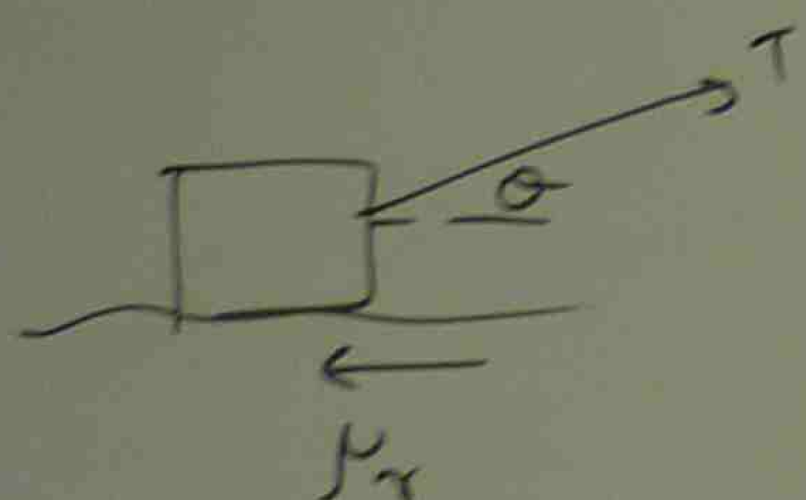
CRITICAL MAXIMUM ANGLE



$\tan\theta = \mu_r$

$\theta = \tan^{-1}\mu_r$

μ_r = FRICTION COEFFICIENT OF SURFACE

θ = ANGLE TO FORCE

UNIFORM CIRCULAR MOTION

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

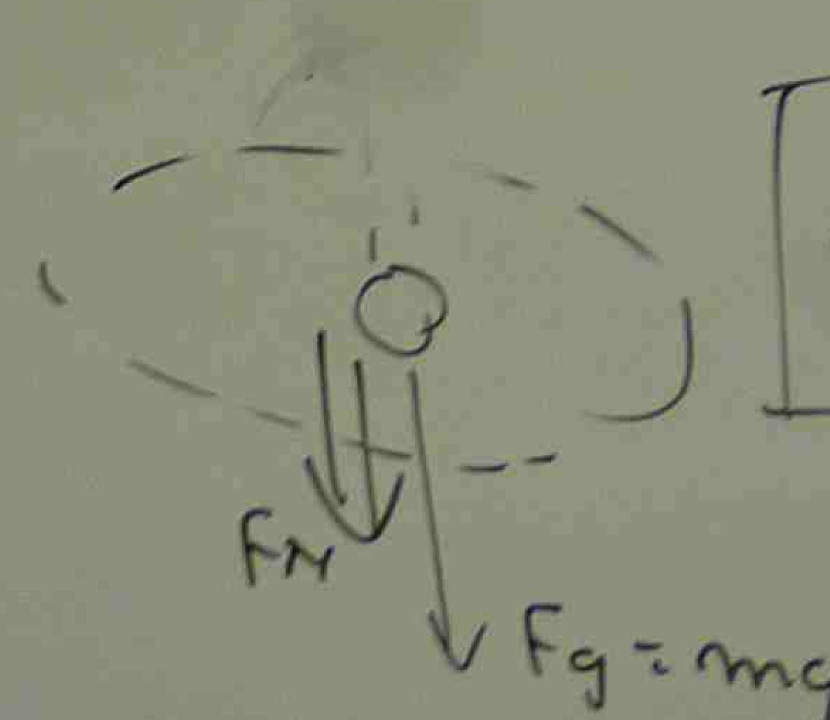
a = CENTRIPETAL ACCELERATION

V = VELOCITY

R = RADIUS OF MOTION

CENTRIPETAL FORCE $F = m\,a$

$$F = m\,\frac{v^2}{R}$$



$$\boxed{-\;F_N - mg = m\left(-\frac{v^2}{R}\right)}$$

pb

Loo

Spe

AT

TION

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

ACCELERATION

MOTION

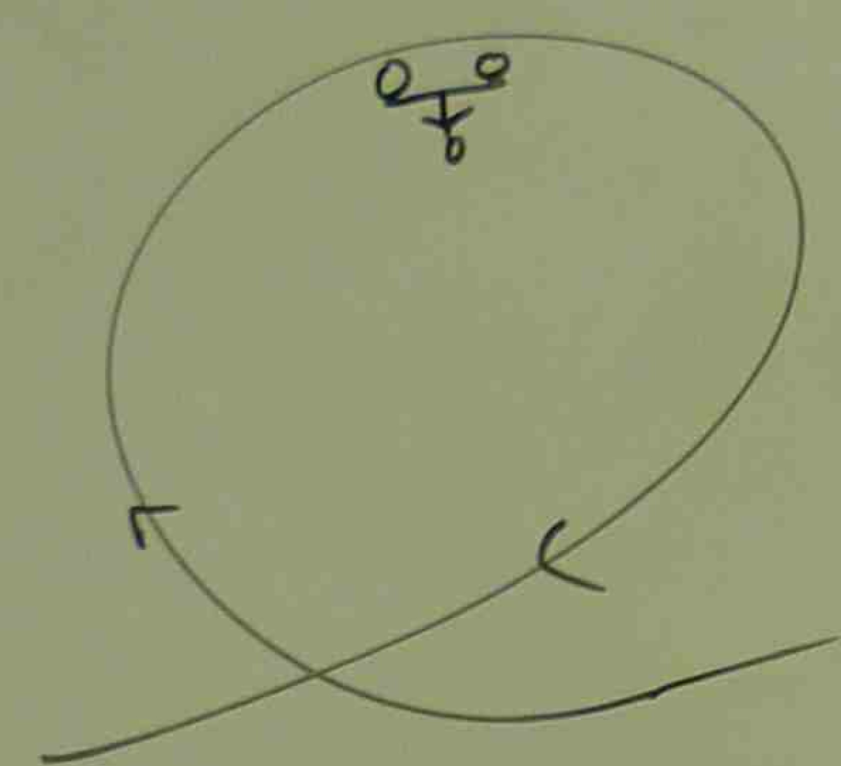
$= m\,a$

$= m\,\frac{v^2}{R}$

$$\boxed{F_N - mg = m\left(-\frac{v^2}{R}\right)}$$

pb THE CIRCUS PERFORMER IS RIDING A BICYCLE IN THE LOOP WITH RADIUS $R = 2.7\,m$ WHAT IS THE LEAST SPEED AT THE TOP OF LOOP AND FORCE

$m = 20\,kg$



$\uparrow F_N$

$$F = m\frac{v^2}{R}$$

$$= \frac{20 \times 5.1^2}{2.7}$$

$$= 192\ N$$

$$-F_N - mg = m\left(-\frac{v^2}{R}\right)$$

AT TOP OF THE LOOP $F_N = 0$

$$-0 - mg = m\left(-\frac{v^2}{R}\right)$$

$$-\cancel{m}g = \cancel{m}\left(-\frac{v^2}{R}\right)$$

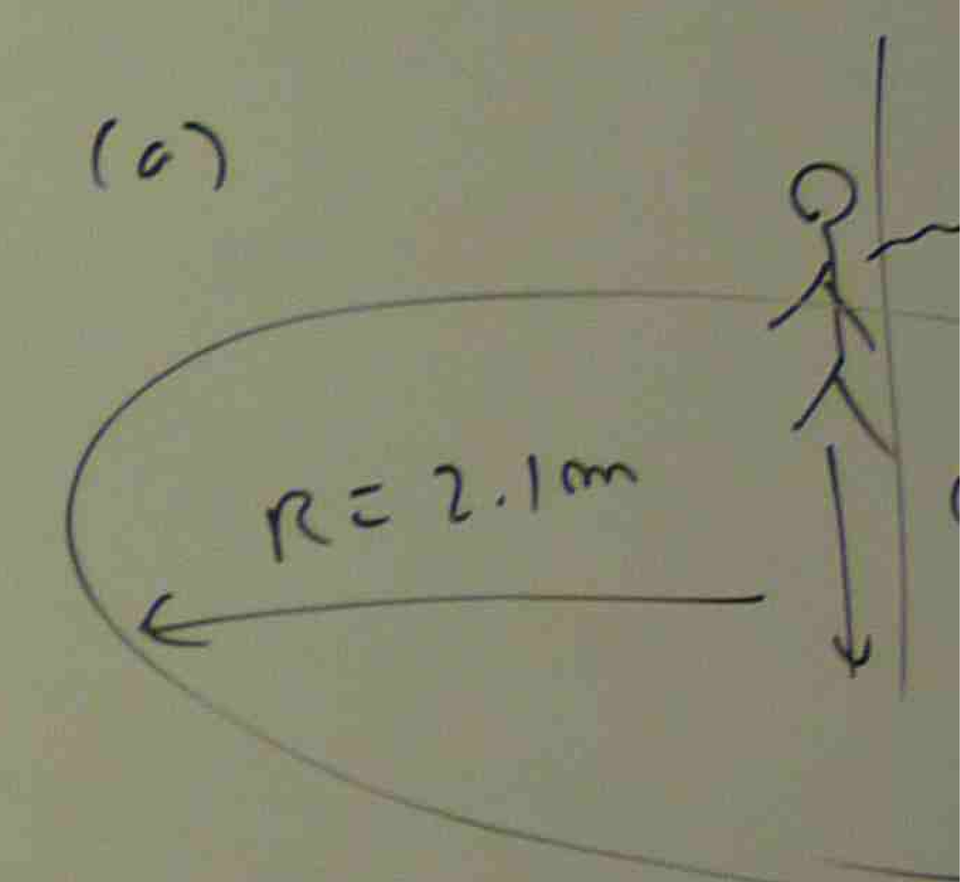
$$v^2 = gR \rightarrow v = \sqrt{gR} = \sqrt{9.81 \times 2.7} = 5.1\ m/s.$$

pb SUPPOSE THAT THE μ_s BETWEEN THE CANVAS IS 0.4 AND 2.1m

(a) WHAT MINIMUM SPEED THE RIDER HAVE IF WHEN THE FLOOR

(b) IF THE RIDER'S THE MAGNITUDE OF

(a)

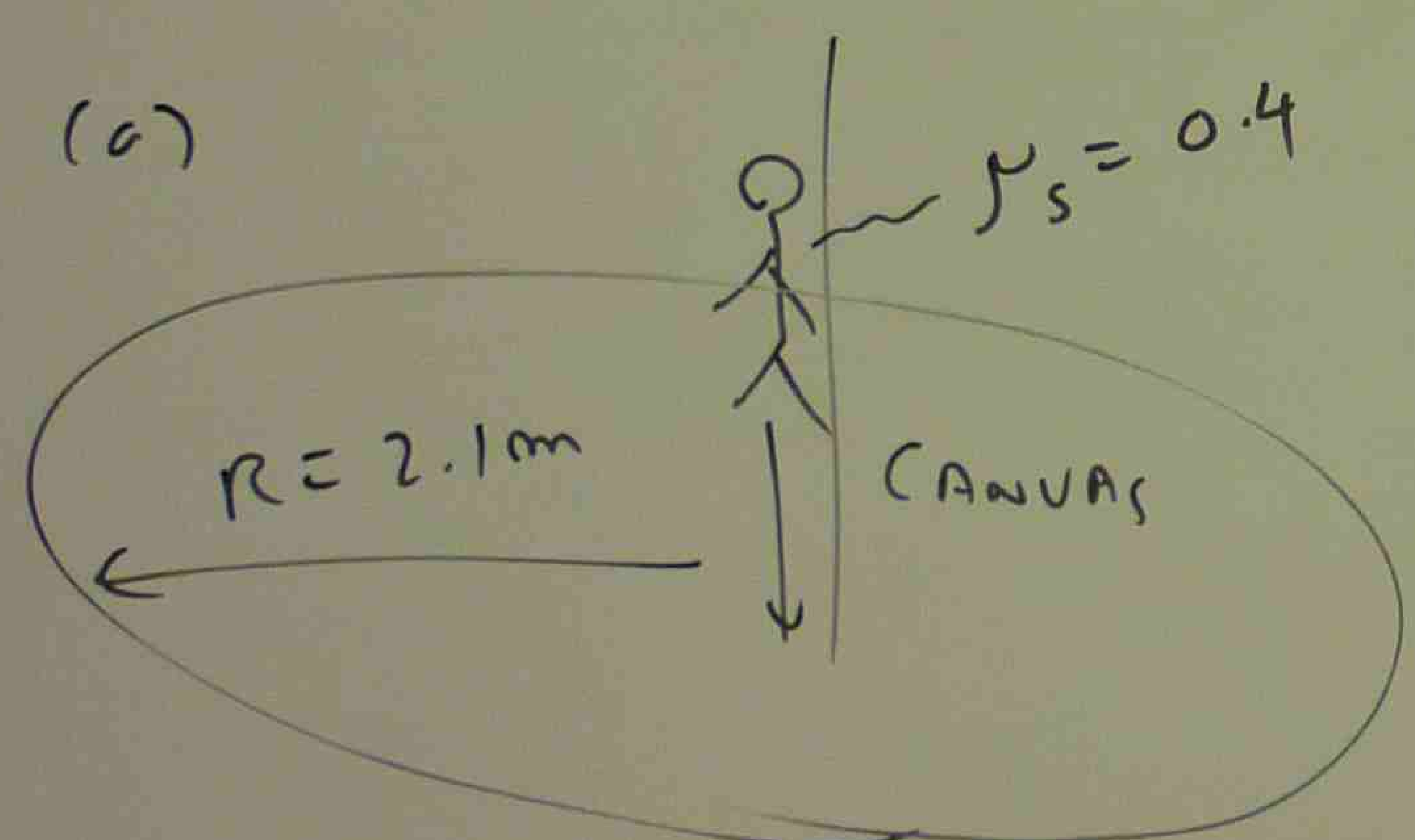


Pb SUPPOSE THAT THE COEFFICIENT OF STATIC FRICTION μ_s BETWEEN THE RIDER'S CLOTHING AND THE CANVAS IS 0.4 AND THE CYLINDER RADIUS "R" IS 2.1m

(a) WHAT MINIMUM SPEED (V) MUST THE CYLINDER AND THE RIDER HAVE IF THE RIDER IS NOT TO FALL WHEN THE FLOOR DROPS?

(b) IF THE RIDER'S MASS IS 49 kg, WHAT IS THE MAGNITUDE OF CENTRIPETAL FORCE ON RIDER

(a)



$$\boxed{f_N = \frac{mg}{\mu_s}}$$

$$-f_N - mg = m\left(-\frac{v^2}{R}\right)$$

DO NOT FALL

$$\mu_s f_N = mg$$

$$\boxed{-f_N = -m\left(\frac{v^2}{R}\right)}$$

$$-\frac{mg}{\mu_s} = -m\,\frac{v^2}{R}$$

$$\frac{g}{\mu_s} = \frac{v^2}{R}$$

$$\frac{gR}{\mu_s} = v^2$$

$$v = \sqrt{\frac{gR}{\mu_s}}$$

$$= \sqrt{\frac{9.81 \times 2.1}{0.4}}$$

$$= 7.2\,m/s$$

(b) $f_N = m\frac{v^2}{R} = 49 \times \frac{7.2^2}{2.1}$

$$= 1200N$$

DRAG

D = D

C_p = D

A = EFFECT

C.S.A

V = VELO

D =

$$\boxed{-f_N = -m\left(\frac{v^2}{R}\right)}$$

$$-\frac{mg}{\mu_s} = -m\,\frac{v^2}{R}$$

$$\frac{g}{\mu_s} = \frac{v^2}{R}$$

$$\frac{gR}{\mu_s} = v^2$$

$$v = \sqrt{\frac{gR}{\mu_s}}$$

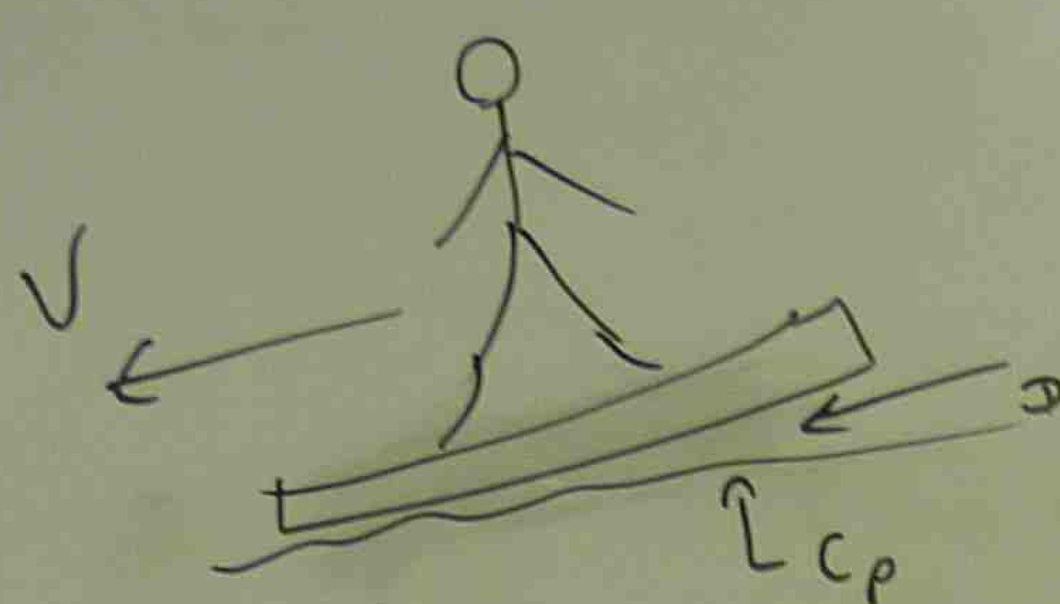
$$= \sqrt{\frac{9.81\times 2.1}{0.4}}$$

$$= 7.2\,m/s$$

(b) $f_N = m\frac{v^2}{R} = 49\times\frac{7.2^2}{2.1}$

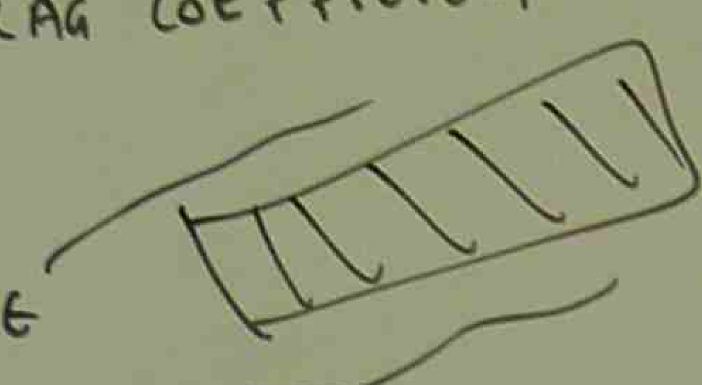
$= 1200N$

DRAG FORCE AND TERMINAL SPEED



D = DRAG FORCE

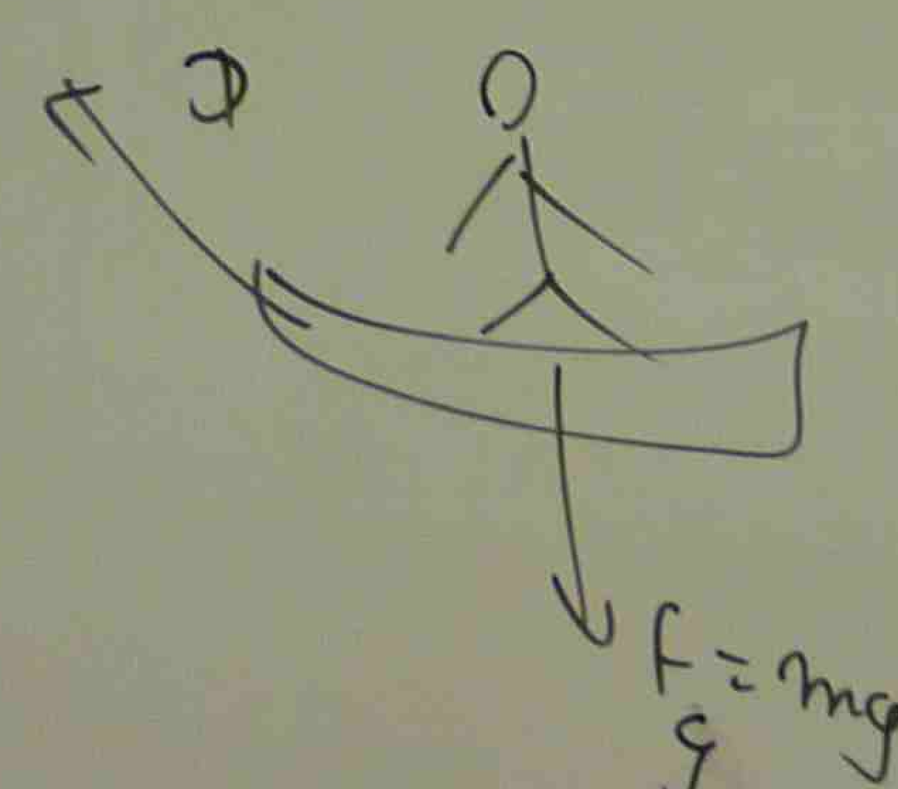
C_D = DRAG COEFFICIENT



A = EFFECTIVE C.S.A

V = VELOCITY

$$D = \frac{1}{2}C_D A V^2$$



$$D - F_g = m\,a$$

If $a=0$ — MOVING AT CONSTANT VELOCITY

$$D - F_g = m\times 0$$

$$D - F_g = 0$$

$$D = F_g$$

$$\frac{1}{2}C_D A v^2 = F_g$$

$$v^2 = \frac{2F_g}{C_D A}$$

$$v = \sqrt{\frac{2F_g}{C_D A}}$$

pb

IF A FALLING CAT ...

97 km/hr WHILE ...

OUT, DOUBLING ...

IT REACHES A NEW ...

$$V = \sqrt{\frac{2F_g}{C_D A}}$$

$$V_1 = \sqrt{\frac{2F_g}{C_D A_1}}$$

$$V_2 = \sqrt{\frac{2F_g}{C_D A_2}}$$

$$V_2 = \sqrt{\frac{2F_g}{C_D\times 2A}}$$

$$\frac{V_1}{V_2} = \frac{\sqrt{\frac{2F_g}{C_D\times A_1}}}{\sqrt{\frac{2F_g}{C_D\times 2A}}}$$

SPEED

$D - F_g = m\, a$

If $a = 0$ — MOVING AT CONSTANT VELOCITY

$D - F_g = m \times 0$

$D - F_g = 0$

$D = F_g$

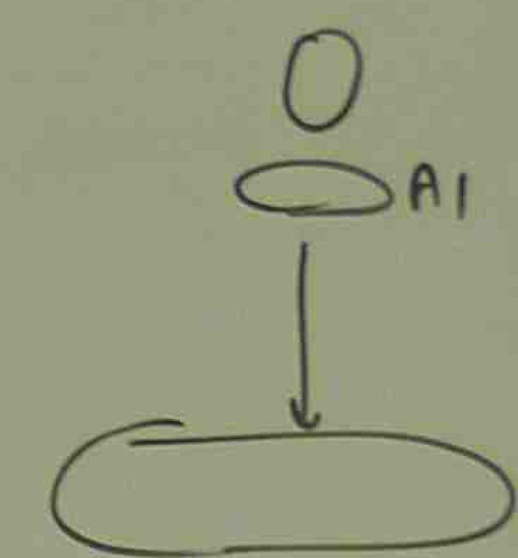
$\frac{1}{2} C \rho A v^2 = F_g$

$v^2 = \frac{2 F_g}{C \rho A}$

$v = \sqrt{\frac{2 F_g}{C \rho A}}$

pb

IF A FALLING CAT REACHES A FIRST TERMINAL SPEED OF 97 km/hr WHILE IT IS TUCKED IN AND THEN STRETCHES OUT, DOUBLING A, HOW FAST IS IT FALLING WHEN IT REACHES A NEW TERMINAL SPEED?



A_1 $v_1 = 97$

A_2 $v_2 = ?$

$v = \sqrt{\frac{2 F_g}{C \rho A}}$

$v_1 = \sqrt{\frac{2 F_g}{C \rho A_1}}$

$v_2 = \sqrt{\frac{2 F_g}{C \rho A_2}}$

$v_2 = \sqrt{\frac{2 F_g}{C \rho \times 2 A_1}}$

$\frac{v_1}{v_2} = \sqrt{\frac{\frac{2 F_g}{C \rho \times A_1}}{\frac{2 F_g}{C \rho \times 2 A_1}}}$

$A_2 = 2 A_1$

$\frac{v_1}{v_2} = \sqrt{\frac{2 F_g}{C \rho \times A_1} \times \frac{C \rho \times 2 A_1}{2 F_g}}$

$\frac{97}{v_2} = \sqrt{2}$

$v_2 = \frac{97}{\sqrt{2}} = \frac{97}{1.4142} = 68$ km/hr

pb

A RAIN DROP WITH ...

A CLOUD THAT IS AT ...

GROUND. THE DRAG COE...

0.6. ASSUME THAT TH...

ITS FALL. THE DENSI...

THE DENSITY OF ρ_a ...

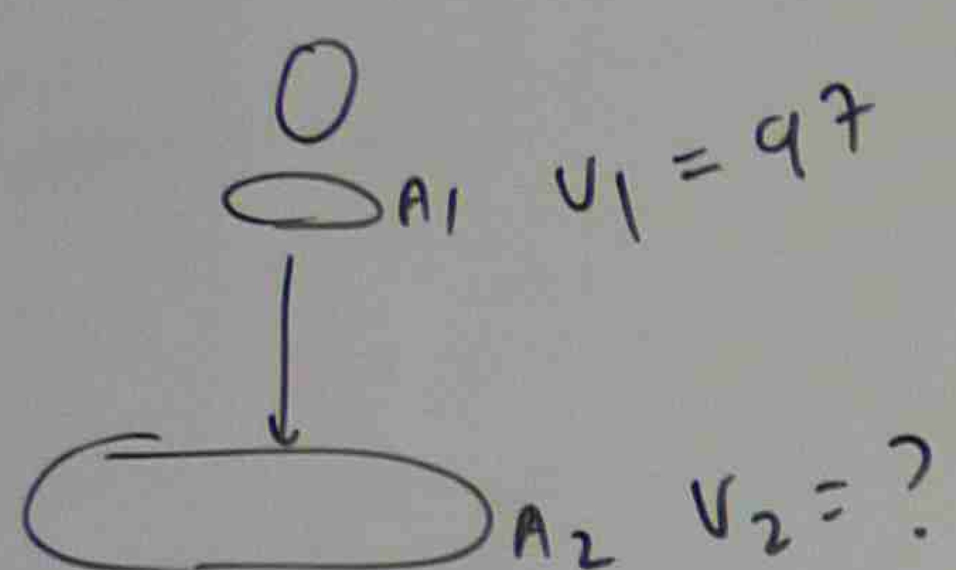
WHAT IS TERMINAL ...

$v = \sqrt{\frac{2 F_g}{C \rho_a A}}$

$= \sqrt{\frac{2 \times \frac{4}{3} \pi r^3 \ldots}{0.6 \times \pi \ldots}}$

$= \sqrt{\frac{2 \times 4 \times \pi \times \ldots}{0.6 \times \pi \ldots}}$

...HES A FIRST TERMINAL SPEED OF
...S TUCKED IN AND THEN STRETCHES
... HOW FAST IS IT FALLING WHEN
...RMINAL SPEED?



$A_2 = 2A_1$

$$\frac{v_1}{v_2} = \sqrt{\frac{2f_g}{C_p \times A_1} \times \frac{C_p \times 2A_1}{2f_g}}$$

$$\frac{97}{v_2} = \sqrt{2}$$

$$v_2 = \frac{97}{\sqrt{2}} = \frac{97}{1.4142} = 68 \text{ km/hr}$$

pb. A RAIN DROP WITH RADIUS $R = 1.5$ mm FALLS FROM A CLOUD THAT IS AT HEIGHT $h = 1200$ m ABOVE THE GROUND. THE DRAG COEFFICIENT C FOR THE DROP IS 0.6. ASSUME THAT THE DROP IS SPHERICAL THROUGHOUT ITS FALL. THE DENSITY OF WATER ρ_w IS $= 1000 \text{ kg/m}^3$.
THE DENSITY OF ρ_a IS 1.2 kg/m^3.
WHAT IS TERMINAL SPEED OF THE DROP?

$$v = \sqrt{\frac{2 f_g}{C \rho_a A}}, \quad f_g = \frac{4}{3}\pi R^3 \rho_w g$$

$$A = \pi R^2$$

$$C\rho_a = 0.6$$

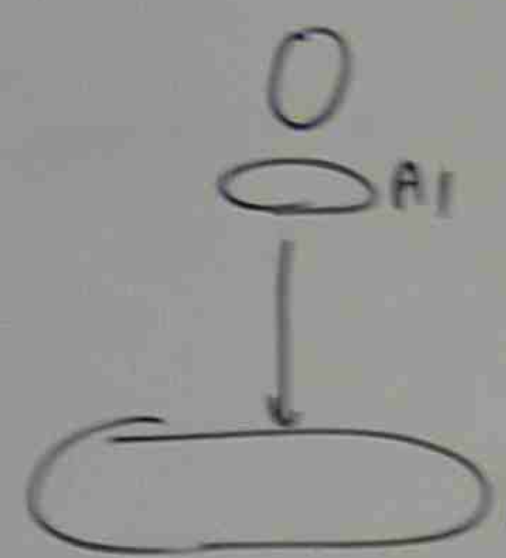
$$= \sqrt{\frac{2 \times \frac{4}{3}\pi R^3 \rho_w g}{0.6 \times \pi R^2}}$$

$$= \sqrt{\frac{2 \times 4 \times \pi \times R \times \rho_w g}{0.6 \times \pi}}$$

$$v = \sqrt{\frac{2 \times 4 \times \pi \times 1.5 \times 10^{-3} \times 1000 \times 9.81}{0.6 \times \pi}}$$

$$= 7.4 \text{ m/s}$$

REACHES A FIRST TERMINAL SPEED OF
IT IS TUCKED IN AND THEN STRETCHES
A, HOW FAST IS IT FALLING WHEN
TERMINAL SPEED?



$A_2 = 2A_1$

$$\frac{v_1}{v_2} = \sqrt{\frac{2f_g}{C\rho \times A_1} \times \frac{C\rho \times 2A_1}{2f_g}}$$

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WHAT IS TERMINAL SPEED OF THE DROP?

$$V = \sqrt{\frac{2 f_g}{C \rho_a A}}, \quad f_g = \frac{4}{3}\pi R^3 \rho_w g$$

$$A = \pi R^2$$

$$C\rho_a = 0.6$$

$$= \sqrt{\frac{2 \times \frac{4}{3}\pi R^3 \rho_w g}{0.6 \times \pi R^2}}$$

$$= \sqrt{\frac{2 \times 4 \times \pi \times R \times \rho_w g}{1.2 \times 0.6 \times \pi}}$$

$$V = \sqrt{\frac{2 \times 4 \times \pi \times 1.5 \times 10^{-3} \times 1000 \times 9.81}{1.2 \times 0.6 \times \pi}}$$

$$= 7.4 \text{ m/s}$$

UNIFORM CIRCULAR MOTION

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

(1) ROUNDING A CURVE IN A CAR

(2) ORBITING EARTH

---

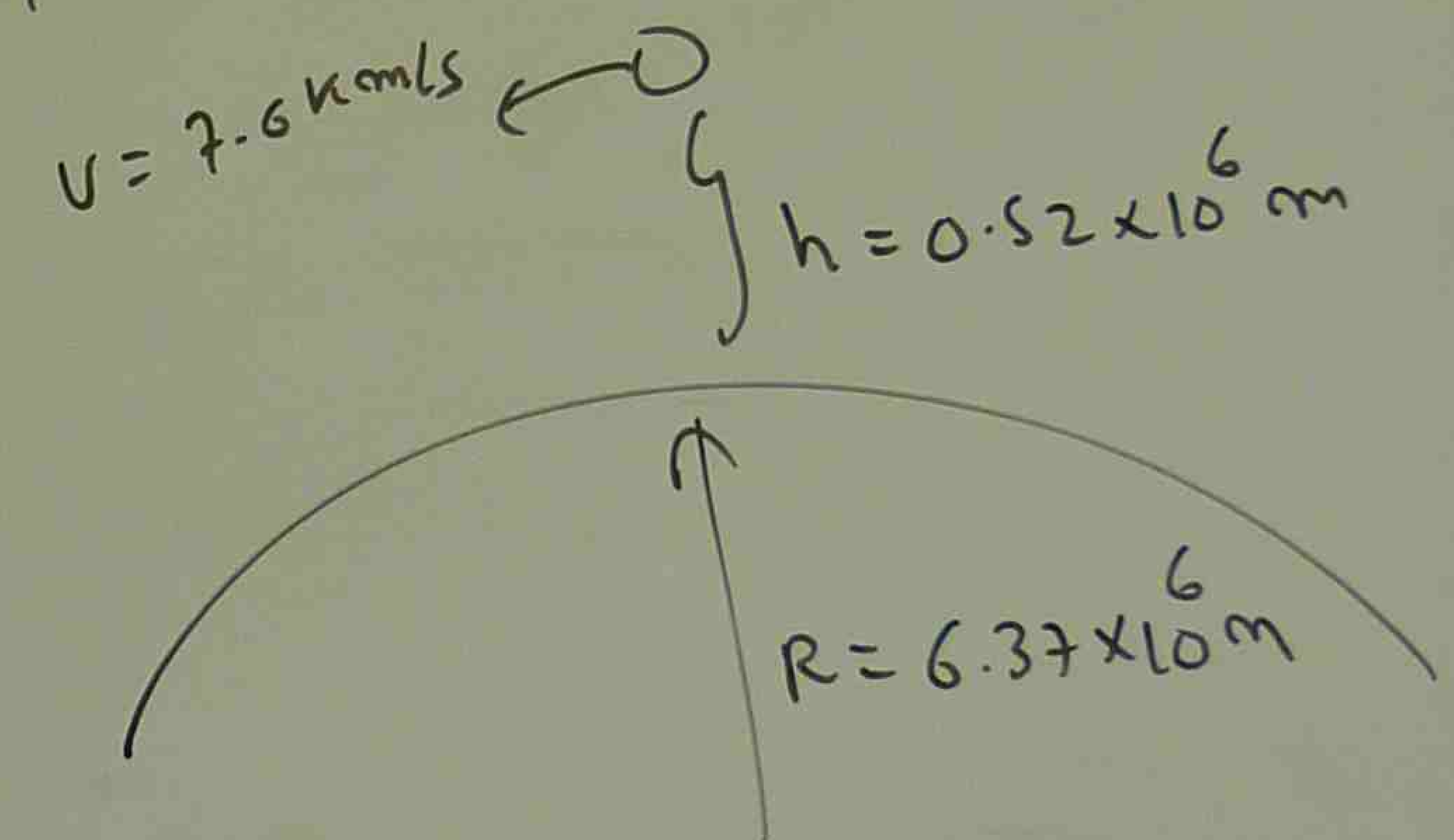
pb

A ASTRONAUT ON INTERNATIONAL SPACE STATION IN CIRCULAR ORBIT AROUND EARTH AT ALTITUDE 520 km. CONSTANT SPEED $V = 7.6$ km/s.

MASS IS 79 kg

FIND ACCELERATION.

$520\text{ km} = 0.52 \times 10^6$ m



$7.6\text{ km/s} = 7.6 \times 10^3$ m/s

$$a = \frac{v^2}{R} = \frac{(7.6 \times 10^3)^2}{R_{EARTH} + h} = \frac{(7.6 \times 10^3)^2}{0.52 \times 10^6 + 6.37 \times 10^6}$$

$$= 8.4 \text{ m/s}^2$$

UNIFORM CIRCULAR MOTION

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

(1) ROUNDING A CURVE IN A CAR

(2) ORBITING EARTH

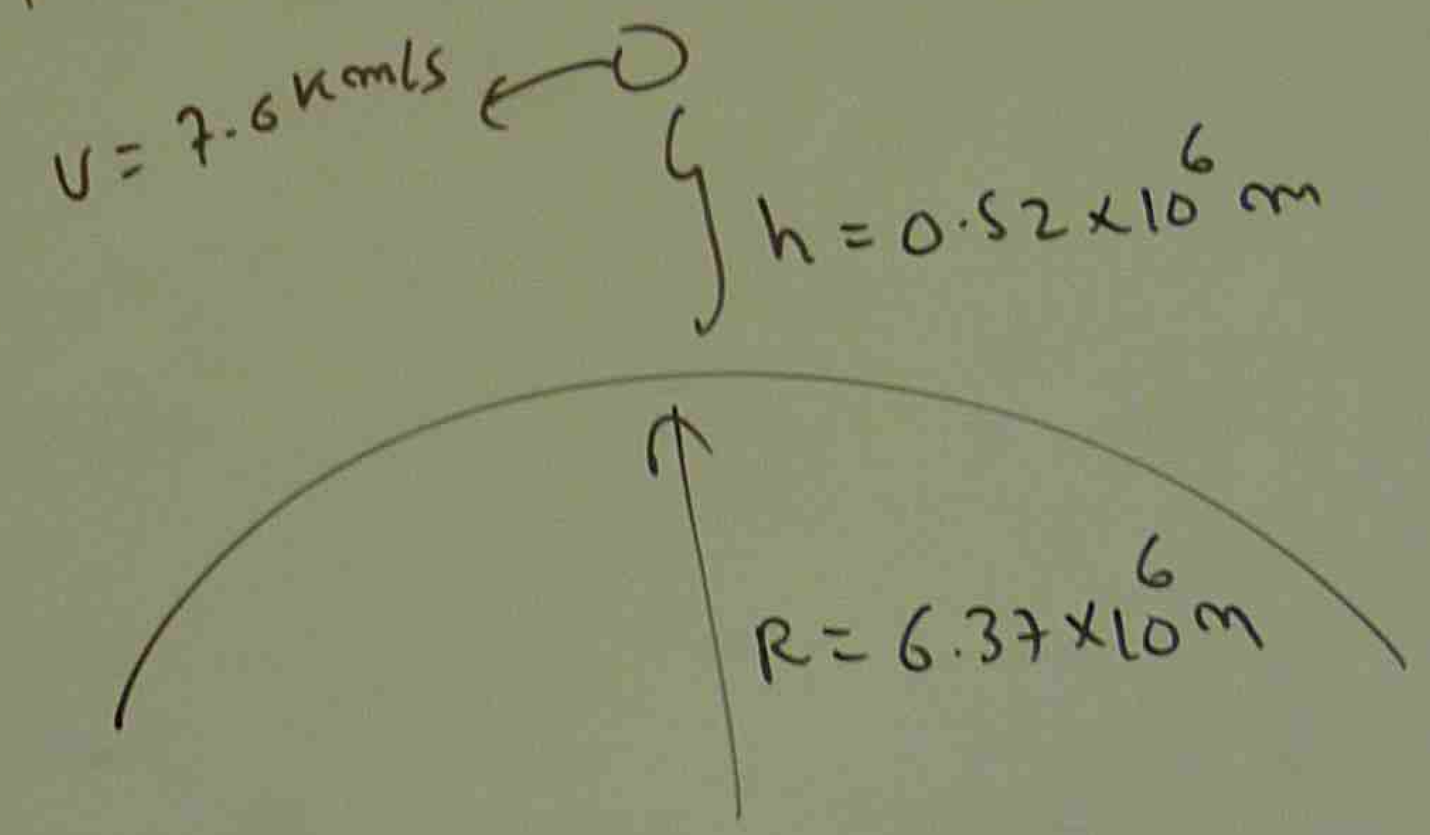
pb

A ASTRONAUT ON INTERNATIONAL SPACE STATION IN CIRCULAR ORBIT AROUND EARTH AT ALTITUDE 520 km. CONSTANT SPEED $v = 7.6$ km/s.

MASS IS 79 kg

FIND ACCELERATION.

$520\,\text{km} = 0.52 \times 10^6\,\text{m}$



$7.6\,\text{km/s} = 7.6 \times 10^3\,\text{m/s}$

$$a = \frac{v^2}{R} = \frac{(7.6 \times 10^3)^2}{R_{EARTH} + h} = \frac{(7.6 \times 10^3)^2}{0.52 \times 10^6 + 6.37 \times 10^6}$$

$$= 8.4\ \text{m/s}^2$$