Centripetal Force

v_T : TANGENTIAL VELOCITY

r : RADIUS.

Things to Know about Circular Motion:

CIRCUMFERENCE : $C = 2\pi r$

An Inward Radial Force is required to keep an object on a Circular Path.

↳ this force is called CENTRIPETAL FORCE.

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

m → MASS

v → TANGENTIAL VELOCITY

r → radius of the path.

F_c → CENTRIPETAL FORCE

Alternatively, if you consider the Constant Tangential Velocity case ($a_T = 0$) then:

$$v_T = \frac{d}{t}$$

but the path is circular, so $d = 2\pi r$ if $t = T$ (THE TIME for one COMPLETE REVOLUTION)

Then: $F_c = \frac{mv^2}{r} = \frac{m}{r}\left(\frac{2\pi r}{T}\right)^2$

$$F_c = \frac{m}{r}\,\frac{4\pi^2 r^2}{T^2}$$

$$F_c = \frac{4\pi^2 mr}{T^2}$$

Nikray

How Much force is required to get a 500kg car around a 30m radius curve at 50 km/h?

UNITS!! $50\ ^{km}/_{h} \times 1000\ ^{m}/_{km} = 50000\ ^{m}/_{hour}$.

$$50000\ ^{m}/_{hour} \times \frac{1}{60}\ ^{hour}/_{minute} \times \frac{1}{60}\ ^{minute}/_{second} = 13.89\ ^{m}/_{s}$$

$$F_c = \frac{mv^2}{r} = \frac{(500)(13.89)^2}{30} = \frac{(500)(192.90)}{30} = 3215.02N.$$

An inward radial force of 3215.02N is required to drag the car around the curve.

A Human being cannot survive if exposed to ten times normal gravity for more than a few minutes.

Fighter pilots frequently carry out manoeuvres at MACH 1.5 $\left(500\ ^{m}/_{s}\right)$

What is the tightest curve a pilot can make at this speed without expiring?

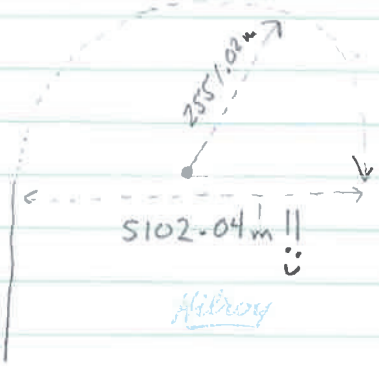
$F_c = 10F_g = 10mg$ ← A Centripetal force of $10F_g$ is the most allowed.

$$F_c = \frac{mv^2}{r} \longrightarrow 10mg = \frac{mv^2}{r}$$

$$r = \frac{v^2}{10g} \qquad g = 9.8\ ^{m}/_{s^2}$$

$$r = \frac{(500)^2}{10(9.8)}$$

$$r = 2551.02\ m$$



1. Calculate the Centripetal Force needed to keep a 20kg object travelling along a Circular Path with a Radius of 3m, with a Tangential Velocity of 4 m/s.

2. Calculate the Centripetal Force experienced by a 5kg object travelling along a Circle of Radius 12m if the Object Completes a Rotation once every 3 seconds.

3. You can swing a Stopper on a string so that it travels along a Circular Path with Radius 3m. The Stopper has a mass of 20g, and the string will snap if it experiences more than 50N of tension. Calculate the Maximum Speed the Stopper can Reach.

4. What is the least amount of time a fighter Jet needs to complete a 180° turn with a Radius of 1000m if the Pilot can only survive 9 g's of Force?

5. Calculate the Rotational Period of the Stopper.

6. Calculate the Tangential Velocity of the fighter Jet.

Space Tube."

Simulate Gravity by creating an identical centripetal force in a spinning can.

Use the equation for Centripetal force that depends on T.

$F_c = \frac{4\pi^2 m r}{T^2}$

a 3m radius tubular living room.

I want $F_c = F_g$

$\therefore \frac{4\pi^2 m r}{T^2} = mg \xrightarrow{\text{Rearrange}} 4\pi^2 r = gT^2$

If we are facing a radius of 3m,

$4(3.14)^2(3) = 9.8T^2$

$T^2 = 12.085\ldots$

$T = \sqrt{12.085\ldots} = 3.47\ldots$ seconds.

The tube would have to complete a rotation every 3.47 seconds.

At this rate of rotation, what is the force simulated at their head (at a radius of 1m)

Use $T = 3.47$ seconds, $r = 1$ metre

$F_c = \frac{4\pi^2 m(1)}{(3.47)^2}$

$F_c = 3.267m$

Compare to Gravity:

$\frac{F_c}{F_g} = \frac{3.267m}{mg} = \frac{3.267}{9.8}$

$= 0.333\ldots$

$\approx 33\%$

Your head would only experience about 33% of Normal Gravity.

Fix it so that your head experiences 95% of the gravity your feet are feeling.

$$F_{C_{HEAD}} = \frac{4\pi^2 m r_{HEAD}}{T_{HEAD}^2}$$

* Make this one Simulate 95% of Gravity on Earth

$$0.95 g T_{HEAD}^2 = 4\pi^2 r_{HEAD}$$

$$F_{C_{FEET}} = \frac{4\pi^2 m (r_{HEAD}+2)}{T_{feet}^2}$$

* Make this one Simulate Gravity on Earth

$$mg = \frac{4\pi^2 m (r_{HEAD}+2)}{T_{feet}^2}$$

$$g T_{feet}^2 = 4\pi^2 (r_{HEAD}+2)$$

Now, since the equation depends on the rotation period not the Tangential Velocity, you can equate:

$T_{HEAD} = T_{FEET}$ (as long as the layers are staying together.)

& $0.95\left(g T_{FEET}^2\right) = 4\pi^2 r_{HEAD}$ use Substitution Method!!

$0.95\left(4\pi^2 (r_{HEAD}+2)\right) = 4\pi^2 r_{HEAD}$

$0.95 (r_{HEAD}+2) = r_{HEAD}$

$0.95 r_{HEAD} + 1.90 = r_{HEAD}$

$1.90 = r_{HEAD} - 0.95 r_{HEAD}$

$r_{HEAD} = \frac{1.90}{0.05}$

$r_{HEAD} = 38\text{m}$

MORE!! →

Use $T = 12.7$ second (see left colum)

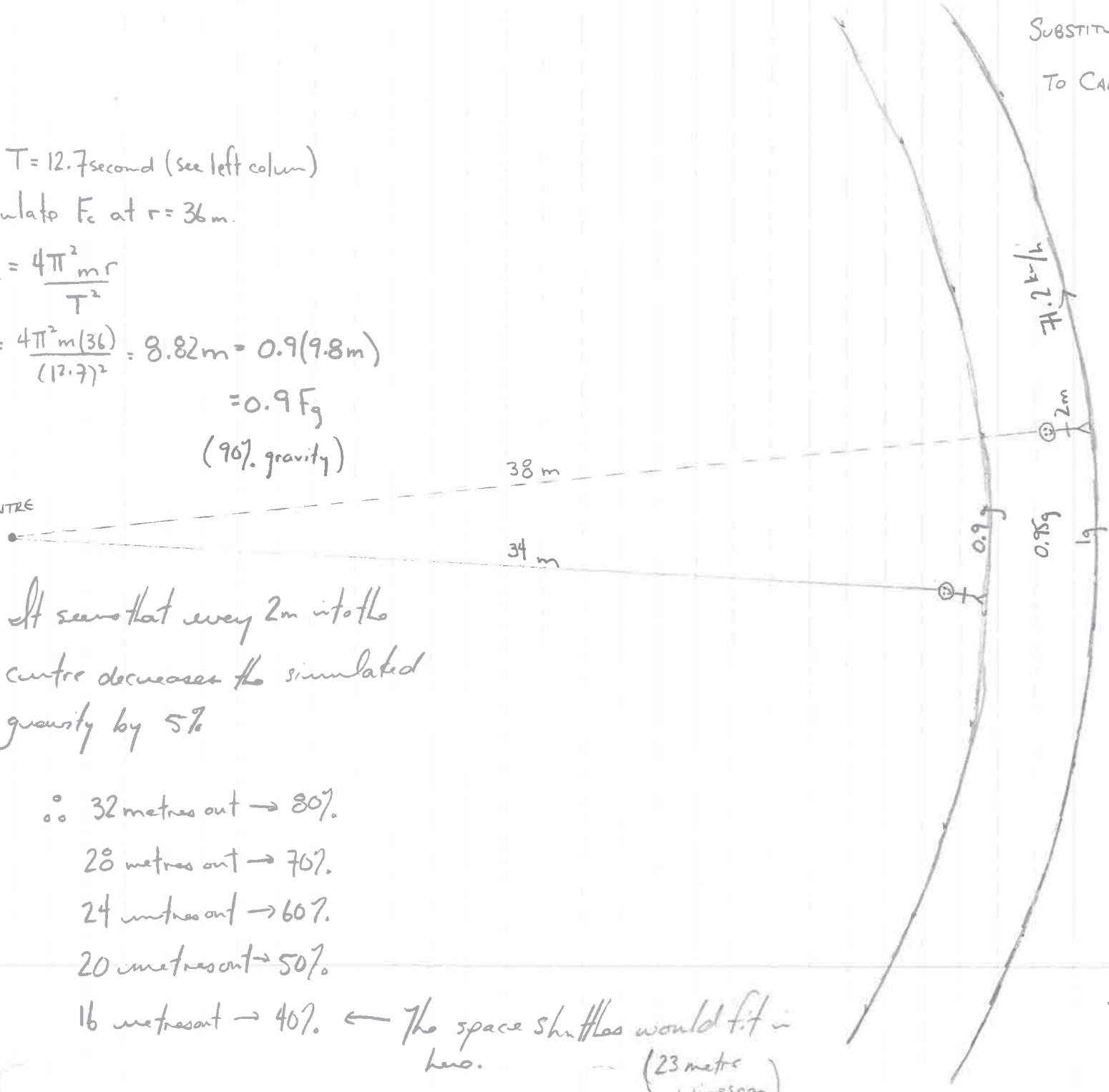
Calculate F_c at $r = 36$ m.

$$F_c = \frac{4\pi^2 m r}{T^2}$$

$$F_c = \frac{4\pi^2 m(36)}{(12.7)^2} = 8.82m = 0.9(9.8m)$$

$$= 0.9 F_g$$

(90% gravity)



It seems that every 2m into the centre decreases the simulated gravity by 5%

∴ 32 metres out → 80%

28 metres out → 70%

24 metres out → 60%

20 metres out → 50%

16 metres out → 40% ← The space shuttles would fit in here. (23 metre wingspan)

Substitute $r_{HEAD} = 38$

To Calculate $T_{HEAD} (= T_{FEET})$

$$gT_{FEET}^2 = 4\pi^2 (r_{HEAD} + 2)$$

$$T_{FEET}^2 = \frac{4\pi^2 (38+2)}{9.8}$$

$$T_{FEET}^2 = 161.136\ldots$$

$$T_{FEET} = \sqrt{161.136\ldots}$$

$$T_{FEET} = 12.7 \text{ seconds.}$$

Calculate the Tangential Velocity:

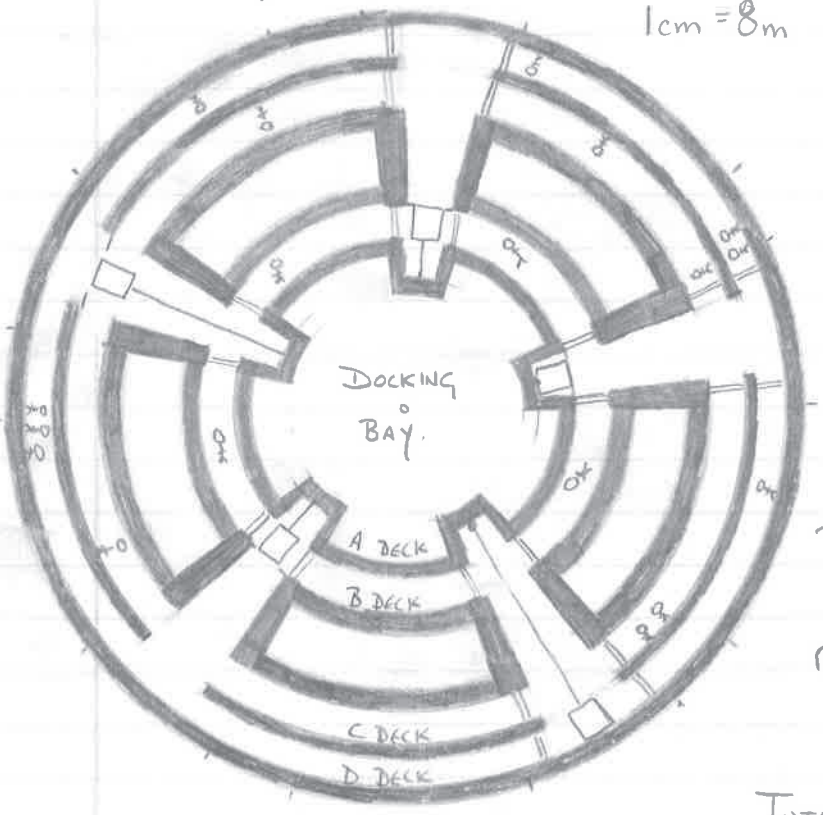
$$V_T = \frac{2\pi r}{T}$$

$$V_T = \frac{2\pi(40)}{12.7}$$

$$V_T = 19.79 \frac{m}{s}$$

$$V_T \approx 71 \frac{km}{h}$$

A Proposal:



1cm = 8m

Rotation Period 12.7 seconds.
Outer Diameter 84m.

A Deck: Open To Space for Docking

$r_A = 16m \quad \therefore F_c = \frac{4\pi^2(16)m}{(12.7)^2} = 0.4\,F_g$

Total Area: $A = \pi r^2 h$
$A = \pi(16)^2 h$
$A = 804.24h$.
(7% of Station)

B Deck: Storage + Manufacturing

$r_B = 22m \quad \therefore F_c = \frac{4\pi^2(22)m}{(12.7)^2} = 0.55\,F_g$

Total Area: $A = \pi r^2 h$
$A = \pi(22)^2 h$
$A = 1520.53h$
(14% of Station)

C Deck: Habitation!!

$r = 34m \quad \therefore F_c = 0.9F_g$
(See previous page)

Total Area: $A = \pi r^2 h$
$A = \pi(34)^2 h$
$A = 3629.84h$.
(33% of Station)

D Deck: More Habitation!!

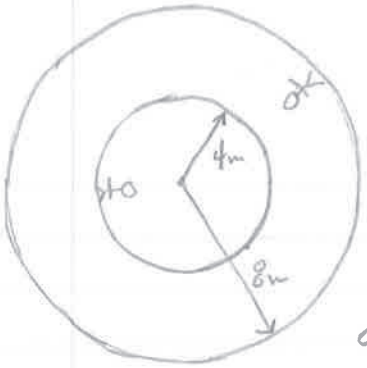
$r = 40\,m \quad \therefore F_c = 1.0F_g$
(see previous page)

Total Area: $A = \pi r^2 h$
$A = \pi(40)^2 h$
$A = 5026.55h$.
(46% of Station)

Total Walkable Area:
10981.16h.

Tangential Velocity of Outer Edge:

$V_T = \frac{2\pi r}{T} = \frac{2\pi(42)}{12.7} = 20.78\frac{m}{s} \approx 74.8\frac{km}{h}$



7. A two Storey Space Tube has an Inner Radius of 4m, and an Outer Radius of 8m.

a) Calculate the Rotation Period that would Simulate Earth's Gravity on the floor of the Inner Ring.

b) Use the Rotation Period you just found to Calculate the Strength of the Simulated Gravity on the floor of the Outer Ring.

c) Calculate the Tangential Velocity of the Outer Ring.

d) Calculate the Rotation Period that would Simulate Earth's Gravity on the floor of the Outer Ring.

e) Use the Rotation Period you just found to Calculate the Strength of the Simulated Gravity on the floor of the Inner Ring.

f) Calculate the Tangential Velocity of the Outer Ring.