■ KEY ■

First Name:______________________________ Last Name:______________________________

L04 – Worksheet – Gravitational Forces and Fields /20 marks

Part 1: Gravitational Force in 1-Dimension

Q1: Given that the mass of Mars is 6.42 $\times 10^{23}$ kg and the radius is 3.40$\times 10^{6}$m, then the force of gravity acting on a 150kg astronaut standing on the surface of Mars would be ***a.bc*** x 10^{d} N, where ***a, b, c,*** and ***d*** are ___, ___, ___, and ___.

*(Record your **four digit** answer in the Numerical Response boxes below)*

5	5	6	2

$F_g = \frac{Gm_1m_2}{r^2} = \frac{(6.67\times10^{-11})(6.42\times10^{23})(150)}{(3.40\times10^{6})^2}$

$F_g = 555.64N$

$F_g \approx 5.56\times10^{2}N$

Use the following information to answer Q2:

From your ***Data Booklet***, Earth has a radius of 6.37 x 10^{6} m, and a mass of 5.97 x 10^{24} kg.

NOTE: This information would ***not*** be given to you on a test... you need to reference your *Data Booklet* for it.

Q2: A 150kg Astronaut is in orbit above the surface of Earth and experiences a gravitational force of 735N. For this to be true, then the Astronaut must be ***a.bc*** x 10^{d} m above the surface of the Earth, where ***a, b, c,*** and ***d*** are ___, ___, ___, and ___.

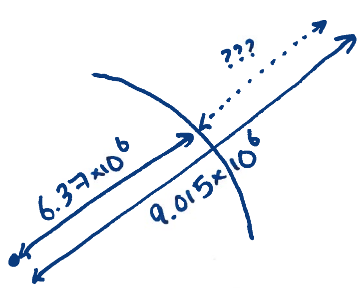
*(Record your **four digit** answer in the Numerical Response boxes below)*

2	6	4	6

$F_g = \frac{Gm_1m_2}{r^2} \Rightarrow r^2 = \frac{Gm_1m_2}{F_g} = \frac{(6.67\times10^{-11})(5.97\times10^{24})(150)}{735}$

$r^2 = 8.12651...\times10^{13}$

$r = 9.014715...\times10^{6}m$



Astronaut is $2.64\times10^{6}m$ above the surface of the Earth.

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Part 2: Gravitational Fields in 1-Dimension

Q3: If the mass of Mars is 6.42 $\times10^{23}$ kg and the radius is 3.40×10^{6}m, what is the gravitational field strength of the surface of the planet?

*(Record your **three digit** answer in the Numerical Response boxes below)*

3	.	7	0

$$g = \frac{Gm_{source}}{r^2} = \frac{(6.67\times10^{-11})(6.42\times10^{23})}{(3.40\times10^{6})^2}$$

$$g = 3.70\ N/kg \quad \text{or} \quad 3.70\ m/s^2$$

Q4: If the acceleration due to gravity on the surface of Mercury is 3.703 m/s^2, then the force of gravity acting on a 150kg astronaut on the surface would be ***a.bc*** x 10^{d} N, where ***a, b, c,*** and ***d*** are ___, ___, ___, and ___.

*(Record your **four digit** answer in the Numerical Response boxes below)*

5	5	5	2

$$F_g = mg$$
$$= (150)(3.703)$$
$$= 555.45N$$
$$F_g \approx 5.55\times10^{2}\ N$$

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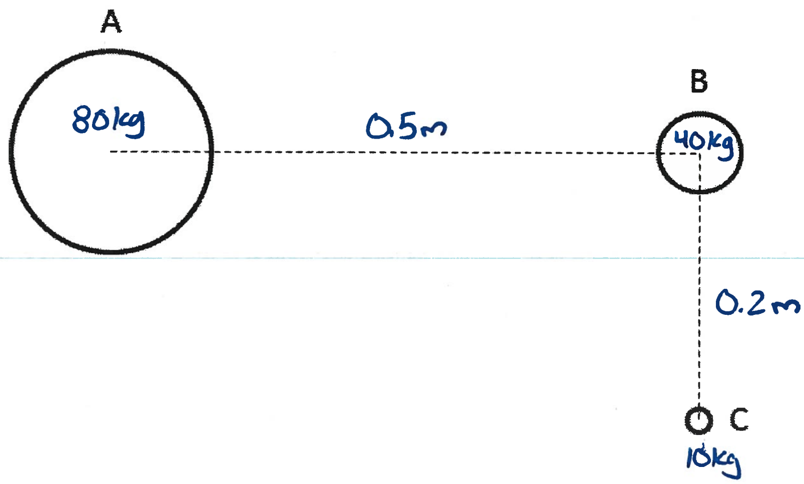
Part 3: Gravitational Forces and Fields in 2-Dimensions

Q5: If $m_A = 80kg$, $m_B = 40kg$, $m_C = 10kg$, $r_{AB} = 0.5m$, and $r_{BC} = 0.2m$, then object B will accelerate in what direction, using polar coordinates.

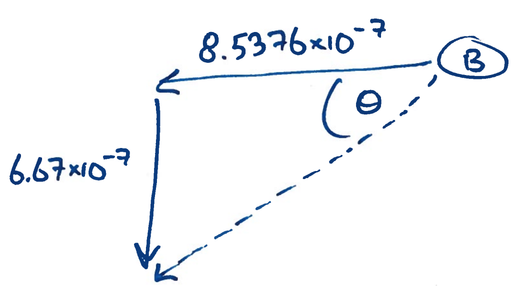


*(Record your **three digit** answer in the Numerical Response boxes below)*

2	1	8	

$$F_{AB} = \frac{G m_A m_B}{r^2} = \frac{(6.67\times10^{-11})(80)(40)}{(0.5)^2} = 8.5376\times10^{-7}\ N$$

$$F_{BC} = \frac{G m_B m_C}{r^2} = \frac{(6.67\times10^{-11})(40)(10)}{(0.2)^2} = 6.67\times10^{-7}\ N$$



$$\tan\theta = \frac{o}{a}$$

$$\theta = \tan^{-1}\left(\frac{6.67\times10^{-7}}{8.5376\times10^{-7}}\right)$$

$$\theta = \tan^{-1}(0.78125)$$

$$\theta = 37.9987^\circ$$

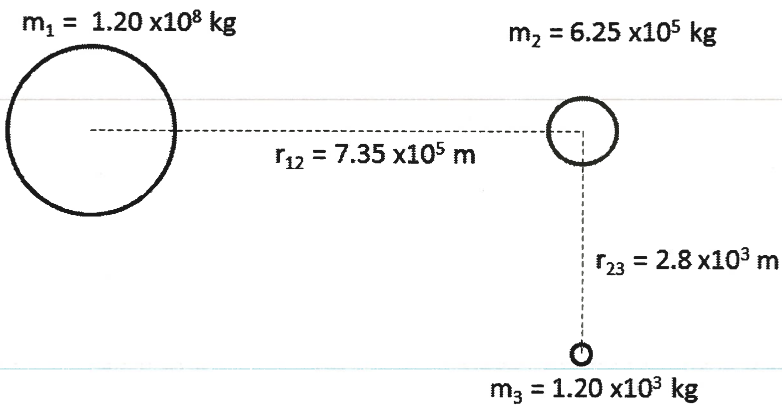
In polar coordinates...

$$\theta = 217.9987^\circ$$

$$\theta \approx 218^\circ$$

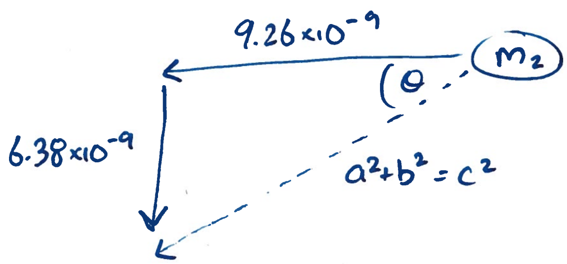
KEY

Q6: What is the instantaneous acceleration (magnitude and direction) of the second mass, m_2? *(3 marks)*



$$F_{12} = \frac{Gm_1m_2}{r^2} = \frac{(6.67\times10^{-11})(1.20\times10^{8})(6.25\times10^{5})}{(7.35\times10^{5})^2} = 9.26\times10^{-9}\ N$$

$$F_{23} = \frac{Gm_1m_2}{r^2} = \frac{(6.67\times10^{-11})(6.25\times10^{5})(1.20\times10^{3})}{(2.80\times10^{3})^2} = 6.38\times10^{-9}\ N$$



$\tan\theta = \frac{o}{a}$

$\theta = \tan^{-1}\left(\frac{6.38\times10^{-9}}{9.26\times10^{-9}}\right)$

$\theta = 34.57°$, or $214.6°$ in Polar

$a^2+b^2=c^2$

$c = 1.12\times10^{-8}\ N$

So $F_{net} = 1.12455\times10^{-8}\ N\ [214.6°]$

$$a = \frac{F_{net}}{m} = \frac{1.12455\times10^{-8}}{6.25\times10^{5}} = 1.799\times10^{-14}\ m/s^2$$

$$\boxed{a \approx 1.80\times10^{-14}\ m/s^2\ [214.6°]}$$

KEY

Part 4: r^2 Relationship

Q7: Two objects experience a gravitational force between them. If each object triples in mass, and the distance between them is doubled, then the gravitational force increases by a factor of $\frac{a}{b}$, where $\frac{a}{b}$ is a reduced fraction. ***a*** and ***b*** are ___ and ___.

(Record your ***two digit*** *answer in the Numerical Response boxes below)*

9	4		

$$F_g = \frac{Gm_1m_2}{r^2} \qquad F_{new} = \frac{G(3m_1)(3m_2)}{(2r)^2} = \frac{9Gm_1m_2}{4r^2}$$

So increases by a factor of $\frac{9}{4}$.

Q8: The force of gravity between two objects is 250N. The mass of each object is tripled, and the distance between them is halved. What is the magnitude of the force of gravity acting on each object?

(Record your ***four digit*** *answer in the Numerical Response boxes below)*

9	0	0	0

$$F_g = \frac{Gm_1m_2}{r^2} = 250N \qquad F_{new} = \frac{G(3m_1)(3m_2)}{(\frac{1}{2}r)^2} = \frac{9Gm_1m_2}{\frac{1}{4}r^2}$$

$$= \frac{36}{1}\left(\frac{Gm_1m_2}{r^2}\right)$$

$$= 36(250N)$$

$$= 9000N$$

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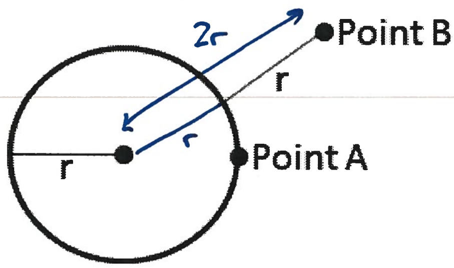
Q9: If the force of gravity at point A is 100N, what is the force of gravity at point B?



We are doubling our distance.

$F_g = \frac{Gm_1m_2}{r^2} = 100N$

$F_{new} = \frac{Gm_1m_2}{(2r)^2} = \frac{Gm_1m_2}{4r^2}$

$= \frac{1}{4}\left(\frac{Gm_1m_2}{r^2}\right)$

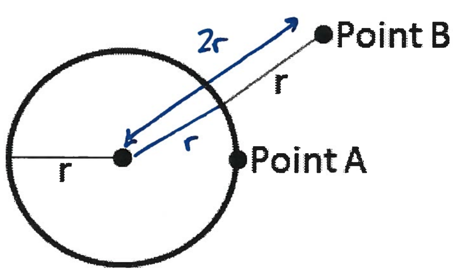
$= \frac{1}{4}(100N)$

$= 25.0N$

*(Record your **three digit** answer in the Numerical Response boxes below)*

2	5	.	0

Q10: If the gravitational field at Point B is 18 N/kg, what is the acceleration due to gravity on the surface of the planet?



We are halfing our distance

$g = \frac{Gm}{r^2} = 18\ N/kg$

$g_{new} = \frac{Gm}{(\frac{1}{2}r)^2} = \frac{Gm}{\frac{1}{4}r^2}$

$= 4\left(\frac{Gm}{r^2}\right) = 4(18)$

$= 72\ N/kg$

$= 72.0\ N/kg$

*(Record your **three digit** answer in the Numerical Response boxes below)*

7	2	.	0

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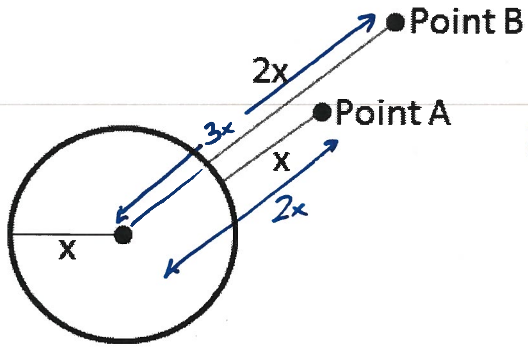
Q11: If the force of gravity at point B is 64N, what is the force of gravity at point A?



We are now at $\frac{2}{3}$ the distance.

$F_g = \frac{Gm_1m_2}{r^2} = 64N$

$F_{new} = \frac{Gm_1m_2}{(\frac{2}{3}r)^2} = \frac{Gm_1m_2}{\frac{4}{9}r^2}$

$= \frac{9}{4}\left(\frac{Gm_1m_2}{r^2}\right)$

$= \frac{9}{4}(64\ N)$

$= 144\ N$

*(Record your **three digit** answer in the Numerical Response boxes below)*

1	4	4	

KEY

Part 5: Multi-Step Questions

Q12: An object on Venus is dropped from 10m above the ground, and reaches the ground 1.505 seconds later. The gravitational force acting on a nearby 150kg astronaut would be ***a.bc*** x 10^d N, where ***a, b, c,*** and ***d*** are ____, ____, ____, and ____.

*(Record your **four digit** answer in the Numerical Response boxes below)*

1	3	2	3

(− up, + down)

$d = v_i t + \frac{1}{2}at^2$

$10 = (0)(1.505) + \frac{1}{2}a(1.505)^2$

$10 = (\frac{1}{2})a(2.265025)$

$a = 8.8299\ m/s^2$

$F_g = mg$

$= (150)(8.8299)$

$= 1324.49\ N$

$\approx 1.32 \times 10^3\ N$

Q13: If the gravitational field strength on the surface of Mercury is 3.703 N/kg, how long would it take a 10kg mass to drop 15m?

*(Record your **three digit** answer in the Numerical Response boxes below)*

2	.	8	5

$a = 3.703\ m/s^2$

$d = 15m$

$v_i = 0\ m/s$

(− up, + down)

$d = v_i t + \frac{1}{2}at^2$

$15 = (0)t + \frac{1}{2}(3.703)(t^2)$

$15 = 1.8515t^2$

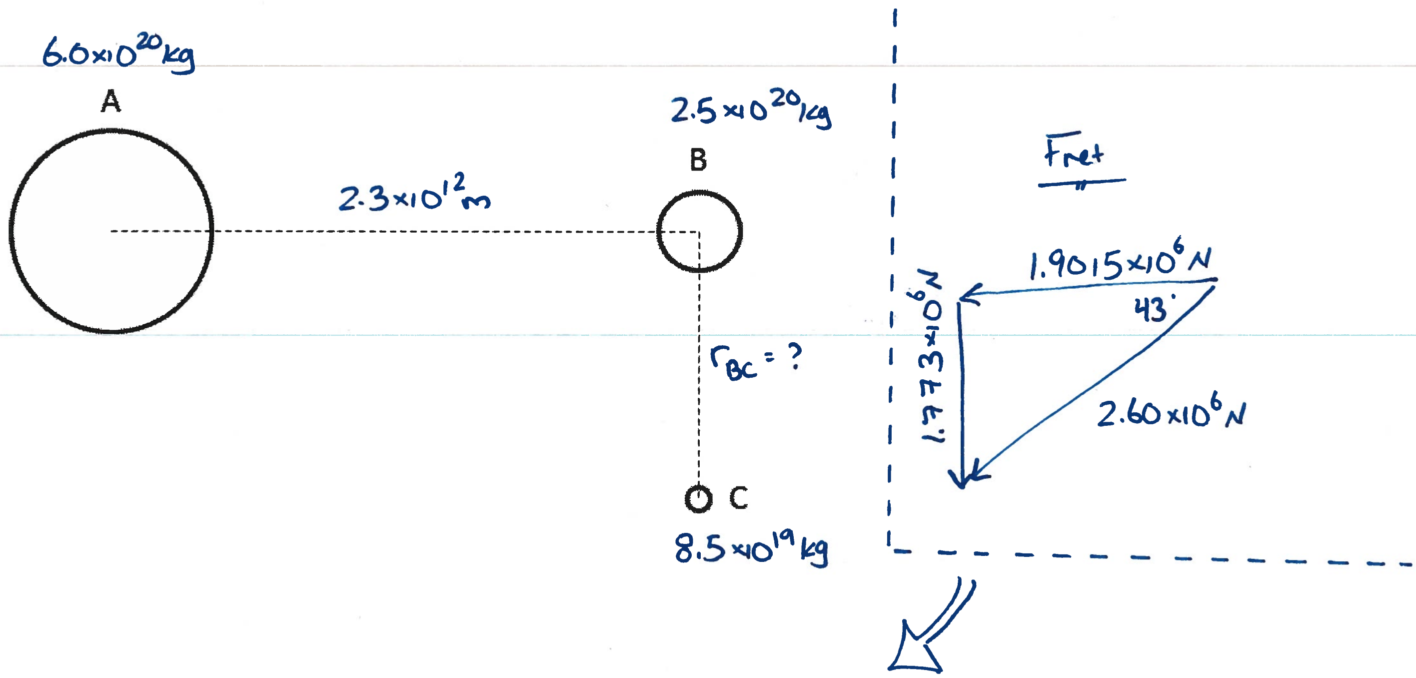
$8.1015 = t^2$

$t = 2.84632...\ s$

$t \approx 2.85s$

KEY

Q14: Given: $m_A = 6.0\times10^{20}$ kg, $m_B = 2.5 \times 10^{20}$ kg, $m_C = 8.5 \times 10^{19}$ kg, $r_{AB} = 2.3 \times 10^{12}$ m, and $F_{NET} = 2.60 \times 10^{6}$N [223°]. How far away from object B is object C? *(3 marks)*



$F_{BC} = 1.773\times10^{6}$ N

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

$$r^2 = \frac{Gm_1m_2}{F_g} = \frac{(6.67\times10^{-11})(2.5\times10^{20})(8.5\times10^{19})}{1.773\times10^{6}}$$

$$r^2 = 7.993336\ldots\times10^{23}$$

$$\boxed{r = 8.94\times10^{11}\ \text{m}}$$

KEY

Use the following information to answer Q15:

The Earth's Moon has a mass of 7.35 x10^{22} kg and a radius of 1.74 x10^{6} m.

Q15: If an object were held 15m above the surface of the moon and dropped, how much time would it take for the object to hit the surface of the moon? *(2 mark)*

$$g = \frac{Gm}{r^2} = \frac{(6.67\times10^{-11})(7.35\times10^{22})}{(1.74\times10^{6})^2} = 1.619\ N/kg$$

− (up) / + (down)

$v_i = 0$

$a = 1.619\ m/s^2$

$d = 15m$

$t = ?$

$d = v_i t + \frac{1}{2}at^2$

$15 = (0)t + \frac{1}{2}(1.619)t^2$

$15 = 0.8096\ t^2$

$18.527 = t^2$

$\boxed{t = 4.30s}$