Kepler's law of periods to explain.)

5.

Marking Criteria	Marks
• Equates KE to GPE • Algebraic steps shown • Correct expression for escape velocity	2
Any two of the above	1

6.

Marking Criteria	Marks
• Uses Kepler's Law, shows eqn • Correct calculation • Answer in terms of Earth hours = 55.94 hours	2
Answer given correctly, but no working shown OR Answer not given in correct units (hours)	1

7.

Marking Criteria	Marks
• Determines Kepler constant for earth • Writes correct expression for orbit radius of satellite • Calculates value for radius • Determines altitude correctly • Correct units	**4**
• Does the math but no algebra AND • No errors OR • As Above + 1 error	**3**
1 error and no algebra AND correct value	**2**
One sensible relevant statement only	**1**

8. a)

Criteria	Marks
Correct numerical answer	1

use $U = -G\frac{m_1 m_2}{r}$, where r = radius + altitude
G = 6.67 × 10^{-11}
Radius = 6370 000 m
Alt = 8000 000 m
Me = 6.0 × 10^24
Ms = 2000

$$U = -6.67 \times 10^{-11} \frac{6.0 \times 10^{24} \times 2.0 \times 10^{3}}{6.37 \times 10^{6} + 0} = -1.26 \times 10^{11} J$$

b)

Criteria	Marks
Clear statement relating the energy required to place a satellite in orbit to the various types of work that must be done. Hence, in addition to the energy required to lift the satellite to correct height, (PE) energy is also required; to give the satellite the correct velocity to keep it in orbit (i.e. KE), to overcome air friction when travelling through	3

the atmosphere, and some energy is lost as heat (because rocket engines are not 100% efficient).	
Clear statement that energy is required for one of above in addition to the energy required to raise the satellite to the correct height (PE) or a poorly expressed response that mentions two of the factors above.	2
A response that mentions one of the factors above in addition to PE.	1

A good response would include:

In addition to the work required raising the satellite to the correct height, work must be done to give the satellite the correct horizontal velocity to keep it in orbit at this height.

Work must also be done to overcome air friction and some energy is lost as heat because the rocket engines are not 100% efficient.

9.
$R = 3\sqrt{GM/4\pi^2 \times t^2}$
$= (3\sqrt{6.67 \times 10^{-11} \times 6.0 \times 20^{24} / 4\pi^2}) \times (24 \times 60 \times 60)^2$
= 44 02271.876 m
Radius of Earth equals = 6371 000
Altitude = 44 02271.876 - 6371 000
= 1968728.124m

Criteria	Marks
• Correctly subs into Correct equation in SI units • Correct altitude given	2
• Single error made in calculation	1

10.
$F_c = F_g$
$m_1 v_2/r = G m_1 M_2/d^2$
$v = \sqrt{GM_2/r}$
From the above equation shows that orbital speed is only dependant on G, mass of planet and radius. SO therefore, is independent of mass of satellite

Criteria	Marks
• Correctly shows orbital velocity formulae	2
• Single error made in derivation	1