HALE SCHOOL

PHYSICS

Circular Motion and Gravitation

YEAR 12 Unit 3A Test 2012

Test Score:

Name:	Set:	Teacher: JAA MV

INSTRUCTIONS:

- ☐ Time Allowed = 40 minutes
- ☐ Total Marks = 40 marks
- ☐ Answer all questions in the space provided.
- ☐ Rough working is permitted on the question paper.
- ☐ Show all relevant working details in order to acquire full marks.
- ☐ Graphic Calculators are Not permitted for this paper.
- ☐ ***Do Not write in pencil. (Note: a 1 mark penalty will be incurred)**
- ☐ ***Do Not borrow materials. (Note: a 1 mark penalty will be incurred)**

POST ASSESSMENT REVIEW (to be completed upon return of your marked paper)

SELF-ASSESSMENT:

Relative Weaknesses –Objective No.

Relative Strengths –Objective No.

Major Concerns: (be specific)

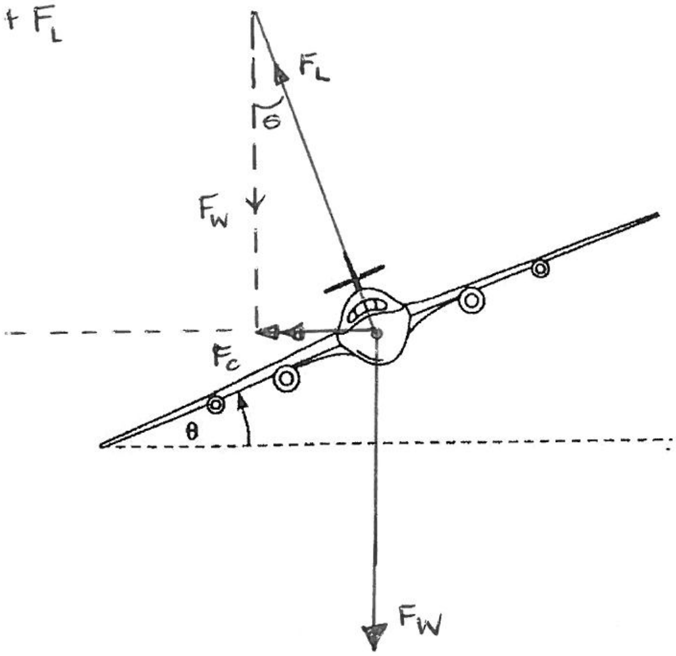
Action Plan: (be specific)

Q1 [4 marks]

An aircraft from the Red Arrows display team makes a steeply banked horizontal turn with a radius of 205 m. Assume that the combined mass of the aircraft is 2.50 x10^3 kg and it experiences a centripetal acceleration of 50.0 ms^{-2}.

1a) Carefully show how each of the major forces are acting on the aircraft, and how they combine to produce the resultant force (vectors on the diagram) (2 marks)

$\vec{F_c} = \vec{F}_{NET} = \vec{F_W} + \vec{F_L}$



1b) Determine the angle of the banking required to successfully achieve this manoeuvre.

USING $\tan\theta = {}^{opp}/_{adj} = \frac{F_c}{F_W}$

$= \frac{\frac{mv^2}{r}}{m.g}$

$= \frac{a_c}{g} = \frac{50.0}{9.81}$

$= 5.10$

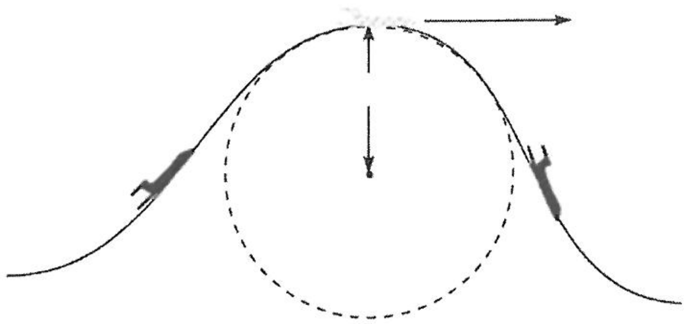
$\therefore \theta = 78.9°$ ABOVE THE HORIZONTAL

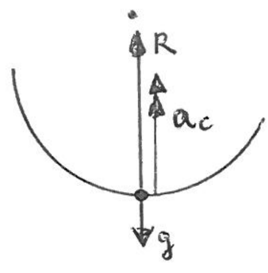
(OR $\theta = 10.1°$ FROM THE VERTICAL)

(2marks)

Q2 [4 marks]

A 'top gun' jet pilot demonstrates some spectacular manoeuvre during an air show. In one of his stunts he flies the aircraft in vertical loops while travelling at high speeds.





R IS EXPERIENCED

$R = a_c + g$

$\therefore R = 7g$

Pilots have been known to 'black-out' when **"experiencing"** accelerations exceeding 7.00 g's. If the jet is moving at a speed of 905 km h^{-1} at the lowest point of the loops, determine the minimum radius of the circle that the pilot can safely execute.

SINCE $\vec{F_c} = \vec{F_W} + \vec{R}$

THEN $F_c = m(-g + 7g)$

$\therefore \frac{\cancel{m}v^2}{r} = \cancel{m}(6g)$

$\therefore r = \frac{v^2}{6g}$

$= \frac{(905 \times 1000/3600)^2}{6 \times 9.8}$

$= 1075$ m

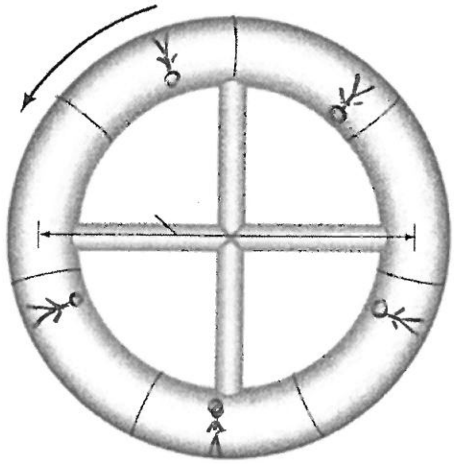
$\therefore r = 1.08$ km (3 S.F)

(4marks)

Q4 [6 marks]

A projected space station essentially consists of a circular tube that is set rotating about its centre (like a bicycle tube). The circle formed by the tube has a diameter of 1.10 km.

4a) On which wall will people be able to walk? Draw a stick figure in the diagram to represent your answer and carefully justify your answer.



THE OUTSIDE (INNER WALL) AS SHOWN

THE INERTIA PUSHES THEM TO THE OUTSIDE WALL (AS THEY ARE DIRECTED TANGENTIALLY AT EACH POINT). THE WALL PROVIDES THE NECESSARY REACTION FORCE TO ACCELERATE THEM TOWARD THE CENTRE OF ROTATION (TO MAINTAIN A CIRCULAR PATH) (2 marks)

4b) What must be the rate of rotation (revolutions per day) if an effect equal to the gravity experienced at the surface of the Earth is to be simulated.

SINCE $F_c = F_w$

$\frac{\cancel{m}v^2}{r} = \cancel{m}.g$

$\therefore v = \sqrt{r.g}$

$= \sqrt{\frac{1100}{2} \times 9.80}$

$= 73.4\ ms^{-1}$

SINCE $v = \frac{2\pi r}{T}$

$T = \frac{2\pi r}{v}$

$= \frac{2\pi(550)}{73.4}$

$= 47.1\ s$

SINCE ONE DAY $= 8.64 \times 10^4\ s$

THEN N°/ REVOLUTIONS PER DAY

$= \frac{8.64 \times 10^4}{47.1}$

$= 1.84 \times 10^3$

ALTERNATIVELY:

SINCE $v = \frac{2\pi r}{T}$

THEN $\frac{4\pi^2 r^2}{T^2} = r.g$

$\therefore T^2 = \frac{4\pi^2 r}{g}$

$= \frac{4\pi^2\ 550}{9.80}$

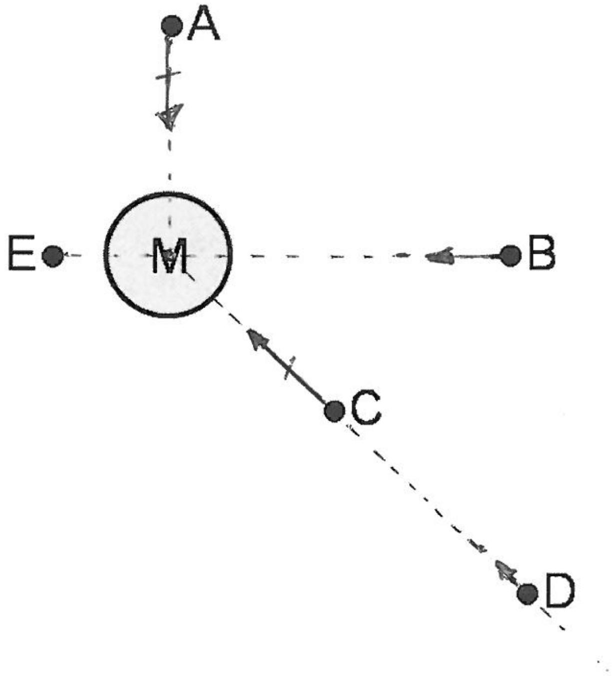
$\therefore T = 47.1\ s$

$\Rightarrow 1.84 \times 10^3$ REVS. PER DAY.

(4 marks)

Q6 [4 marks]

The diagram below shows five points, labelled 'A' to 'E', in free space around a mass M.
You may wish to use a ruler to help you answer this question.



POSITIONS	RELATIVE DISTANCE
M → E	15 mm
m → A	30 mm
m → B	45 mm
m → C	30 mm
m → D	65 mm

6a) Which points have the same magnitude of gravitational field strength due to M?

POINTS A AND C (HAVE THE SAME DISTANCE FROM MASS M)

$g \propto \frac{1}{r^2}$

(1mark)

6b) Which points experience the same direction of gravitational field due to M (as viewed in this diagram)?

POINTS C AND D (RADIAL FIELD TOWARD M)

(1mark)

6c) Determine the ratio of the gravitational field strength at E to the gravitational field strength at B

$$\frac{g_E}{g_B} = \frac{\frac{\cancel{G}.\cancel{M}}{r_E^2}}{\frac{\cancel{G}.\cancel{M}}{r_B^2}} = \frac{r_B^2}{r_E^2} = \frac{(45)^2}{(15)^2} = \frac{(3 \times 15)^2}{(1 \times 15)^2}$$

$$= \frac{9}{1} \quad \text{OR} \quad 9:1$$

IE $g_E \approx 9 \times g_B$

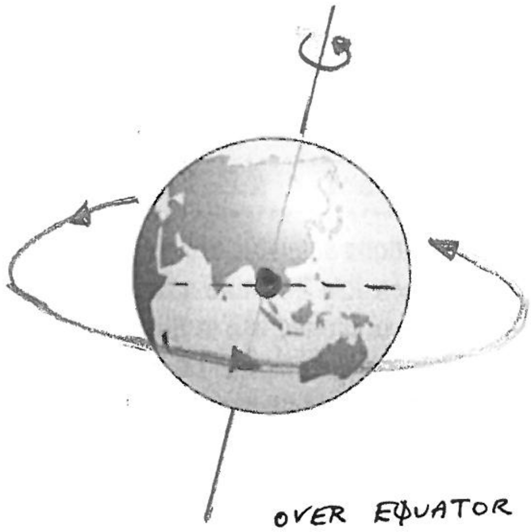
(2marks)

Q7 [7 marks]

7a) On the diagrams below, **carefully** illustrate a polar orbit and a geostationary orbit.

CIRCULAR ORBIT
ABOUT EARTH'S C.O.G

Polar orbit
(2 marks)



OVER EQUATOR
WEST TO EAST

Geostationary orbit
(2 marks)

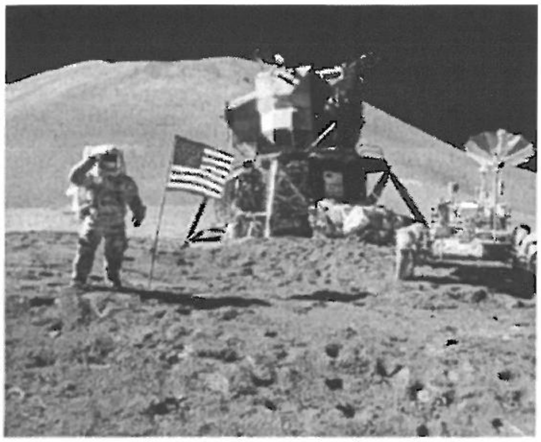
7b) Are you more likely to observe a weather satellite or a telecommunications satellite in the night sky? Carefully explain.

- AT A MUCH LOWER ALTITUDE, THE WEATHER SATELLITE MUST MOVE FASTER THAN A COMMUNICATION SATELLITE, TO MAINTAIN A STABLE ORBIT.
- THIS REQUIRES A MUCH SHORTER PERIOD THAN THE 24 HOURS OF A GEO-STATIONARY COMMUNICATIONS SATELLITE.
- IT WILL THUS MOVE, RELATIVE TO THE OBSERVER, THROUGH THE NIGHT SKY AND WILL BE EASIER TO DETECT.
- THE COMMUNICATIONS SATELLITE APPEARS STATIONARY AS IT HAS THE SAME PERIOD OF ROTATION AS THE EARTH AND THEREFORE DIFFICULT TO TELL APART FROM THE "STARS".

(3 marks)

Q5 [11 marks]

The Earth's moon has always been of primary interest to astronomers and this lead to one of the most significant achievements of the 20th century –Man landing on the Moon.



5a) Calculate the period for the Moon in orbit around the Earth.

SINCE $F_c = \frac{mv^2}{r}$ AND $V = \frac{2\pi r}{T}$ AND $F_c = F_G = \frac{G.mM_E}{r^2}$

THEN $\frac{\cancel{m}\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{G.\cancel{m}.M_E}{r^2}$

THUS $4\pi^2 r^3 = G.M_E.T^2$

$\therefore T^2 = \frac{4\pi^2 r^3}{G.M_E}$

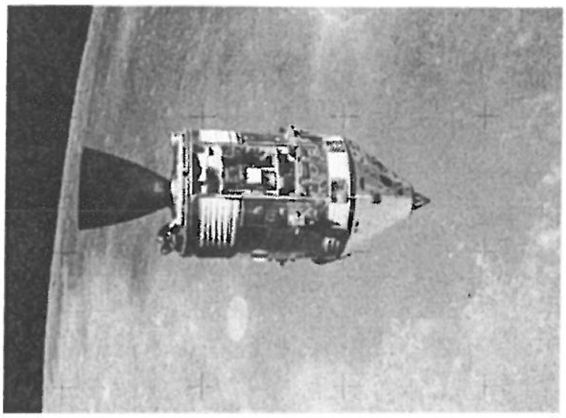
$= \frac{4\pi^2 (3.84 \times 10^8)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}$

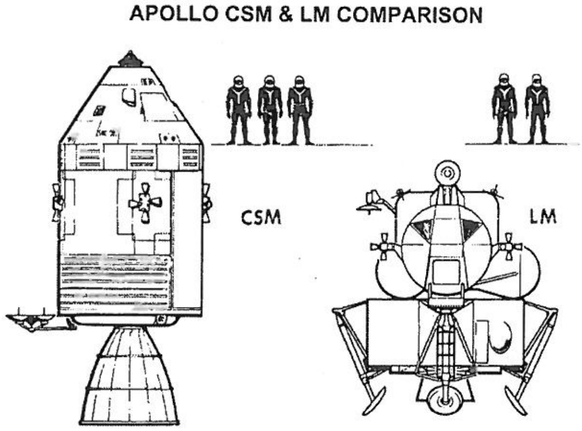
$\therefore T = 2.37 \times 10^6$ s

$\therefore T = 27.4$ DAYS

(5 marks)

5b) An important aspect of the Apollo Lunar landing missions was the return of the Lunar Landing Module to the orbiting Command Module before returning to the astronauts to Earth.





Determine the height above the Moon for which an orbit will effectively allow a Lunar Command Module to remain "fixed" above the Lunar Landing Module situated on the Moon's surface. (Assume that the period of rotation of the Moon is 27.3 days)

A LUNAR-STATIONARY ORBIT : $F_c = F_G$

$\therefore \dfrac{\cancel{m_c} v^2}{r_o} = G \cdot \dfrac{m_m \cancel{m_c}}{\cancel{r_o}^2}$

SINCE $v^2 = \dfrac{G \cdot m_m}{r_o}$ AND $v = \dfrac{2\pi r}{T}$

THEN $\dfrac{4\pi^2 r_o^2}{T^2} = \dfrac{G\, m_m}{r_o}$

$\therefore r_o^3 = \dfrac{G \cdot m_m\, T^2}{4\pi^2}$

$= \dfrac{6.67 \times 10^{-11} \times 7.35 \times 10^{22} \times (27.3 \times 24 \times 60 \times 60)^2}{4\pi^2}$

$\therefore r_o = 8.84 \times 10^7$ m

SINCE $h = r_o - r_m$

$= 8.84 \times 10^7 - 1.74 \times 10^6$

$= 8.67 \times 10^7$ m

$\therefore h = 8.67 \times 10^4$ km ABOVE MOON'S SURFACE.

(6 marks)