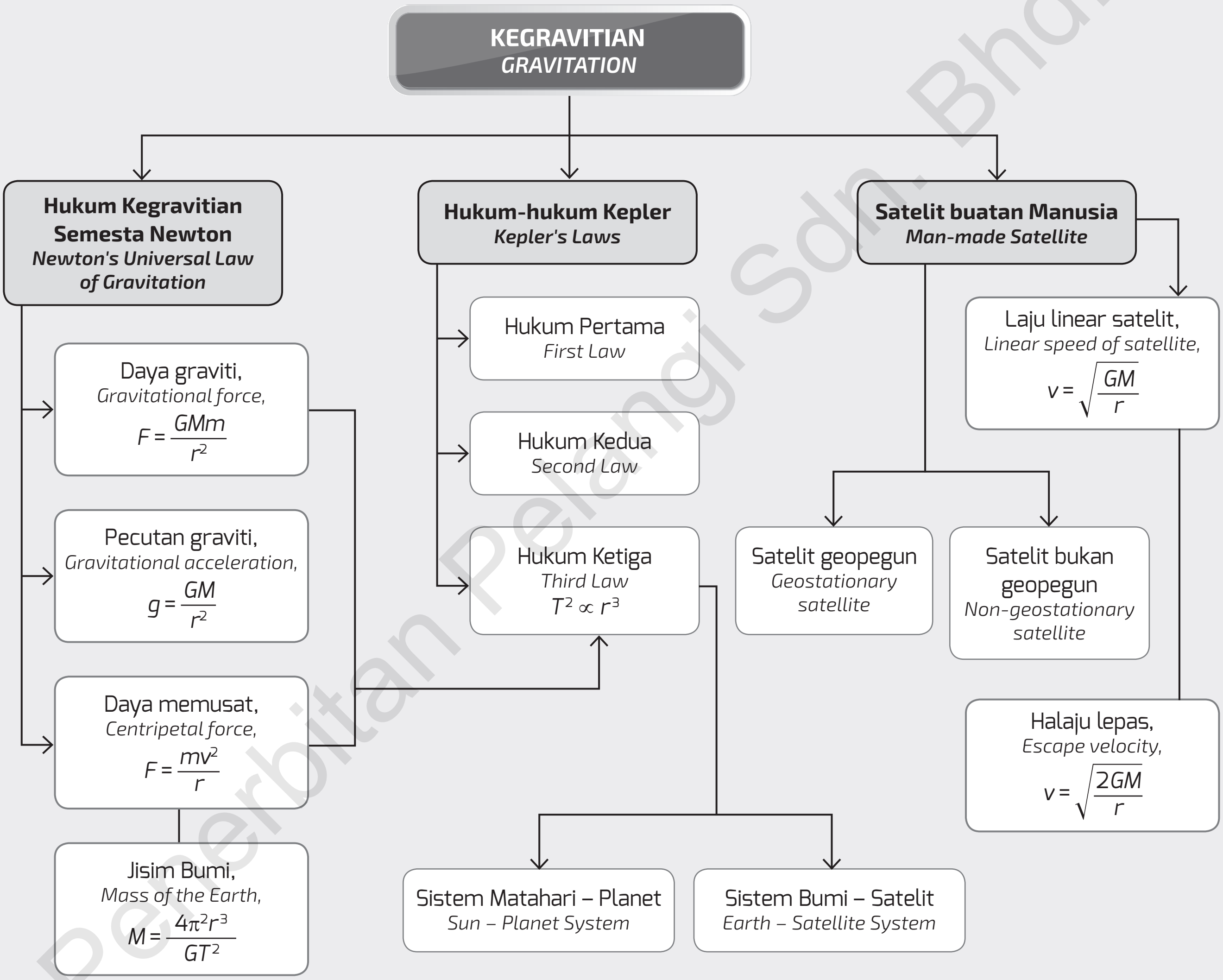
BAB 3 Kegravitian
Gravitation

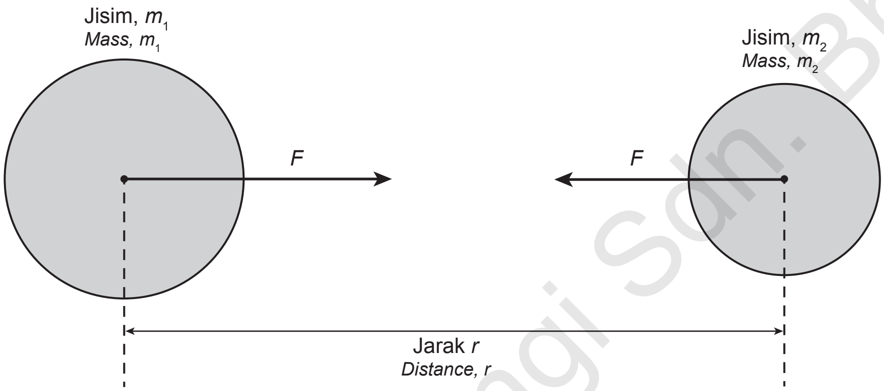
PETA Konsep



3.1 Hukum Kegravitian Semesta Newton
Newton's Universal Law of Gravitation

1. Isaac Newton menyatakan daya graviti yang melibatkan dua jasad mempunyai hubungan berikut: TP1 TP2
Isaac Newton states that gravitational forces involving two bodies have the following relationship:

- Daya graviti berkadar terus dengan hasil darab jisim bagi dua jasad, iaitu $F \propto m_1m_2$
  The gravitational force is directly proportional to the product of the mass of two bodies, $F \propto m_1m_2$
- Daya graviti berkadar songsang dengan kuasa dua jarak di antara pusat dua jasad tersebut, iaitu $F \propto \frac{1}{r^2}$.
  The gravitational force is inversely proportional to the square of the distance between the centres of the two bodies, $F \propto \frac{1}{r^2}$.



2. Dalam bentuk persamaan, daya graviti,
In the form of equations, gravitational force,

$$F \propto m_1m_2$$
$$F \propto \frac{1}{r^2}$$
$$\rightarrow F \propto \frac{m_1m_2}{r^2}$$

3. **Hukum Kegravitian Semesta Newton** menyatakan bahawa daya tarikan graviti di antara dua jasad adalah berkadar terus dengan hasil darab jisim-jisimnya dan berkadar songsang kepada kuasa dua jarak pemisahan di antaranya.

Newton's Universal Law of Gravitation *states that the gravitational attraction between two bodies is directly proportional to the product of the both masses and inversely proportional to the square of the distance separating them.*

4. Rumus Hukum Kegravitian Semesta Newton,
The Newton's Universal Law of Gravitation,

$$F = G\frac{m_1m_2}{r^2}$$

Dimana / *Where,*
F = daya graviti antara dua jasad / *gravitational force between two bodies*
m_1 = jisim jasad pertama / *mass of the first body*
m_2 = jisim jasad kedua / *mass of the second body*
r = jarak di antara pusat jasad pertama dan pusat jasad kedua / *the distance between the centre of the first body and the centre of the second body*
G = pemalar kegravitian / *universal gravitational constant* ($G = 6.67 \times 10^{-11}$ N m² kg⁻²)

Contoh 1

Kira daya antara dua objek yang mempunyai jisim 1000 kg dan 5000 kg dipisahkan dengan jarak 2 meter. ($G = 6.67 \times 10^{-11}$ N m² kg⁻²)
Calculate the force between two objects that have masses of 1000 kg and 5 000 kg separated by a distance of 1 m. ($G = 6.67 \times 10^{-11}$ N m² kg⁻²)

Penyelesaian / *Solution*:

$m_1 = 1000$ kg
$m_2 = 5000$ kg
$r = 2$ m
$G = 6.67 \times 10^{-11}$ N m² kg⁻²

Senaraikan maklumat yang diberi dengan simbol.
List the information given using symbols.

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

Kenal pasti dan tulis formula yang digunakan.
Identify and write the formula used

$$= \frac{6.67 \times 10^{-11} \times 1000 \times 5000}{2^2}$$

$$= 8.34 \times 10^{-5} \text{ N}$$

Buat gantian numerikal ke dalam rumus dan lakukan penghitungan.
Substitue the numerals into the formula and do the calculations.

BAB 3

Menyelesaikan Masalah Melibatkan Hukum Kegravitian Semesta Newton
Solving Problems Involving Newton's Universal Law of Gravitation

1. Diberikan dua jasad berjisim m_1 dan m_2 mengalami daya graviti yang diberikan dengan formula berikut,
Given that two bodies of mass m_1 and m_2 experience the gravitational force given by the following formula,

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

(a) Jika kedua-dua jisim jasad digandakan, apa yang berlaku kepada daya graviti? TP4
If the masses of both objects are doubled, what happens to the gravitational force?

Penyelesaian / *Solution*:

Daya graviti asal,
The original gravitational force,

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

Jika kedua-dua jisim jasad digandakan,
If both the masses of the body doubled,

$$F_1 = G\frac{2m_1 2m_2}{r^2} = 4G\frac{m_1 m_2}{r^2}$$

Maka daya graviti baharu ialah ___empat___ kali ganda daya graviti asal.
Then the new gravitational force is ___four___ times the original gravitational force.

Semakin besar jisim, semakin ___besar___ daya graviti. *The larger the mass, the ___larger___ the gravitational force.*

(b) Jika jisim kedua-dua jasad tidak berubah, tetapi jarak di antara dua jasad dikurangkan ke satu per empat daripada jarak asal, apakah yang berlaku kepada daya graviti?
If the masses of the two objects do not change, the distance between the two bodies is reduced to one fourth of the original distance, what happens to the gravitational force?

Penyelesaian / *Solution*:

Daya graviti asal,
The original gravitational force,

$$F = G\frac{m_1m_2}{r^2}$$

Jika jarak di antara dua jasad diubah menjadi satu per empat,
If the distance between two bodies is changed to one-fourth,

$$F_1 = G\frac{m_1m_2}{\left(\frac{1}{4}r\right)^2} = 16G\frac{m_1m_2}{r^2}$$

Maka daya graviti baharu ialah enam belas kali ganda daya graviti asal.
So the new gravitational force is sixteen times the original gravitational force.

Daya graviti berkurang apabila jarak di antara dua objek bertambah.
Gravitational force is reduced when the distance between two objects increases.

Contoh 2

1. Kira daya graviti antara seorang budak lelaki berjisim 50 kg yang berada di atas permukaan Bumi. Bumi mempunyai jisim 5.97×10^{24} kg dan jejari 6.37×10^6 m. ($G = 6.67 \times 10^{-11}$ N m² kg⁻²)
Calculate gravitational force between a boy of 50 kg who is resting on the Earth's surface. The Earth has a mass of 5.97×10^{24} kg and a radius of 6.37×10^6 m. ($G = 6.67 \times 10^{-11}$ N m^2 kg^{-2})

Penyelesaian / *Solution*:

$m_1 = 50$ kg
$m_2 = 5.97 \times 10^{24}$ kg
$r = 6.37 \times 10^6$ m
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$$F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 50 \times 5.97 \times 10^{24}}{(6.4 \times 10^6)^2}$$

$= 486$ N

2. Jarak di antara pusat Bumi dan Bulan ialah 3.8×10^8 m. Jisim Bumi ialah, $m_e = 5.97 \times 10^{24}$ kg dan jisim Bulan adalah, $m_m = 7.36 \times 10^{22}$ kg. Berapakah daya graviti antara Bumi dan Bulan?
The distance between the Earth and the Moon centres is 3.8×10^8 m. The mass of the Earth is, $m_e = 5.97 \times 10^{24}$ kg and the mass of the Moon is, $m_m = 7.36 \times 10^{22}$ kg. What is the gravitational force between the Earth and the Moon?

Penyelesaian / *Solution*:

$m_e = 5.97 \times 10^{24}$ kg
$m_m = 7.36 \times 10^{22}$ kg
$r = 3.8 \times 10^8$ m
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$$F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 7.36 \times 10^{22}}{(3.8 \times 10^8)^2}$$

$= 2.03 \times 10^{20}$ N

Tugasan 1

1. Sebuah satelit mengorbit Bumi pada jarak 40 km. Satelit ini mempunyai jisim 750 kg dan jisim Bumi adalah $m_e = 5.97 \times 10^{24}$ kg. Berapakah daya graviti antara planet dan satelit? (Jejari Bumi = 6.37×10^6 m)
A satellite is orbiting the Earth at a distance of 40 km. The satellite has a mass of 750 kg and the mass of the Earth is, $m_e = 5.97 \times 10^{24}$ kg. What is the gravitational force between the planet and the satellite? (Earth Radius = 6.37×10^6 m)

$m_s = 750$ kg
$m_e = 5.97 \times 10^{24}$ kg
$h = 40$ km
$r = 6.37 \times 10^6$ m
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$$F = \frac{Gm_1m_2}{(r+h)^2}$$
$$= \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 750}{(6.37 \times 10^6 + 40 \times 10^3)^2}$$
$$= 7.27 \times 10^3 \text{ N}$$

2. Jisim Matahari ialah 2.0×10^{30} kg dan jisim Bumi adalah, $m_e = 5.97 \times 10^{24}$ kg. Jarak di antara pusat Bumi dan pusat Matahari adalah 1.50×10^{11} km. Berapakah daya graviti antara Matahari dan Bumi?
The mass of the Sun is 2.0×10^{30} kg and the mass of the Earth is, $m_e = 5.97 \times 10^{24}$ kg. The distance from the Earth is 1.50×10^{11} km. What is the gravitational force between the Sun and the Earth?

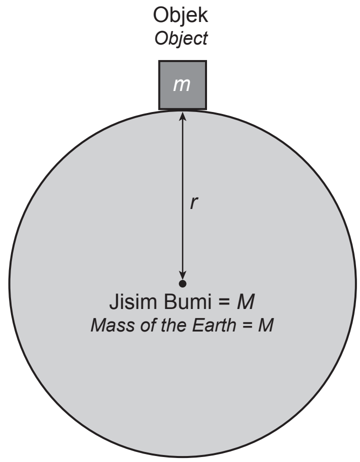
$m_e = 5.97 \times 10^{24}$ kg
$m_s = 2.0 \times 10^{30}$ kg
$r = 1.5 \times 10^{11}$ m
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$$F = \frac{Gm_1m_2}{r^2}$$
$$= \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 2.0 \times 10^{30}}{(1.5 \times 10^{11})^2}$$
$$= 3.54 \times 10^{22} \text{ N}$$

Menghubung Kait Pecutan Graviti, *g* di Permukaan Bumi dengan Pemalar Kegravitian Semesta, *G*
Relating the Gravitational Acceleration, g on the Surface of the Earth to Universal Gravitational Constant, G

1. Menurut Hukum Gerakan Kedua Newton, daya graviti boleh diungkapkan sebagai, $F = mg$. Daripada Hukum Kegravitian Semesta Newton, daya graviti, F diungkapkan sebagai $F = G\frac{m_1m_2}{r^2}$.
According to Newton's Second Law of Motion, the gravitational force can be expressed as, $F = mg$. From the Newton's Universal Law of Gravitation, gravitational force, F is expressed as $F = G\frac{m_1m_2}{r^2}$.

2. Jika satu objek yang berada di permukaan Bumi, objek akan mengalami daya graviti, seperti dinyatakan dalam Hukum Gerakan Kedua Newton.
If an object were on the surface of the Earth, the object would experience gravitational force, as stated in the Newton's Second Law of Motion.



3. Berdasarkan rajah di atas, jika, / *Based on the above diagram, if,*
M = jisim Bumi / *the mass of the Earth*
m = jisim objek / *object mass*
r = jarak di antara pusat Bumi dan pusat objek
distance between the centre of the Earth and the centre of the object

Kita boleh menghubungkan daya graviti yang menyebabkan objek jatuh dengan suatu pecutan graviti, g menggunakan rumus $F = mg$ dan daya graviti yang menarik objek ke arah pusat Bumi, $F = G\frac{Mm}{r^2}$, maka

We can relate the gravitational force that causes objects to fall with a gravitational acceleration, g using the formula F = mg and the gravitational force that pulls objects toward the center of the Earth, $F = G\frac{Mm}{r^2}$, hence

$$mg = G\frac{Mm}{r^2}$$
$$g = \frac{GM}{r^2}$$

Mansuhkan faktor sepunya, m
Cancel the common factor, m

Contoh 3

Hitungkan pecutan graviti sebuah objek berjisim 50 kg di atas permukaan Bumi. Diberikan jisim Bumi ialah 5.97×10^{24} kg dan jejari Bumi ialah 6.37×10^{6} m. [$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}]
Calculate the gravitational acceleration of an object with mass of 50 kg above the surface of the Earth. Given that the mass of the Earth is 5.97×10^{24} kg and the radius of the Earth is 6.37×10^{6} m
[$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}]

Penyelesaian / *Solution*:

$M = 5.97 \times 10^{24}$ kg
$r = 6.37 \times 10^{6}$ m
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{(6.37 \times 10^{6})^2}$$
$$= 9.81 \text{ m s}^{-2}$$

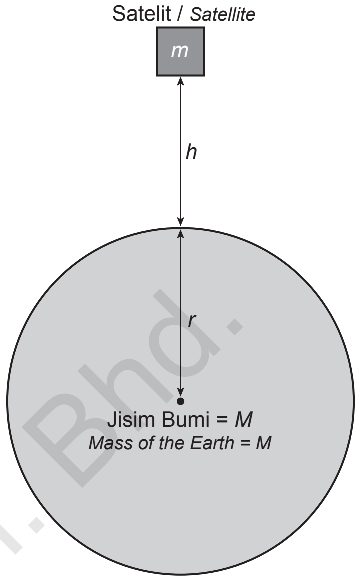
4. Jika satu satelit yang mengorbit mengelilingi Bumi, objek akan mengalami daya graviti, yang dinyatakan dalam Hukum Gerakan Kedua Newton.
If a satellite is orbiting around the Earth, the object will experience a gravitational force, expressed in Newton's Second Law of Motion.

5. Berdasarkan Rajah 1, jika / *Based on Diagram 1, if,*
M = jisim Bumi / *the mass of the Earth*
m = jisim objek / *object mass*
r = jarak di antara pusat Bumi dan pusat objek
the distance between the centre of the Earth and the centre of the object
h = ketinggian objek dari permukaan Bumi / *height of the object from the Earth*

Kita boleh menghubungkan daya graviti yang menyebabkan objek jatuh dengan suatu pecutan graviti, g menggunakan rumus $F = mg$ dengan daya graviti yang menarik objek ke arah pusat Bumi, $F = \frac{GMm}{r^2}$, maka
We can relate the gravitational force that causes objects to fall with a gravitational acceleration, g using the formula $F = mg$ and the gravitational force that pulls the objects toward the centre of the Earth, $F = \frac{GMm}{r^2}$, hence

$$mg = \frac{GMm}{(r+h)^2}$$
$$g = \frac{GM}{(r+h)^2}$$

Mansuhkan faktor sepunya, m
Cancel the common factor, m



Rajah 1 / *Diagram 1*

Contoh 4

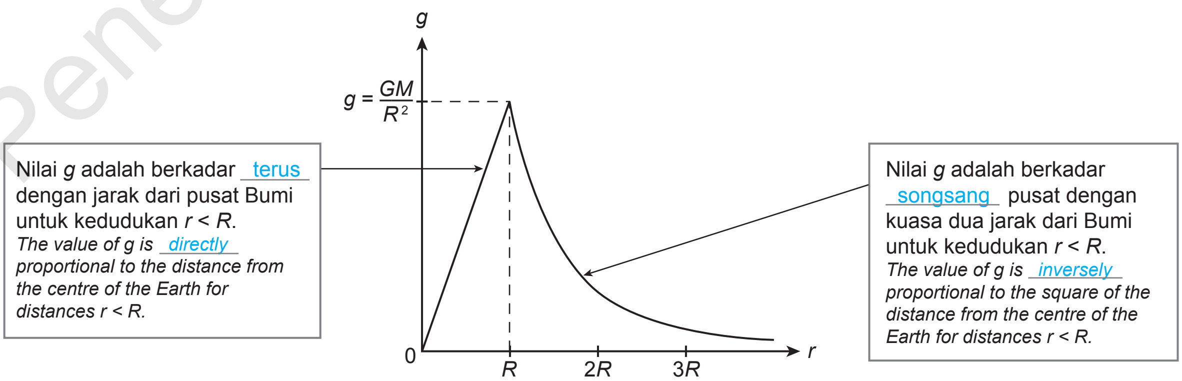
Sebuah satelit berjisim 300 kg mengorbit mengelilingi Bumi pada ketinggian 550 km. Diberikan jisim Bumi ialah 5.97×10^{24} kg dan jejari Bumi ialah 6.37×10^{6} m. Berapakah nilai pecutan graviti di kedudukan satelit itu? [$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}]
A 300 kg satellite is orbiting around the Earth at the height of 550 km. Given that the mass of the Earth is 5.97×10^{24} kg and the radius of the Earth is 6.37×10^{6} m. What is the value of gravitational acceleration at the location of the satellite? [$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}]

Penyelesaian / ***Solution***:

$m_e = 5.97 \times 10^{24}$ kg
$r = 1.5 \times 10^{11}$ m
$h = 550 \times 10^{3}$ m
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$$mg = G\frac{Mm}{r^2}$$
$$g = \frac{GM}{(r+h)^2} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{(6.37 \times 10^{6} + 550000)^2}$$
$$= 8.32 \text{ m s}^{-2}$$

5. Rajah 2 menunjukkan lakaran graf variasi nilai pecutan graviti, g dengan jarak, r dari pusat Bumi.
Diagram 2 show the skatch of graph of variation of the value of gravitational acceleration, g with the distance, r from the centre of the Earth.



Rajah 2 / *Diagram 2*

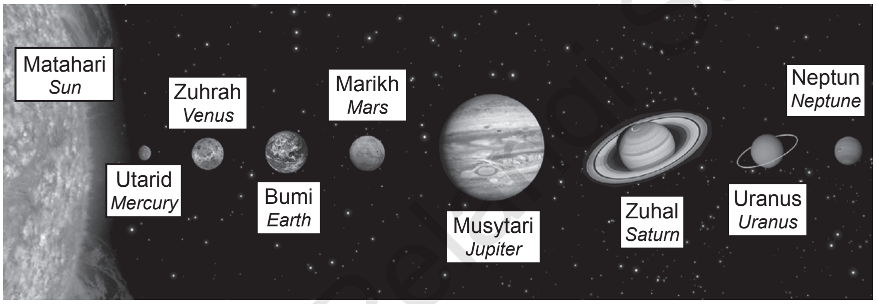
Kepentingan Mengetahui Nilai Pecutan Graviti
The Importance of Knowing the Value of the Gravitational Acceleration

1. Pecutan graviti adalah berbeza berdasarkan __jisim__ planet atau bulan dan __jarak__ dari pusat jisimnya dan permukaannya. Atas sebab itu, graviti mempunyai tarikan yang lebih __rendah__ pada jasad berjisim kecil daripada Bumi. Formula untuk pecutan graviti ialah $g = \frac{GM}{r^2}$.
The gravitational acceleration is different based on the __mass__ of the planet or moon and the __distance__ from its center of mass and its surface. For that reason, gravity has a __lesser__ pull on bodies of smaller mass than the Earth. The formula for gravitational acceleration is $g = \frac{GM}{r^2}$.

2. Contoh-contoh pecutan graviti bagi planet yang berlainan:
Examples of gravitational accelerations on different planets:

i-THINK Peta titi

Planet / *Planet*	Bumi / *Earth*	as	Musytari / *Jupiter*	as	Marikh / *Mars*
Pecutan graviti / ***Gravitational acceleration*** **(m s^{-2})**	9.81		24.79		3.71



3. Badan manusia dicipta untuk hidup dalam persekitaran dengan pecutan graviti ialah 9.81 m s^{-2}. Semasa penerokaan angkasa yang jauh dari Bumi, badan angkasawan boleh terdedah kepada keadaan graviti rendah atau graviti tinggi.
The human body is created to function in an environment with acceleration of gravity of 9.81 m s^{-2}. During space exploration far from the Earth, astronauts can be exposed to low or high gravity conditions.

4. Apakah kesan graviti terhadap tumbesaran manusia? Kita boleh melihat kesan pecutan graviti yang rendah seperti di Bulan(g_{bulan} = 1.62 m s^{-2}) kepada badan seperti di bawah.
What is the effect of gravity on human growth? We can see the effect on low gravity acceleration such as on the Moon, (g_{moon} = 1.62 m s^{-2})to the body as below.

(a) Jantung berfungsi dengan __baik__ di Bulan kerana graviti adalah __kecil__, maka lebih __senang__ untuk mengepam darah ke seluruh badan. Hal ini mungkin menyebabkan jantung semakin lemah dan lebih kecil.
The heart works __well__ on the Moon because the gravity is __smaller__ so it is __easier__ to pump blood throughout the body. This may cause the heart to become weaker and __smaller__.

(b) Oleh kerana otot dan jantung kurang digunakan, __jisim__ otot akan berkurang. Apabila angkasawan kembali ke Bumi, otot mereka mungkin tidak cukup __kuat__ untuk membolehkan mereka bergerak dengan sendiri.
As the muscles and heart are used less, the muscles lose __mass__. When astronauts return to Earth, their muscles may not be __strong__ enough to allow them to move on their own.

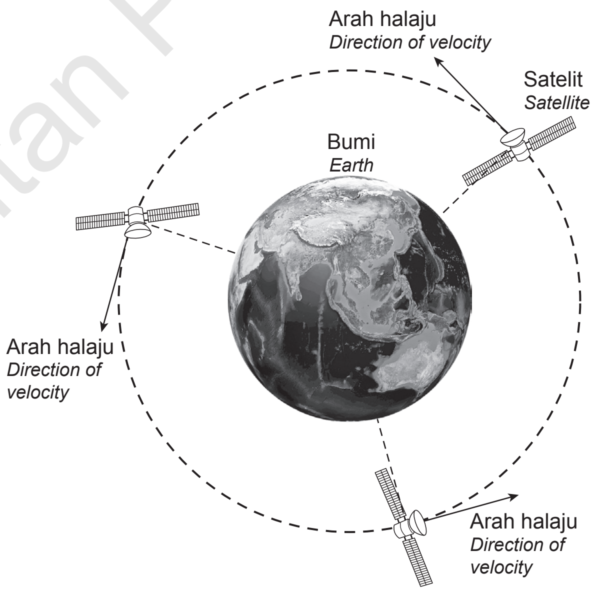
(c) Oleh kerana kekurangan mampatan pada tulang belakang, cakera di antara tulang belakang menyerap lebih banyak cecair berbanding dengan di Bumi. Hal ini menyebabkan para angkasawan semakin tinggi. Pemanjangan tulang belakang ini juga boleh menyebabkan sakit belakang.
Due to the lack of compression on the spine, the discs in the spine absorb more fluid than they do on the Earth. This causes astronauts becoming taller*. This lengthening of the spine can also cause* back pain.

(d) Darah dialirkan lebih ke bahagian atas badan dan jauh dari anggota badan yang di bawah. Semasa di angkasa, muka angkasawan akan mengalami bengkak kerana pengaliran bendalir dan darah berkurangan di kaki dan mengalir lebih ke kepala dan bahagian atas badan.
The blood is flowing more to the upper *part of the body and away from the lower limbs. While in space, astronauts suffer from* swollen *faces as fluid and blood flow decreases to the legs and flow more to the head and upper limbs.*

(e) Menurut penyelidikan NASA, tanpa graviti yang bekerja di tubuh anda, tulang anda kehilangan mineral, dengan ketumpatan turun lebih dari 1% sebulan.
According to NASA research, without the gravity working on your body, your bones lose minerals, with a density of less *than 1% a month.*

Daya Memusat dalam Sistem Gerakan Satelit dan Planet
Centripetal Force in the Motion of Satellites and Planet System

1. Rajah 1 menunjukkan kedudukan bagi sebuah satelit yang sedang mengorbit Bumi dengan laju seragam. Jasad yang sedang bergerak dalam gerakan membulat sentiasa mengalami perubahan arah gerakannya walaupun halajunya tetap.
Diagram 1 shows the position of a satellite orbiting the Earth at a uniform speed. The body that is moving in a circular *motion is constantly changing its direction of motion even when the velocity is* constant.



Rajah 1 / *Diagram 1*

2. Suatu daya memusat yang bertindak sepanjang masa ke arah pusat Bumi diperlukan untuk mengubah arah gerakan jasad.

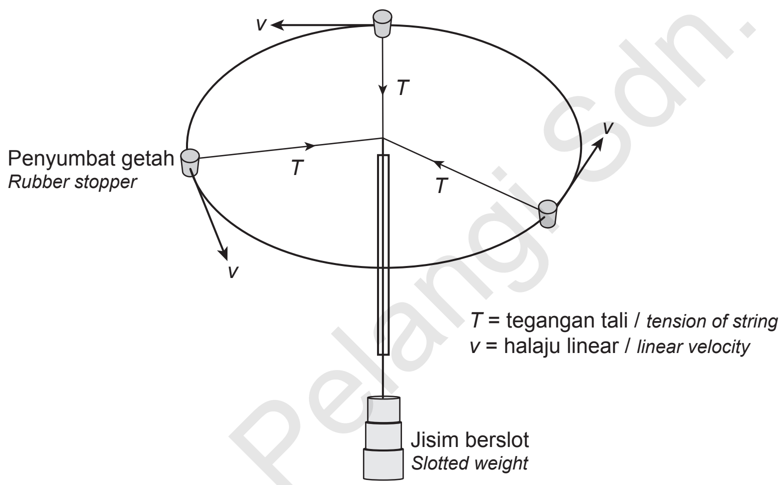
A centripetal force acting all the time toward the centre of the Earth is needed to change the direction of the motion of the body.

3. Dengan gabungan halaju seragam dan daya memusat yang bertindak ke arah satelit tersebut akan menyebabkan satelit membuat gerakan membulat.

The combination of uniform velocity and the centripetal force acting on the satellite will cause the satellite to make a circular motion.

4. Terdapat suatu daya yang bertindak ke atas satelit yang melakukan gerakan membulat dengan arah yang sentiasa menuju ke pusat Bumi itu. Daya ini dikenali sebagai daya memusat.

There is a force acting on the satellite which is moving in a circular motion in the direction of the centre of the Earth. This force is known as the centripetal force.



Rajah 2 / *Diagram 2*

5. Rajah 2 menunjukkan tegangan benang, *T* yang bertindak sebagai daya memusat untuk gerakan penyumbat getah. Magnitud daya memusat bergantung pada jisim jasad, laju gerakan membulat dan jejari bulatan.

Diagram 2 shows the tension of the thread acting as a centripetal force for the movement of the rubber stopper. The magnitude of the force depends on the mass of the body, the speed of movement circle and radius of the circle.

6. Suatu jasad dalam gerakan membulat sentiasa dalam gerakan pecutan. Dalam gerakan pecutan, sentiasa terdapat perubahan halaju sama ada dalam laju atau arah gerakan. Suatu objek dalam gerakan membulat yang seragam bergerak dengan halaju seragam tetapi mengalami pecutan akibat dari perubahan arah gerakan.

A body in circular motion is always in acceleration motion. In acceleration motion, there is always a change in velocity either in speed or direction of motion. An object in a uniform circular motion moves at a uniform velocity but experiences acceleration as a result of a change in direction.

7. Daya memusat yang bertindak dalam gerakan membulat ialah $F = \frac{mv^2}{r}$ di mana
The centripetal force acting in a circular motion is $F = \frac{mv^2}{r}$ *where*
F = Daya memusat / *Centripetal force*
m = jisim / *mass*
v = laju linear / *linear speed*
r = jejari bulatan / *radius of circle*

8. Sistem gerakan satelit dan planet adalah gerakan membulat yang sentiasa mengalami pecutan memusat, a.
Satellites and planetary motion systems are circular motions which are constantly experiencing a centripetal acceleration, a.

Maka, dengan rumus / *So, with formula* $F = ma$ dan / *and* $F = \frac{mv^2}{r}$

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

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

Di mana / *Where,*
v = halaju linear / *linear velocity*
r = jejari orbit / *radius of orbit*

Contoh 5

Daripada Rajah 2, jika penyumbat getah berjisim 0.1 kg diputarkan dengan jejari bulatan, r = 40 cm, berapakah daya memusat yang bertindak ke atas penyumbat getah apabila penyumbat getah itu sedang bergerak dengan laju 10 m s^{-1}?
From Diagram 2, if the 0.1 kg rubber stopper is rotated with a radius of circle, r = 40 cm, what is the centripetal force acting on the rubber stopper when the rubber stopper is moving at a speed of 10 m s^{-1}*?*

Penyelesaian / *Solution*:

m = 0.1 kg, r = 0.4 m, dan v = 10 m s^{-1}

Daya memusat / *Centripetal force*, $F = \frac{mv^2}{r}$, maka $F = \frac{0.1 \times 10^2}{0.4} = 25$ N

Menentukan Jisim Bumi dan Matahari Menggunakan Rumus Hukum Kegravitian Semesta Newton dan Daya Memusat

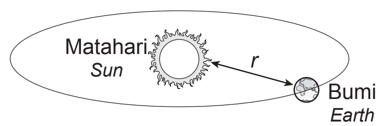
Determining the Mass of the Earth and the Sun Using Newton's Universal Law of Gravitation and Centripetal Force

1. Oleh sebab daya graviti Matahari pada Bumi adalah ___daya memusat___ yang menyebabkan gerakan membulat Bumi mengelilingi Matahari, kita boleh menggunakan Hukum Kegravitian Semesta Newton untuk mencari jisim Matahari.
Since the gravitational force of the Sun on the Earth is the ___centripetal force___ *that causes the Earth's orbit around the Sun, we can use Newton's Universal Law of Gravitation to find the mass of the Sun.*

2. Jika jisim Matahari diwakili oleh M, jisim Bumi diwakili oleh m dan jejari orbit ialah r, maka hubungan antara Hukum Kegravitian Semesta Newton dengan daya memusat ialah:
If the mass of the Sun is represented by M, the mass of the Earth is represented by m and the radius of the orbit is r, then the relationship between the Newton's Universal Law of Gravitation with centripetal force is:

$$F_{graviti} = F_{memusat}$$

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



$r = 1.5 \times 10^8$ km

Persamaan di atas boleh disusun semula untuk mendapatkan jisim Matahari.
The above equation can be rearranged to obtain the mass of the Sun.

Jisim Matahari / *The mass of the Sun*, $M = \frac{rv^2}{G}$

Di mana, nilai G ialah 6.67×10^{-11} N m² kg⁻² dan r ialah 1.5×10^{8} km dan halaju Bumi, $v = \frac{2\pi r}{T}$ dengan T ialah tempoh untuk Bumi mengorbit Matahari iaitu 365.25 hari.
Where, the value of G is 6.67×10^{-11} N m² kg⁻² and r is 1.5×10^{8} km and the velocity of the Earth, $v = \frac{2\pi r}{T}$ where T is the period of the Earth orbiting the Sun that is 365.25 days.

Contoh 6

Tentukan jisim Matahari.
Determine the mass of the Sun.

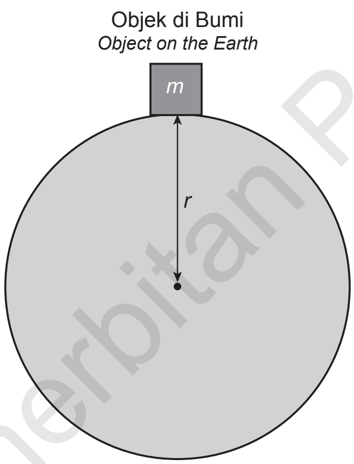
Penyelesaian / *Solution*:

$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
$r = 1.5 \times 10^{8}\ \text{km} = 1.5 \times 10^{11}\ \text{m}$
$T = 365.25$ hari × 24 jam × 60 minit × 60 saat = 31557600 saat
365.25 days × 24 hours × 60 minutes × 60 seconds= 31557600 seconds

Maka / *Hence*, $v = \frac{2\pi r}{T} = \frac{2(3.142)(1.5 \times 10^{11})}{31557600} = 2.99 \times 10^{4}\ \text{m s}^{-1}$

$$M = \frac{rv^2}{G} = \frac{(1.5 \times 10^{11})(2.99 \times 10^{4})^2}{6.67 \times 10^{-11}} = 2.0 \times 10^{30}\ \text{kg}$$

3. Jisim Bumi juga boleh ditentukan dengan menggunakan Hukum Kegravitian Semesta Newton. Jika diberi daya graviti Bumi sama dengan berat objek ke Bumi, maka
The mass of the Earth also can be determined using Newton's Universal Law of Gravitation. If given the gravitational force of the Earth equals the weight of the object to the Earth, hence



$R_E = 6.37 \times 10^{6}$ m
M_E = jisim Bumi / *mass of the Earth*
m = jisim objek / *mass of the object*
$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
$g = 9.8\ \text{m s}^{-2}$

$$F_{graviti} = \frac{GM_E m}{r^2}$$

Berat objek / *Weight of object*, $W = mg$

$$F_{graviti} = W$$
$$\frac{GM_E m}{r^2} = mg$$
$$M_e = g\frac{r^2}{G}$$

Tugasan 1

Tentukan jisim Bumi.
Determine the mass of the Earth.

$$M_e = \frac{gr^2}{G}$$

$$M_e = \frac{9.8(6.37 \times 10^{6})^2}{6.67 \times 10^{-11}} = 5.96 \times 10^{24}\ \text{kg}$$

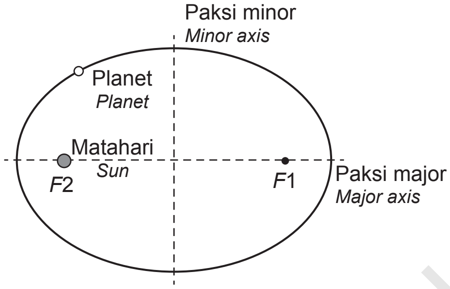
3.2 Hukum Kepler
Kepler's Laws

1. Hukum Kepler Pertama:

Hukum Kepler Pertama menyatakan bahawa orbit bagi setiap planet adalah ___elips___ dengan Matahari berada di satu daripada fokusnya.

Kepler's First Law:

Kepler's First Law states that all planets move in ___elliptical___ orbits, with the Sun at one of its focus.



Daripada model lintasan planet di atas, diperlihatkan orbit berbentuk ___elips___ yang mengelilingi Matahari. Matahari berada pada salah satu titik ___fokusnya___ yang ditanda dengan *F*1 dan *F*2. Pada keadaan tersebut, planet memiliki ___dua___ jarak iaitu jarak terhadap *F*2 dan jarak terhadap *F*1.

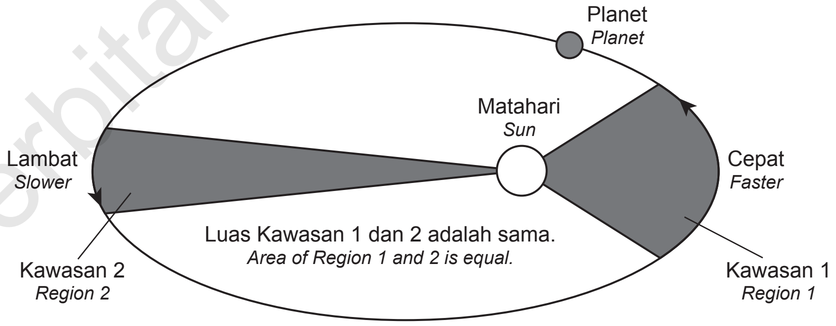
From the model of the trajectory of the planet above is shown an ___elliptical___ orbit around the Sun. The Sun is at one of its ___focal___ points marked by F1 and F2. In that case, the planet has ___two___ distances namely F2 and F1.

2. Hukum Kepler Kedua:

Hukum Kepler Kedua menyatakan bahawa satu garis yang menyambungkan planet dengan Matahari mencakupi luas yang ___sama___ dalam selang masa yang sama apabila planet bergerak dalam orbit.

Kepler's Second Law:

Kepler's Second Law states that a line that connects a planet to the Sun sweeps out equal areas in ___equal___ times when the planet moves in its orbit.



Planet akan bergerak lebih ___cepat___ ketika berada dekat dengan Matahari(kawasan 1), kemudian akan bergerak lebih ___lambat___ ketika berjarak jauh dari Matahari(kawasan 2). Hukum Kepler Kedua menyatakan bahawa luas kawasan 1 dan kawasan 2 adalah ___sama___ walau di mana pun planet berada pada orbitnya dan diukur berdasarkan interval waktu yang sama.

The planets move ___faster___ when they are near the sun (area 1), and then move ___slower___ when they are further away from the sun (area 2). Kepler's Law II states that the areas of the area 1 and area 2 are the ___same___ regardless of whether the planet is in orbit and is measured by the same time interval.

3. Hukum Kepler Ketiga:
Hukum Kepler Ketiga menyatakan bahawa kuasa dua tempoh planet adalah berkadar terus dengan kuasa tiga jejari orbitnya.
Kepler's Third Law:
The square of the period of any planet is directly proportional to the cube of the radius of its orbit.

$$T^2 \propto r^3$$

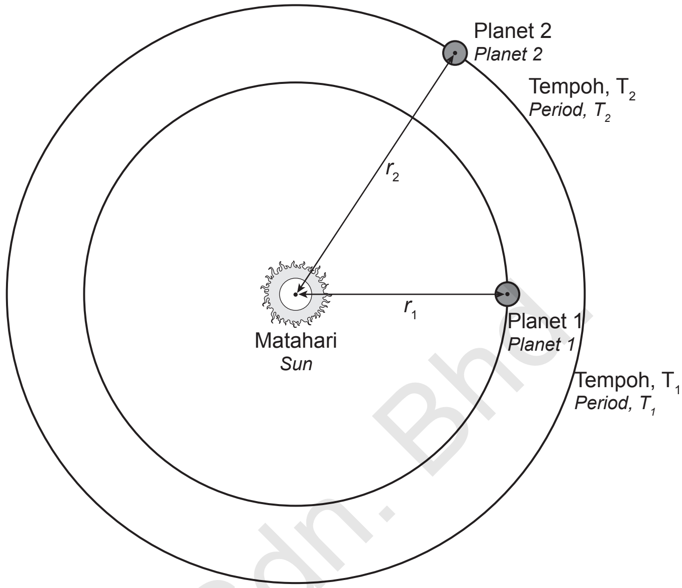
$$\frac{T_1^{\,2}}{r_1^{\,3}} = \frac{T_2^{\,2}}{r_2^{\,3}} = \text{Pemalar / } \textit{Constant}$$

T_1 = tempoh planet 1
period of the planet 1

T_2 = tempoh planet 2
period of the planet 2

r_1 = jarak planet 1 dari Matahari
the distance of planet 1 from the Sun

r_2 = jarak planet 2 dari Matahari
the distance of planet 2 from the Sun



Merumuskan Hukum Kepler Ketiga / *Express Kepler's Third Law*

1. Pertimbangkan sebuah planet dengan jisim m mengorbit dalam gerakan hampir membulat mengelilingi Matahari berjisim M. Kekuatan daya memusat bersih yang bertindak ke atas planet yang mengorbit ini diberikan oleh hubungan berikut:
Consider a planet with mass m to orbit in a nearly circular motion around the Sun of mass M. The net centripetal force acting upon this orbiting planet is given by the following relationship:

$$\text{Daya memusat / } \textit{Centripetal force, } F_C = m\frac{v^2}{r} \quad \cdots\cdots ❶$$

Kekuatan daya memusat bersih ini adalah hasil daya graviti yang menarik planet ke arah Matahari dan boleh diwakili sebagai
This net centripetal force is the result of the gravitational force that attracts the planet towards the Sun and can be represented as

$$\text{Daya graviti / } \textit{Gravitational force, } F_G = G\frac{Mm}{r^2} \quad \cdots\cdots ❷$$

Oleh kerana $F_C = F_G$, ungkapan di atas untuk daya memusat dan daya graviti adalah sama. Oleh itu,
Since $F_C = F_G$, the above expressions for centripetal force and gravitational force are equal. Thus,

$$m\frac{v^2}{r} = G\frac{Mm}{r^2}$$

$$v^2 = \frac{GM}{r} \quad \cdots\cdots ❸$$

Oleh kerana halaju sesuatu objek dalam orbit hampir bulat boleh dianggarkan sebagai
Since the velocity of an object in nearly circular orbit can be approximated as

$$v = \frac{2\pi r}{r} \quad \cdots\cdots ❹$$

Gantikan ❹ dalam ❸, / *Substitute ❹ into ❸,*

$$\left(\frac{2\pi r}{T}\right)^2 = \frac{GM}{r}$$

$$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$$

- Bagi sistem planet dan Matahari, M ialah jisim Matahari.
For planets and the Sun system, M is the mass of the Sun.
- Bagi sistem satelit dan Bumi, M ialah jisim Bumi.
For satellite and the Earth system, M is the mass of the Earth.

3. Mengikut persamaan di atas, nilai sebelah kanan adalah sentiasa sama bagi setiap planet tanpa mengetahui jisim planet tersebut. Maka, boleh dirumuskan nisbah $\frac{T^2}{r^3}$ adalah sama untuk semua planet jika daya yang memegang planet di orbit mereka adalah daya graviti.
According to the equation above, the value on the right is always the same for every planet without knowing the mass of the planet. It can be concluded that the ratio $\frac{T^2}{r^3}$ is the same for all planets if the force holding the planet in their orbit is gravitational force.

$$k = \frac{T^2}{r^3} \qquad k = \text{pemalar / } \textit{constant}$$
$$T^2 = kr^3$$
$$k = \frac{4\pi^2}{GM}$$

Menyelesaikan Masalah Menggunakan Rumus Hukum Kepler Ketiga
Solve Problems Using Kepler's Third Law

$$\frac{T_1^{\,2}}{r_1^{\,3}} = \frac{T_2^{\,2}}{r_2^{\,3}} = \text{Pemalar / } \textit{Constant}$$

1. Bagi planet yang mengorbit Matahari / *For a planet that orbits the Sun;*
r = jarak di antara pusat planet dengan pusat Matahari
the distance between the centre of the planet and the centre of the Sun.

2. Bagi satelit yang mengorbit Bumi / *For satellites orbiting the Earth;*
$r = R + h$ (jarak di antara pusat Bumi dengan pusat satelit / *distance between centre of the Earth and satellite centre*)
R = jejari Bumi / *Earth radius* = 6370 km
h = ketinggian satelit dari permukaan Bumi / *satellite elevation from the Earth's surface*

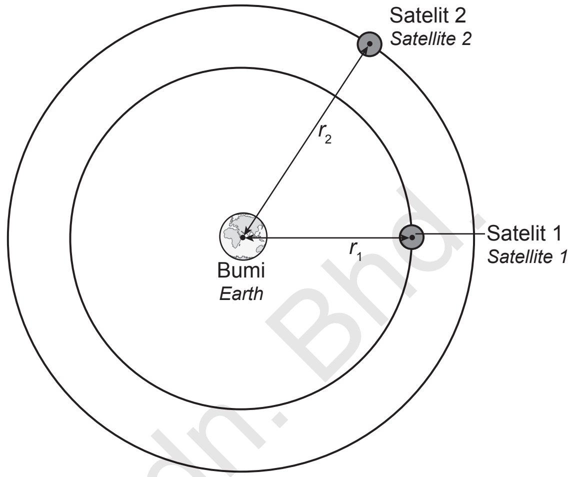
Contoh 8

Tentukan nisbah $\frac{T^2}{r^3}$ untuk planet berikut yang mengorbit Matahari.
Determine the ratio $\frac{T^2}{r^3}$ for the following planets orbiting the Sun.

Planet *Planet*	Tempoh masa (hari) *Period (days)*	Jejari (km) *Radius (km)*	$\frac{T^2}{r^3}$ (s² m⁻³)
Merkuri *Mercury*	87.97	57.9 juta / *million*	$\frac{(87.97 \times 24 \times 60 \times 60)^2}{(57.9 \times 10^6 \times 10^3)^3} = 2.98 \times 10^{-19}$
Zuhrah *Venus*	224.70	108.2 juta / *million*	(a) $\frac{(224.9 \times 24 \times 60 \times 60)^2}{(108.2 \times 10^6 \times 10^3)^3} = 2.98 \times 10^{-19}$
Musytari *Jupiter*	4,332.82	778.3 juta / *million*	(b) $\frac{(4332.82 \times 24 \times 60 \times 60)^2}{(778.3 \times 10^6 \times 10^3)^3} = 2.98 \times 10^{-19}$
Bumi *Earth*	365.26	149.6 juta / *million*	(c) $\frac{(365.26 \times 24 \times 60 \times 60)^2}{(149.6 \times 10^6 \times 10^3)^3} = 2.98 \times 10^{-19}$

Tugasan 2

Rajah 1 menunjukkan Satelit 1 mengorbit Bumi dengan tempoh mengorbit T_1 selama 24 jam atau 86 400 saat. Jika jarak Bumi ke Satelit 1 ialah 3.59×10^7 m dan jejari Bumi ialah 6370 km,
Figure 1 shows the Satellite 1 orbiting the Earth with period of orbit T_1 for 24 hours or 86 400 s. If the Earth's distance to Satellite 1 is 3.59×10^7 m and the radius of the Earth is 6370 km,



Rajah 1 / *Diagram 1*

(a) cari nilai nisbah $\frac{T^2}{r^3}$ untuk Satelit 1.
find the value of ratio $\frac{T^2}{r^3}$ for Satellite 1.

(b) Jika jarak Bumi ke Satelit 2 ialah 3.8×10^7 m, cari tempoh mengorbit T_2 Bumi untuk satelit 2.
If the Earth's distance to satellite 2 is 3.8×10^7 m, find the orbital period, T_2 of the Earth for satellite 2.

Penyelesaian / *Solution*:

(a) Jarak Satelit 1 ke pusat bumi,
Distance of Satellite 1 to the Earth's centre,

$r = R + h = 6370 \text{ km} + 3.59 \times 10^7 \text{ m} = 3.59 \times 10^7 \text{ m} + 6.370 \times 10^6 = 4.227 \times 10^7 \text{ m}$

$$\frac{T^2}{r^3} = \frac{86400^2}{(4.227 \times 10^7)^3} = 9.88 \times 10^{-14} \text{ s}^2 \text{ m}^{-3}$$

(b) Untuk kedua- dua satelit yang mengorbit Bumi, nilai $\frac{T^2}{r^3}$ adalah sama (Hukum Kepler Ketiga).
Maka, untuk Satelit 2, nilai $\frac{T^2}{r^3} = 9.88 \times 10^{-14} \text{ s}^2 \text{ m}^{-3}$.
Jarak dari Satelit 2 ke pusat Bumi ialah
For both satellites orbiting the Earth, the value $\frac{T^2}{r^3}$ is the same (Kepler's Third Law).
Hence, for Satellite 2, the value $\frac{T^2}{r^3} = 9.88 \times 10^{-14} \text{ s}^2 \text{ m}^{-3}$.
The distance from Satellite 2 to the centre of the Earth is

$= 3.8 \times 10^7 \text{ m} + 6370 \text{ km} = 3.80 \times 10^7 \text{ m} + 6.370 \times 10^6 = 4.437 \times 10^7 \text{ m}$

$$\frac{T^2}{(4.437 \times 10^7)^3} = 9.88 \times 10^{-14}$$

$$T^2 = 9.88 \times 10^{-14} \times (4.437 \times 10^7)^3 = 8.63 \times 10^9$$

$$T = 9.29 \times 10^4 \text{ s}$$

3.3 Satelit Buatan Manusia
Man-made Satellites

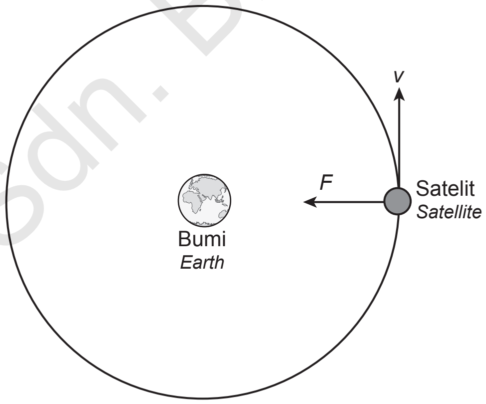
Orbit Satelit / *Satellite Orbit*

1. Satelit adalah objek buatan manusia yang mengorbit ___Bumi___. Satelit digunakan untuk mengkaji ___Bumi___, ___komunikasi___, dan juga untuk memerhatikan ___alam semesta___. Satelit pertama adalah Soviet Sputnik 1, yang dilancarkan pada tahun 1957. Sejak itu, banyak negara telah melancarkan satelit, dengan lebih daripada 3,000 satelit yang sedang beroperasi di sekitar Bumi.
Satellites are man-made objects orbiting the ___Earth___. Satellites are used to study the ___Earth___, for ___communication___, and to observe the ___universe___. The first satellite was the Soviet Sputnik 1, launched in 1957. Since then, many countries have launched satellites, with more than 3,000 satellites operating around the Earth.

2. Satelit-satelit tersebut mengorbit di sekitar Bumi dalam orbit yang berukuran dari 240 km ke 36,200 km. Satelit berada di orbit Bumi yang rendah, bergerak dengan halaju 27,400 km per jam supaya tidak dapat ditarik semula ke atmosfera Bumi.
These satellites orbit around the Earth in orbit ranging from 240 km to 36,200 km. Satellites are in low Earth orbit, traveling at very fast speed of 27,400 km per hour so they will not be pull back to the Earth's atmosphere.

3. Satelit sentiasa dalam gerakan membulat dengan halaju (v), dengan daya tarikan graviti (F) antara satelit dan Bumi. Satelit yang mengorbit lebih dekat dengan Bumi bergerak dengan kelajuan yang tinggi. Satelit yang mengorbit lebih jauh dari Bumi bergerak dengan kelajuan yang lebih rendah.
The satellites are always in a circular motion with velocity (v), with the gravitational force (F) between the satellites and the Earth. The satellite orbiting closer to the Earth is moving at high speed. The satellite orbiting farther away from the Earth move at lower speeds.

4. Rajah di atas menunjukkan sebuah satelit mengorbit Bumi. Jika jisim Bumi diwakili dengan M, jisim satelit diwakili dengan m dan jejari orbit satelit ialah r, maka halaju orbit diterbitkan menggunakan hubungan antara Hukum Kegravitian Semesta Newton dengan daya memusat.
The diagram above shows a satellite orbiting the Earth. If the mass of the Earth is represented by M, the mass of the satellite is represented by m, and the satellite orbital radius is r, hence orbital velocity is derived using the relationship between the Newton's Universal Law of Gravitation with centripetal force.



$$F_{Memusat} = F_{Graviti}$$
$$F_{Centripetal} = F_{Gravity}$$
$$\frac{mv^2}{r} = G\frac{Mm}{r^2}$$
$$v^2 = G\frac{M}{r}$$
$$v = \sqrt{\frac{GM}{r}}$$

Halaju orbit, $v = \sqrt{\frac{GM}{r}}$ ialah halaju yang diperlukan satelit yang bergerak untuk mengorbit bumi dalam orbit membulat.

The orbital velocity, $v = \sqrt{\frac{GM}{r}}$ is the velocity required by a moving satellite to orbit the Earth in a circular orbit.

Satelit Geopegun dan Bukan Geopegun / *Geostationary and Non-geostationary Satellites*

1. Satelit geopegun adalah satelit mengorbit Bumi dalam orbit geopegun pada kelajuan yang sama dengan Bumi berputar pada garis latitud yang sama, secara khusus garis latitud ekuator. Orbit geopegun mengorbit dalam jarak lebih kurang 35,786 km di atas Bumi. Sebuah satelit yang mengorbit dalam orbit geopegun berada di tempat yang sama di langit, dan secara langsung di atas kawasan yang sama pada setiap masa.
Geostationary satellites are satellites orbiting the Earth in geostationary orbit at the same speed as the Earth rotating at the same latitude, specifically the equatorial latitude. Geostationary orbits orbit around 35,786 kilometres above the Earth. A satellite orbiting in geostationary orbit in the same spot in the sky, and directly above the same area at all times.

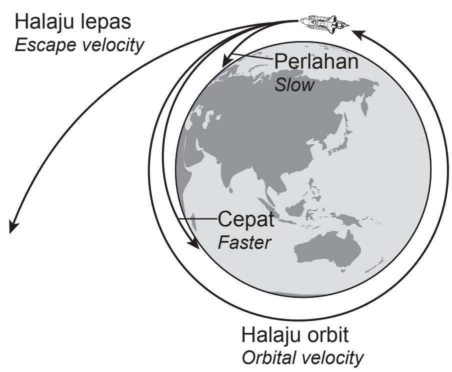
2. Satelit geopegun biasanya digunakan untuk pelbagai tujuan, seperti sistem komunikasi, Internet, TV kabel penyiaran, Sistem Posisi Global, isyarat radio, dan ramalan cuaca.
Geopegun satellites are commonly used for a variety of purposes, such as communications systems, the Internet, broadcasting cable TV, Global Position System, radio signals and weather forecasts.

3. Secara umumnya, kita boleh meletakkan satelit dalam tiga jenis orbit.
Generally we can place satellites in three orbits
   (i) Orbit geopegun, kira-kira 35,786 km atas bumi
   Geostationary Orbits, about 35.786 km above the Earth
   (ii) Orbit Pertengahan Bumi (MEO), kira-kira 8000 km atas bumi
   Middle-Earth Orbit MEO), about 8000 km above the earth
   (iii) Orbit Rendah Bumi, dari 160 hingga 2000 km di atas Bumi. Jadi satelit bukan geopegun adalah satelit yang tidak diletakkan dalam orbit geopegun.
   Low Earth Orbit, from 160 to 2000 km above the Earth. So a non-geostationary satellites are satellites that are same placed in geostationary orbit.

Halaju Lepas / *Escape Velocity*

1. Halaju lepas, v adalah halaju minimum yang diperlukan suatu objek di permukaan Bumi untuk mengatasi daya graviti dan terlepas ke angkasa. Sebagai contoh, sebuah roket yang masuk ke angkasa perlu mencapai halaju lepas untuk bebas dari Bumi.
The escape velocity, v is the minimum velocity required by an object on the Earth surface to overcome gravitational force and escape to space. For example, a rocket that went into the space need to achieve escape velocity to be free of the Earth.

2. Halaju lepas akan dicapai apabila tenega kinetik minimum yang dibekalkan kepada objek telah mengatasi tenaga keupayaan graviti.
Escape velocity is achieved when the minimum kinetic energy supplied to the object overcomes the gravitational potential energy.



Tenaga Keupayaan + Tenaga Kinetik Minimum = 0
Potential Energy + Minimum Kinetic Energy = 0

3. Objek berjisim m, boleh melepaskan diri daripada tarikan graviti Bumi berjisim, M pada jarak dari pusat Bumi, r, hanya apabila tenaga kinetiknya sama dengan tenaga keupayaan graviti. Tenaga kinetik objek tersebut dengan jisim, m yang bergerak dengan halaju, v ialah $EK = \frac{1}{2}mv^2$. Tenaga keupayaan graviti objek itu, diberikan dengan rumus
An object with mass of m, can release from the gravitational pull of a large object with mass of M at the distance from the centre of the Earth, r, only when its kinetic energy equals the gravitational potential energy. The kinetic energy of an object with mass m moving with velocity v can be given by $KE = \frac{1}{2}mv^2$. The gravitational potential energy of this object can be given by the formula

$$U = \frac{GMm}{r}$$

G = pemalar kegravitian / *gravitational constant* ($G = 6.67 \times 10^{-11}$ N m^2 kg^{-2})

4. Menyamakan kedua-dua persamaan, kita dapat: $\frac{1}{2}mv^2 = \frac{GMm}{r}$
Equating both expressions, we found,

Maka, halaju lepas / *Hence, escape velocity,* $v = \sqrt{\frac{2GM}{r}}$

G = pemalar kegravitian / *gravitational constant* = 6.67×10^{-11}
M = jisim planet atau jasad / *mass of planet or body*
r = jejari planet atau jasad / *radius of planet or body*

Contoh 10

Jejari Bumi adalah 6.4×10^6 m, dan jisim Bumi adalah 5.97×10^{24} kg. Apakah halaju lepas dari permukaan Bumi?
The radius of the Earth is 6.4×10^6 m, and the mass of the Earth is 5.97×10^{24} kg. What is the escape velocity from the surface of the Earth?
($g = 9.8$ m s^{-2}, $G = 6.67 \times 10^{-11}$)

Penyelesaian / *Solution*:

Untuk mencari halaju lepas daripada permukaan Bumi,
To find escape velocity from the surface of the Earth,

$$v = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2(6.67 \times 10^{-11})(5.98 \times 10^{24})}{6.4 \times 10^6}} = 11164 \text{ m s}^{-1} = 11.2 \text{ km s}^{-1}$$

Kaedah alternatif / *Alternative method*

$$v = \sqrt{\frac{2GM}{R}} \text{ dan / and } g = \frac{GM}{R^2}$$

$$v = \sqrt{2gR}$$
$$= \sqrt{2 \times 9.8 \times 6.4 \times 10^6}$$
$$= 11164 \text{ m s}^{-1} = 11.2 \text{ km s}^{-1}$$

Tugasan 3

Jika jejari Bulan adalah 1.74×10^6 m, dan jisim Bulan ialah 7.35×10^{22} kg, apakah halaju lepas yang diperlukan untuk meninggalkan Bulan?
If the radius of the Moon is 1.74×10^6 m, and the mass of the Moon is 7.35×10^{22} kg, what is the escape velocity needed to reach in order to leave the Moon?

The escape velocity / *Halaju lepas*, $v = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2(6.67 \times 10^{-11})(7.35 \times 10^{22})}{1.74 \times 10^6}} = 2374 \text{ m s}^{-1}$

PRAKTIS SPM 3

Soalan Objektif

1. Hukum Kegravitian Semesta Newton menyatakan daya graviti antara dua objek berkadar terus dengan hasil darab jisim kedua-dua jasad itu dan berkadar songsang dengan
Newton's Universal Law of Gravitation states that the gravitational force between two objects is directly proportional to the product of masses of the two objects and inversely proportional to

A jarak di antara dua objek.
distance between the two objects.

B kuasa dua hasil darab jejari jasad.
square of the product of the body's radii.

(C) kuasa dua jarak di antara pusat dua jasad.
square of the distance between the centres of the two objects.

D kuasa tiga jarak di antara dua jasad dari pusat.
cube of the distance between the centres of the two objects.

2. Sekiranya jarak di antara dua zarah adalah dua kali ganda, apakah yang berlaku kepada daya graviti di antara dua zarah itu?
If the distance between two particles is doubled, what happened to the gravitational force between them?

(A) Dikurangkan kepada satu perempat daripada nilai asal
Is reduced to one-fourth of the original value

B Dikurangkan kepada separuh daripada nilai asal
Is reduced to half of the original value

C Menjadi dua kali ganda
Becomes double

D Menjadi empat kali ganda
Becomes four times

3. Jika jisim Bumi menjadi empat kali, apakah yang akan berlaku kepada nilai *g*?
If the mass of the Earth becomes four times, what will happen to the value of g?

A Double
Dua kali ganda

B Tiada kesan
No effect

(C) Empat kali
Four times

D Separuh
Half

4. Jika jejari Bumi itu dikurangkan dan jisimnya tetap sama, apa yang berlaku kepada pecutan disebabkan oleh graviti di permukaan Bumi?
If the radius of the Earth were to be reduced and its mass were to remain the same, what happens to the acceleration due to gravity on the surface of the Earth?

A Tetap sama
Remain the same

B Menurun
Decreases

C Sifar
Zero

(D) Bertambah
Increases

5. Antara berikut, yang manakah boleh diaplikasikan oleh Hukum Kegravitian Semesta?
Which of the following can be applied by the Universal Law of Gravitation?

A Planet di sekitar Matahari.
The planets around the Sun.

B Bumi dan bulan.
The earth and the moon.

C Bumi dan epal.
The earth and the apple.

(D) Sebarang pasangan jasad.
Any pair of bodies.

6. Apakah berat sesuatu objek dalam satelit yang mengorbit di sekeliling Bumi?
What is the weight of an object in a satellite orbiting around the Earth?

A Berat sebenar
Actual weight

B Kurang daripada berat sebenar
Less than the actual weight

C Lebih besar daripada berat sebenar
Greater than the actual weight

(D) Sifar
Zero

7. Apakah yang menyebabkan pergerakan Bulan pada orbitnya?
What is the reason for the motion of the Moon on its orbit?

A Daya graviti yang dikenakan di Bumi oleh Bulan.
The gravitational force exerted on the Earth by the Moon.

B Daya graviti yang dikenakan oleh Matahari.
The gravitational force exerted by the Sun.

C Daya graviti yang diterapkan oleh planet-planet.
The gravitational force exerted by the planets.

(D) Daya graviti yang dikenakan pada Bulan oleh Bumi.
The gravitational force exerted on the Moon by the Earth.

8. Suatu objek dengan berat 200 N berada di permukaan Bumi. Cari beratnya jika ia adalah 1×10^6 m di atas permukaan. Diberikan $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, $M_{Bumi} = 6.0 \times 10^{24}$ kg, $R_{Bumi} = 6.4 \times 10^6$ m.
An object weighs 200 N on the surface of the Earth. Find its weight if it was 1×10^6 m above the surface.
Given, $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, $M_{Earth} = 6.0 \times 10^{24}$ kg, $R_{Earth} = 6.4 \times 10^6$ m.

A 73.1 N
B 146.2 N
C 218.2 N
D 292.2 N

9. Daya graviti pada wanita 50 kg ialah 500 N. Wanita itu juga mengenakan daya tarikan graviti ke Bumi. Berapa besar daya ini?
The force of gravity on a 50 kg woman is 500 N. The woman also exerts a gravitational force on the Earth. How large a force is this?

A 0 N
B 245 N
C 500 N
D 980 N

10. Daya graviti antara dua jisim ialah 120 N apabila jaraknya ialah 20 m. Jika jarak di antara dua jisim berubah dan daya graviti menjadi 480 N, berapakah jarak baharu di antara dua jisim tersebut?
The gravitational force between two masses was 120 N when they were 20 m apart. If the distance between them was changed and the gravitational force became 480 N, how far apart were they then?

A 2 m
B 8 m
C 10 m
D 15 m

11. Satu garisan yang dilukis dari sebuah planet ke Matahari sentiasa meliputi kawasan dengan luas yang sama dalam selang masa yang sama, apabila planet itu bergerak lebih jauh dari Matahari, planet akan bergerak dengan
A line drawn from a planet to the Sun always sweeps over equal areas in equal intervals of time When the planet moves further from the Sun, the planet will move

A cepat
faster
B lambat
slower
C tetap pada setiap titik
constant at every point
D tiada satu pun di atas
none of the above

12. Tempoh satelit geopegun ialah
The period of geostationary artificial satellite is

A 24 jam
24 hours
B 6 jam
6 hours
C 48 jam
48 hours
D 12 jam
12 hours

13. Tempoh satelit di orbit bulatan berjejari R adalah *T*. Tempoh satelit lain dalam orbit bulat berjejari 4*R* adalah
The period of a satellite in a circular orbit of radius R is T. The period of another satellite in circular orbit of radius 4R is

A $8T$
B $\frac{T}{8}$
C $2T$
D $\frac{T}{4}$

14. Jarak Zuhrah dan Zuhal dari Matahari masing-masing ialah hampir 10^{11} m dan 10^{12} m. Dengan anggapan bahawa kedua-dua planet bergerak dalam orbit bulat, nisbah tempoh kedua-dua planet ialah
The distance of Venus and Saturn from the Sun are nearly 10^{11} m and 10^{12} m respectively. Assuming that they move in circular orbits, their periodic times would be in the ratio of

A $0.1\sqrt{0.1}$
B 100
C $10\sqrt{10}$
D 10000

15. Hukum Kepler Ketiga menyatakan
Kepler's Third Law states

A orbit planet di sekeliling Matahari adalah elips, dengan matahari pada satu fokus.
the orbit of a planet around the sun is an ellipse, with the sun at one focus.
B paksi semimajor adalah sama dengan jarak purata planet dari Matahari.
the semimajor axis is equal to the planet's average distance from the Sun.
C kuasa dua tempoh orbit planet adalah berkadar terus dengan kuasa tiga jejari orbitnya.
the square of the orbital period of a planet is proportional to its orbital radius.
D tiada jawapan betul.
none of these answers is correct.

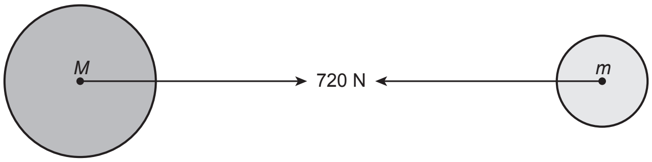
16. Jika *r* mewakili jejari orbit sebuah satelit berjisim *m* yang bergerak dalam orbit membulat di sekeliling sebuah planet berjisim *M*, halaju satelit itu diberikan oleh
If r represents the radius of the orbit of a satellite of mass m moving round a planet of mass M, the velocity of the satellite is given by

A $v = \sqrt{(GM/r)}$
B $v^2 = \frac{GMm}{r}$
C $v = \frac{GMm}{r^2}$
D $v^2 = \frac{gM}{R}$

Soalan Struktur

Bahagian A

1. Rajah 1 menunjukkan dua jasad dengan jisim *M* dan *m* masing-masing. Kedua-dua jasad itu berada di angkasa lepas.
Diagram 1 shows two bodies with mass of M and m respectively. Both bodies are placed in space.



Rajah 1 / *Diagram 1*

Kekuatan daya tarikan graviti antara dua jisim adalah 720 N.
The strength of gravitational force between the two bodies is 720 N.

(a) Berdasarkan Hukum Kegravitian Semesta Newton, lengkapkan ayat berikut.
Based on Newton's Universal Law of Gravitation, complete the following sentence.

Semakin besar jisim kedua-dua jasad, semakin ____besar____ daya tarikan graviti.

Daya tarikan graviti ____berkurang____ apabila jarak di antara kedua-dua jasad bertambah.

The greater the mass of both bodies, the ____greater____ the force of gravitational attraction.

The force of gravitational attraction ____decreases____ as the distance between the two bodies increases.

[2 markah / *marks*]

(b) Apakah nilai daya tarikan graviti yang akan berlaku jika satu daripada jisim menjadi dua kali ganda dan jarak di antara dua jasad tidak berubah?
What will be the force of gravitational attraction if one of the mass is doubled and the distance between them unchanged?

$$F = G\frac{Mm}{R^2}$$

$$720 = G\frac{Mm}{R^2}$$

Jika satu daripada jisim menjadi dua kali ganda dan jarak di antara dua jasad tidak berubah,
If one mass is doubled and the distance remains the same,

$$F_{new} = G\frac{2Mm}{R^2} = G\frac{2Mm}{R^2} = 2G\frac{Mm}{R^2} = 2(720) = 1440 \text{ N}$$

[2 markah / *marks*]

(c) Apakah nilai daya tarikan graviti yang akan berlaku jika satu daripada jisim menjadi setengah kali ganda dan jarak di antara dua jasad bertambah tiga kali ganda?
What will be the force if one mass is halved and the distance between them is tripled?

$$F = G\frac{Mm}{R^2}$$

$$720 = G\frac{Mm}{R^2}$$

Jika satu daripada jisim menjadi separuh dan jarak menjadi tiga kali ganda,
If one of the mass is halved and the distance is tripled,

$$F_{new} = G\frac{\frac{1}{2}Mm}{(3R)^2} = G\frac{\frac{1}{2}Mm}{9R^2} = \frac{1}{18}G\frac{Mm}{R^2} = \frac{1}{18}(720) = 40 \text{ N}$$

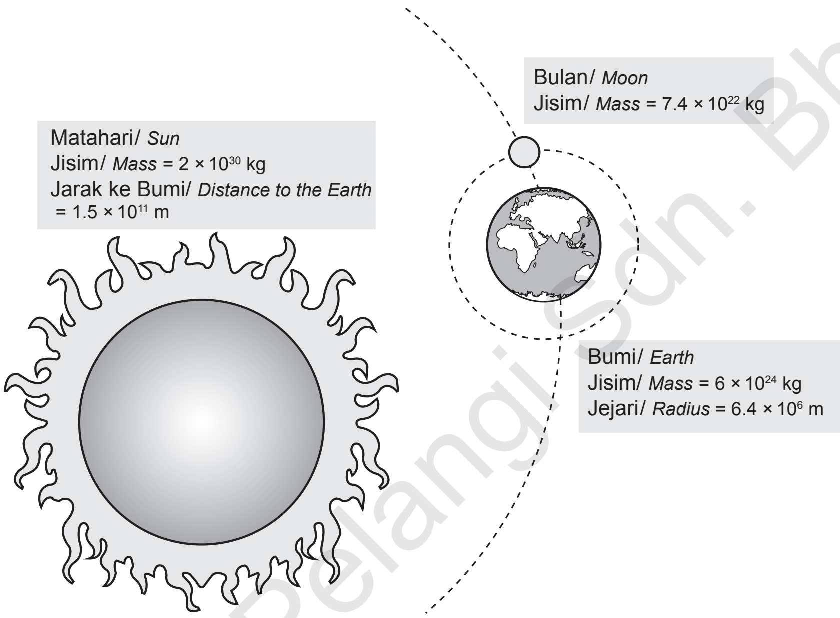
[2 markah / *marks*]

(d) Tanpa menggunakan pengiraan, nyatakan apa yang berlaku kepada magnitud daya tarikan graviti jika jarak di antara dua jasad dikurangkan menjadi separuh?
Without using calculation, state what happened to the magnitude of gravitational force attraction if the distance between two bodies is halved?

Bertambah empat kali ganda / *Become quadruple.*

[1 markah / *mark*]

2. Rajah 2 di bawah menunjukkan kedudukan Matahari, Bumi dan Bulan.
Diagram 2 below shows the position of the Sun, Earth and Moon



Rajah 2 / *Diagram 2*

(a) Nyatakan Hukum Kegravitian Semesta Newton.
State the Newton's Law of Universal Gravitation.

Hukum Kegravitian Semesta Newton menyatakan bahawa daya graviti antara dua jasad adalah berkadar terus dengan hasil darab jisim kedua-dua jasad dan berkadar songsang dengan kuasa dua jarak di antara pusat dua jasad tersebut.

Newton's law of universal gravitation states that the gravitational force between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

[2 markah / *marks*]

(b) Ungkapkan Hukum Kegravitian Semesta Newton dalam bentuk formula.
Express Newton's Law of Universal Gravitation in formula form.

$F = G\frac{Mm}{R^2}$

[1 markah / *mark*]

(c) Hitungkan daya graviti antara sebiji buah kelapa berjisim 1 kg dan Bumi.
Calculate gravitational force between a 1 kg coconut and the Earth.
(Diberikan / *Given* $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2})

Jisim kelapa / *Mass of the coconut* = 1.0 kg
Jisim Bumi / *Mass of the Earth* = 5.97×10^{24} kg
Jarak di antara pusat kelapa dan pusat Bumi = 6.4×10^6 m
Distance between the centre of coconut and the centre of the Earth

$$F = G\frac{Mm}{R^2} = 6.67 \times 10^{-11} \times \frac{5.97 \times 10^{24} \times 1}{(6.4 \times 10^6)^2} = 9.72 \text{ N}$$

[1 markah / *mark*]

(d) Hitungkan daya graviti antara Bumi dan Matahari.
Calculate gravitational force between the Earth and the Sun.
(Diberikan / *Given* $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2})

Jisim matahari / *Mass of the Sun* = 2×10^{30} kg
Jisim Bumi / *Mass of the Earth* = 5.97×10^{24} kg
Jarak di antara pusat matahari dan pusat Bumi = 1.5×10^{11} m
Distance between the centre of the Sun and the centre of the Earth

$$F = G\frac{Mm}{R^2} = 6.67 \times 10^{-11} \times \frac{5.97 \times 10^{24} \times 2 \times 10^{30}}{(1.5 \times 10^{11})^2} = 3.54 \times 10^{22} \text{ N}$$

[1 markah / *mark*]

(e) Daya graviti antara Bumi dan Bulan ialah 2.0×10^{20} *N*. Berapakah jarak di antara pusat Bumi dan pusat Bulan?
Gravitational force between the Earth and the Moon is 20×10^{20} N. What is the distance between the centre of the Earth and the centre of the Moon?

Jisim bulan / *Mass of the Moon* = 7.4×10^{22} kg
Jisim Bumi / *Mass of the Earth* = 5.97×10^{24} kg
Jarak di antara pusat Bumi dan pusat Bulan / *Distance between the centre of the Earth and the centre of the Moon* = *R* m

$$F = G\frac{Mm}{R^2}$$

$$2.0 \times 10^{20} = 6.67 \times 10^{-11} \times \frac{5.97 \times 10^{24} \times 7.4 \times 10^{22}}{R^2}$$

$$R^2 = 6.67 \times 10^{-11} \times \frac{5.97 \times 10^{24} \times 7.4 \times 10^{22}}{2.0 \times 10^{20}} = 1.48 \times 10^{17}$$

$$R = 3.84 \times 10^8 \text{ m}$$

[1 markah / *mark*]

3. Jadual berikut menunjukkan maklumat beberapa planet yang diperolehi pelajar.
The following table shows the information of a few planets obtained by the students.

Planet / *Planet*	**Jisim / *Mass***	**Jejari / *Radius***
(a) Bumi / *Earth*	6.0×10^{24} kg	6.4×10^6 m
(b) Marikh / *Mars*	6.4×10^{23} kg	3.4×10^6 m
(a) Uranus / *Uranus*	8.7×10^{25} kg	2.5×10^7 m

(a) Cari magnitud daya graviti yang dialami oleh suatu objek 50 kg apabila berada di atas permukaan setiap satu daripada planet berikut.
Find the magnitude of the gravitational force a 50 kg object would experience when on the surface of each of the following planets.
(Diberikan / *Given* $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2})

(i) Daya graviti Bumi
Gravitational force of the Earth

$$F = G\frac{Mm}{R^2}$$

$$F = 6.67 \times 10^{-11} \times \frac{6 \times 10^{24} \times 50}{(6.4 \times 10^6)^2} = 488.5 \text{ N}$$

[1 markah / *mark*]

(ii) Daya graviti Marikh
Gravitational force of the Mars

$$F = G\frac{Mm}{R^2}$$

$$F = 6.67 \times 10^{-11} \times \frac{6.4 \times 10^{23} \times 50}{(3.4 \times 10^6)^2} = 184.6 \text{ N}$$

[1 markah / *mark*]

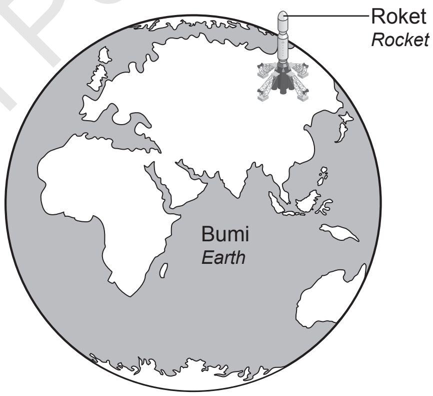
(iii) Daya graviti Uranus
Gravitational force of the Uranus

$$F = G\frac{Mm}{R^2}$$

$$F = 6.67 \times 10^{-11} \times \frac{8.7 \times 10^{25} \times 50}{(2.5 \times 10^7)^2} = 464.23 \text{ N}$$

[1 markah / *mark*]

(b) Rajah 3 di bawah menunjukkan sebuah roket berada di tapak pelancaran.
Diagram 3 below shows a rocket at rocket launch site.



Rajah 3 / *Diagram 3*

(i) Jika roket yang berada di tapak pelancaran mengalami daya graviti 5.0×10^5 N, berapakah jisim roket itu?
If the rocket at the launch site experienced gravitational force of 5.0×10^5 N, what is the mass of the rocket?

$$F = G\frac{Mm}{R^2}$$

$$5.0 \times 10^5 = 6.67 \times 10^{-11} \times \frac{6.4 \times 10^{24} \times m}{(6.4 \times 10^6)^2}$$

$$m = \frac{5 \times 10^5 \times (6.4 \times 10^6)^2}{6.67 \times 10^{-11} \times 6.4 \times 10^{24}} = 47976 \text{ kg}$$

[2 markah / *marks*]

(ii) Jika roket berada 100 km dari permukaan Bumi, apakah perubahan terhadap daya graviti yang bertindak ke atas roket tersebut?
If the rocket at 100 km above the Earth surface, what is the change of gravitational force acted on the rocket?

(Bertambah / *Increase*, berkurang / *decrease*, sama / *same*)

[1 markah / *mark*]

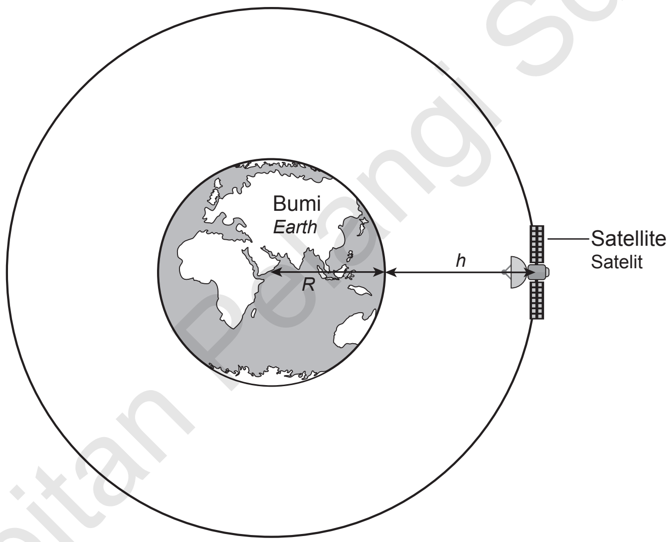
(c) Mengikut Hukum Kegravitian Semesta Newton, daya graviti akan bertindak antara dua orang di permukaan Bumi. Mengapakah dua orang di permukaan Bumi tidak akan merasai kesan daya graviti?
According to Newton's Universal Law of Gravitation, the gravitational force is acted on two person on the surface of the Earth. Why two people on the surface of the Earth will not feel the effects of gravity?

Daya graviti antara dua jasad berjisim kecil mempunyai magnitud yang sangat kecil.

The gravitational force between two small mass bodies have small magnitude.

[2 markah / *marks*]

4. Rajah 4 menunjukkan sebuah satelit berjisim *m*, pada ketinggian *h* dari permukaan Bumi berjisim, *M*. *R* merupakan jejari Bumi dan *h* ialah jarak satelit itu dari permukaan Bumi.
Diagram 4 shows a satellite with mass m, at height h from the surface of the Earth with mass, M. R is the radius of the Earth and h is the distance between the satellite and the surface of the Earth.



Rajah 4 / *Diagram 4*

(a) Ungkapkan jejari orbit satelit dalam sebutan *R* dan *h*.
Express the radius of the satellite in terms of R and h.

$R + h$

[1 markah / *mark*]

(b) Tunjukkan ungkapan pecutan graviti, $g = G\frac{M}{(R+h)^2}$ untuk satelit pada ketinggian, *h* meter.

Show the expression of gravitational acceleration, $g = G\frac{M}{(R+h)^2}$ *for the satellite at height, h meter.*

$F = mg$ dan / *and* $F = G\frac{Mm}{R^2}$

Maka / *Then*, $mg = G\frac{Mm}{R^2}$

Oleh kerana jarak satelit dari pusat Bumi / *Due to the satellite distance from the centre of the Earth* $= R + h$

Maka / *Then*, $mg = G\frac{M}{(R+h)^2}$

[2 markah / *marks*]

(c) Satelit tersebut mengorbit mengelilingi Bumi pada ketinggian 500 km. Berapakah nilai pecutan graviti di kedudukan satelit tersebut?
(Diberikan $G = 6.67 \times 10^{-11}$ N m² kg⁻², jisim Bumi $M = 6 \times 10^{24}$ kg, jejari Bumi $R = 6.4 \times 10^6$ m)
The satellite orbiting around the Earth at height of 500 km. What is the value of gravitational acceleration athe satellite position?
(Given $G = 6.67 \times 10^{-11}$ N m² kg⁻², mass of the Earth $M = 6 \times 10^{24}$ kg, radius of the Earth $R = 6.4 \times 10^6$ m)

$$g = G\frac{M}{(R+h)^2} = 6.67 \times 10^{-11} \times \frac{6 \times 10^{24}}{(6.4 \times 10^6 + 500\,000)^2} = 8.41 \text{ m s}^{-2}$$

[1 markah / *mark*]

(d) Hitungkan pecutan graviti di permukaan Bumi.
(Diberikan $G = 6.67 \times 10^{-11}$ N m² kg⁻², jisim Bumi = 5.97×10^{24} kg, jejari Bumi = 6.37×10^6 m)
Calculate the gravitational acceleration at the surface of the Earth.
(Given $G = 6.67 \times 10^{-11}$ N m² kg⁻², mass of the Earth = 5.97×10^{24} kg, radius of the Earth = 6.37×10^6 m)

$$mg = G\frac{Mm}{R^2}, \text{ maka } g = G\frac{M}{R^2} = 6.67 \times 10^{-11} \times \frac{5.97 \times 10^{24}}{(6.37 \times 10^6)^2} = 9.81 \text{ m s}^{-2}$$

[1 markah / *mark*]

(e) Daripada jawapan (c) dan (d), apakah faktor yang menentukan nilai pecutan graviti? Terangkan hubungan antara faktor tersebut dengan nilai pecutan graviti.
From the answer (c) and (d), what is the factor to determine the value of gravitational acceleration? Explain the relationship between the factor and the value of gravitational acceleration.

Ketinggian objek. Semakin besar ketinggian objek, semakin kecil nilai pecutan graviti.

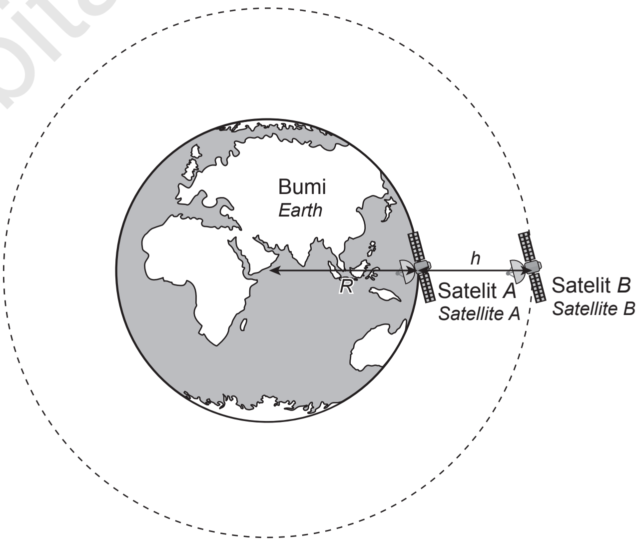
The height of the object. The higher the height of the object, the smaller the value of the gravitational acceleration.

[1 markah / *mark*]

BAB 3

Bahagian B

5. Rajah 5.1 menunjukkan dua buah satelit, satelit *A* dan satelit *B* berjisim *m*, di mana satelit *A* berada di permukaan Bumi dan satelit *B* berada pada ketinggian *h* dari permukaan Bumi berjisim, *M*. *R* merupakan jejari Bumi dan *h* ialah jarak satelit itu dari permukaan Bumi.
Diagram 5.1 shows two satellites, satellite A and satellite B with mass m, where satellite A is on the surface of the Earth and satellite B is at the height h from the surface of the Earth with mass, M. R is the radius of the Earth and h is the distance of the satellite from the surface of the Earth.



Rajah 5.1 / *Diagram 5.1*

(a) Nyatakan Hukum Kegravitian Semesta Newton.
State the Newton's Universal Law of Gravitation. [1 markah / *mark*]

(b) Dengan menggunakan Rajah 5.1,
By using Diagram 5.1,

(i) bandingkan jarak dari pusat Bumi, nilai pecutan graviti dan berat kedua-dua satelit,
compare the distance from the centre of the Earth, the gravitational acceleration value and the weight of both satellites,
[3 markah / *marks*]

(ii) nyatakan hubungan antara jarak dari pusat Bumi dan berat satelit,
state the relationship between the distance from the centre of the Earth and the weight of satellites, [1 markah / *mark*]

(iii) nyatakan kuantiti fizik yang malar dalam mendeduksikan antara jarak dari pusat bumi dan berat satelit seperti dalam jawapan 5(b)(ii).
state the physical quantity that is constant to deduce the relationship between the distance from the centre of the Earth and the weight of the satellite as in answer 5(b) (ii). [1 markah / *mark*]

(c) Sebuah satelit berjisim 200 kg mengorbit mengelilingi Bumi pada ketinggian 500 km. Diberikan jisim Bumi ialah 5.97×10^{24} kg, jejari Bumi ialah 6.37×10^{6} m dan $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}.
Berapakah nilai pecutan graviti dan berat satelit apabila
A 200 kg satellite orbiting the Earth at an altitude of 500 km. Given that the mass of the Earth is 5.97×10^{24} kg, the radius of the Earth is 6.37×10^{6} m and $G = 6.67 \times 10^{-11}$1 N m^2 kg^{-2}.
What is the value of the gravitational acceleration and the weight of the satellite when

(i) berada di permukaan Bumi?
on the surface of the Earth?

(ii) berada pada ketinggian 500 km dari permukaan Bumi?
at an altitude of 500 km from the surface of the Earth?
[4 markah / *marks*]

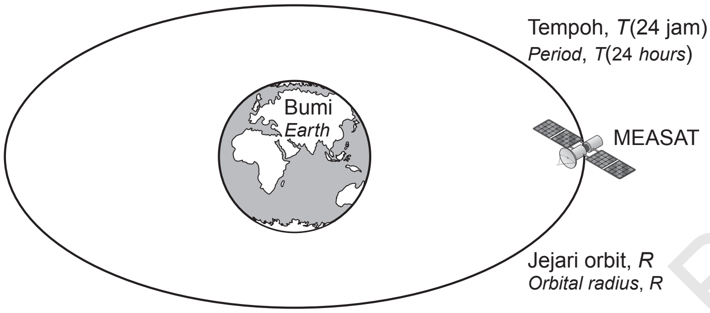
(d) NASA akan menggunakan roket Falcon untuk melancarkan satelit berkomunikasi canggih.
NASA will use its Falcon rocket to launch an advanced communication satellite.

Rajah 5.2 / *Diagram 5.2*

Anda dikehendaki mencadangkan ciri-ciri roket yang sesuai yang boleh bergerak dengan pecutan yang lebih besar dengan ciri keselamatan. Nyatakan dan terangkan cadangan anda berdasarkan ciri-ciri bahan binaan dan bentuk roket.
You are required to suggest the suitable characteristics of the rocket that can travel with greater acceleration with safety features. State and explain your suggestions based on the characteristics of material and shape of the rocket.
[10 markah / *marks*]

Bahagian C

6. Rajah 6.1 menunjukkan satelit MEASAT mengelilingi Bumi.
Diagram 6.1 shows the MEASAT satellite orbits around the Earth.

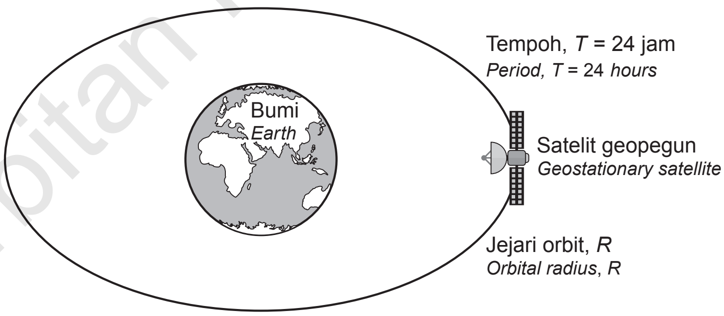


Rajah 6.1 / *Diagram 6.1*

(a) Apakah yang dimaksudkan dengan halaju lepas?
What is meant by escape velocity? [1 markah / *mark*]

(b) Terangkan bagaimana satelit MEASAT boleh dibebaskan daripada tarikan graviti Bumi dengan menggunakan formula halaju lepas, $v = \sqrt{\frac{2GM}{R}}$.
Explain how the MEASAT satellite could be released from gravitational pull of the Earth by using formula of escape velocity, $v = \sqrt{\frac{2GM}{R}}$. [4 markah / *marks*]

(c) Satelit geopegun kekal di atas titik yang sama di Bumi kerana ia mengorbit. Ia kekal sebagai *R* jarak malar dari pusat Bumi.
A geostationary satellite remains above the same point on the Earth as it orbits. It remains as constant distance R from the centre of the Earth.



Rajah 6.2 / *Diagram 6.2*

(i) Tulis satu ungkapan, dalam sebutan *R*, untuk jarak ia bergerak dalam masa 24 jam.
Write down an expression, in terms of R, for the distance it travels in 24 hours.

(ii) Tuliskan, dalam sebutan *R*, ungkapan untuk kelajuannya dalam m s^{-1}.
Write down, in terms of R, an expression for its speed in m s^{-1}.

(iii) Dapatkan nilai *R*.
Find the value of R.
($G = 6.67 \times 10^{-11}$ N m^2 kg^{-1}; mass of Earth = 5.97×10^{24} kg)

[3 markah / *marks*]

(d) Untuk siaran secara langsung Piala Dunia bola sepak ke seluruh dunia, satu rangkaian satelit komunikasi diperlukan untuk merangkumi seluruh Bumi. Untuk tujuan ini, beberapa satelit perlu ditempatkan di atas permukaan Bumi pada tempat-tempat yang tertentu.
To broadcast live World Cup football to the world, a network of communications satellites needed to cover the entire Earth. For this purpose, some satellites need to be placed above the surface of the Earth at certain places.

Jadual 6 menunjukkan ciri-ciri bagi sistem satelit yang berbeza.
Table 6 shows the characteristics of different satellite systems.

Satelit ***Satelitte***	**Jenis satelit** ***Type of satellite***	**Sudut liputan** ***Angle of coverage***	**Tempoh orbit** ***Period of orbit***	**Bilangan minimum satelit** ***Minimum number of satellite***
P	Satelite geopegun *Geostationary satellite*	80°	24 jam/ *hour*	3
Q	Satelite bukan geopegun *Non-geostationary satellite*	120°	36 jam / *hour*	5
R	Satelite geopegun *Geostationary satellite*	120°	24 jam / *hour*	3
T	Satelite bukan geopegun *Non-geostationary satellite*	80°	36 jam / *hour*	5

Jadual 6 / *Table 6*

Kaji spesifikasi keempat-empat ciri bagi sistem tersebut. Terangkan kesesuaian setiap spesifikasi untuk semua satelit dan tentukan sistem satelit yang paling sesuai digunakan untuk siaran secara langsung pertandingan Piala Dunia. Beri sebab untuk pilihan anda. TP5
Study the four specifications of the system above. Explain the suitability of each specification for all satellites and determine the most suitable satellite system for live broadcast of World Cup matches. Give reasons for your choice. [10 markah / *marks*]

PRAKTIS SPM 3

JAWAPAN

Soalan Struktur

Bahagian B

5. (a) Hukum Kegravitian Semesta Newton menyatakan bahawa daya tarikan graviti di antara dua jasad adalah berkadar terus dengan hasil darab jisim-jisimnya dan berkadar songsang dengan kuasa dua jarak pemisahan di antara pusat jasad-jasad itu.
The law of universal gravitation states that the gravitational attraction between two bodies is directly proportional to the product of the both masses and inversely proportional to the square of the distance between the centres of the bodies.

(b) (i) Jarak satelit *A* dari pusat Bumi adalah lebih kecil dari satelit *B*. Nilai pecutan graviti satelit *A* adalah lebih besar dari satelit *B*. Berat satelit *A* adalah lebih besar dari Satelit *B*.
The distance of satellite A from the centre of the Earth is smaller than satellite B. The gravitational acceleration value of satellite A is greater than satellite B. The weight of satellite A is greater than Satellite B.

(ii) Lebih besar jarak dari pusat bumi, lebih kecil berat satelit.
The greater the distance from the centre of the Earth, the smaller the weight of the satellite.

(iii) Jisim / *Mass*

(c) (i) berada di permukaan Bumi
on the surface of the Earth

$M = 5.97 \times 10^{24}$ kg
$R = 6.37 \times 10^{6}$ m
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$$mg = G\frac{Mm}{r^2}$$

$$g = \frac{GM}{r^2} = 6.67 \times 10^{-11} \times \frac{5.97 \times 10^{24}}{(6.37 \times 10^{6})^2}$$

$$= 9.813 \text{ m s}^{-2}$$

Berat / *Weight* = 200 × 9.813
= 1962 N

(ii) berada pada ketinggian 500 km dari permukaan Bumi
at an altitude of 500 km from the surface of the Earth

$M = 5.97 \times 10^{24}$ kg
$R = 6.37 \times 10^{6}$ m
$h = 550 \times 10^{3}$ m
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

$$mg = G\frac{Mm}{r^2}$$

$$g = G\frac{M}{(r+h)^2} = 6.67 \times 10^{-11}\frac{5.97 \times 10^{24}}{(6.37 \times 10^{6} + 500\,000)^2}$$

$$= 8.44 \text{ m s}^{-2}$$

Berat / *Weight* = 200 × 8.44
= 1688 N

(d)

Suggestions *Cadangan*	**Kuantiti Vektor** *Vector Quantities*
Badan roket dibuat dari logam yang sangat kuat dan keras. *The body of rocket is built with metal with high strength and hardness.*	Boleh menahan tekanan dan daya yang tinggi tanpa mengalami kerosakan. *Able to withstand high pressure and force without causing damage.*
Rangka roket diperbuat daripada logam berketumpatan rendah. *Frame of rocket is made of low density metal.*	Lebih ringan, boleh meningkatkan pecutan. *Lighter, can increase acceleration.*
Roket dibina dengan peringkat yang boleh ditanggalkan. *Rocket built with removable stage.*	Setiap peringkat dengan bahan api, pam dan kebuk pembakaran berasingan. Ia akan ditanggalkan apabila bahan bakar dibakar sepenuhnya. Bila jisim berkurangan, pecutan akan bertambah. *Each stage with separate fuel, pump and combustion chamber. It will be removed when the fuel is fully burned. As the mass decreases, the acceleration increases.*
Badan roket diliputi dengan penebat haba. *The body of rocket covered with heat insulator.*	Geseran antara udara dan badan akan meningkatkan haba. Penebat akan mengurangkan kekonduksian haba. *The friction between the air and the body increases the heat. Insulation will reduce heat conductivity.*
Bentuk aerodinamik *Aerodynamic shape*	Kurangkan geseran udara, bergerak lebih cepat. *Reduce air friction, move faster.*

Bahagian C

4. (a) Halaju lepas adalah kelajuan minimum yang diperlukan objek untuk untuk dibebaskan daripada pengaruh graviti jasad yang besar.
Escape velocity is the minimum speed required for objects to be released from the gravitational influence of a massive body.

(b) – Satelit MEASAT boleh dibebaskan daripada tarikan graviti Bumi apabila tenaga kinetiknya sama dengan tenaga keupayaan graviti.
The MEASAT satellite can be released from gravitational pull of the Earth when its kinetic energy is equal to the gravitational potential energy.

– Tenaga kinetik Satelit MEASAT dengan jisim m yang bergerak dengan halaju v boleh diberikan dengan $E_K = \frac{1}{2}mv^2$.
The kinetic energy of the MEASAT satellite with mass m moving with velocity v can be given by $E_K = \frac{1}{2}mv^2$.

– Tenaga keupayaan graviti satelit MEASAT boleh diberikan dengan formula $G\frac{Mm}{R}$ di mana
G = pemalar kegravitian
($G = 6.67 \times 10^{-11}$ N m^2 kg^{-2})
The gravitational potential of the MEASAT satellite can be given by the formula $G\frac{Mm}{R}$ where
G = gravity constant kegravitian ($G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2})

– Menyamakan kedua, kita dapat: $\frac{1}{2}mv^2 = G\frac{Mm}{R}$
Equating the two formulas, we obtain: $\frac{1}{2}mv^2 = G\frac{Mm}{R}$
Maka, halaju lepas, $v = \sqrt{\frac{2GM}{R}}$
So, escape velocity, $v = \sqrt{\frac{2GM}{R}}$

(c) (i) Gerakan dalam bulatan, maka jarak ialah ukur lilit bulatan = $2\pi R$
Movement in a circle, so the distance is a circle's circumference = $2\pi R$

(ii) Masa satu putaran orbit
Time of one rotation orbit
= 24 × 60 × 60 = 86 400 s
$v = \frac{s}{t} = \frac{2\pi R}{86\ 400}$

(iii) $F_{memusat} = F_{graviti}$
$m_S\frac{v^2}{R} = G\frac{Mm_S}{R^2}$
$v^2 = G\frac{M}{R}$
$\left(\frac{2\pi R}{86\ 400}\right)^2 R = 6.67 \times 10^{-11}(5.97 \times 10^{24})$
$R^3 = \frac{86\ 400^2}{4\pi^2}(6.67 \times 10^{-11})\ (5.97 \times 10^{24})$
$R = 4.2 \times 10^7$ m

(d) – Jenis satelit: Satelit geopegun
Types of satellite: Geostationary satellite
Supaya berada di atas kawasan yang sama pada setiap masa.
So that in the same spot above the same area at all times.

– Sudut liputan: 120º
Angle of coverage: 120º
Supaya dapat meliputi kawasan yang lebih luas
In order to cover a wider area

– Tempoh orbit / *Duration of orbit*:
24 jam / *hour*
Supaya ia mengorbit pada kelajuan yang sama seperti Bumi berputar
So that it orbit at the same speed as the earth rotating.

– Bilangan minimum satelit: 3
Minimum number of satellites: 3
Menjimatkan kos untuk siaran langsung meliputi seluruh dunia.
Save costs for covering live events around the world.
Sistem satelit yang paling sesuai: *R*
The most suitable satellite system: R

– Sebab sistem satelit *R* ialah satelite geopegun, sudut liputan ialah 120º, tempoh orbit ialah 24 jam dan bilangan minimum satelit ialah 3.
Because satellite system R is geostationary satellite, 120º angle of coverage, duration orbit is 24 hours, and the minimum number of satellites is 3.