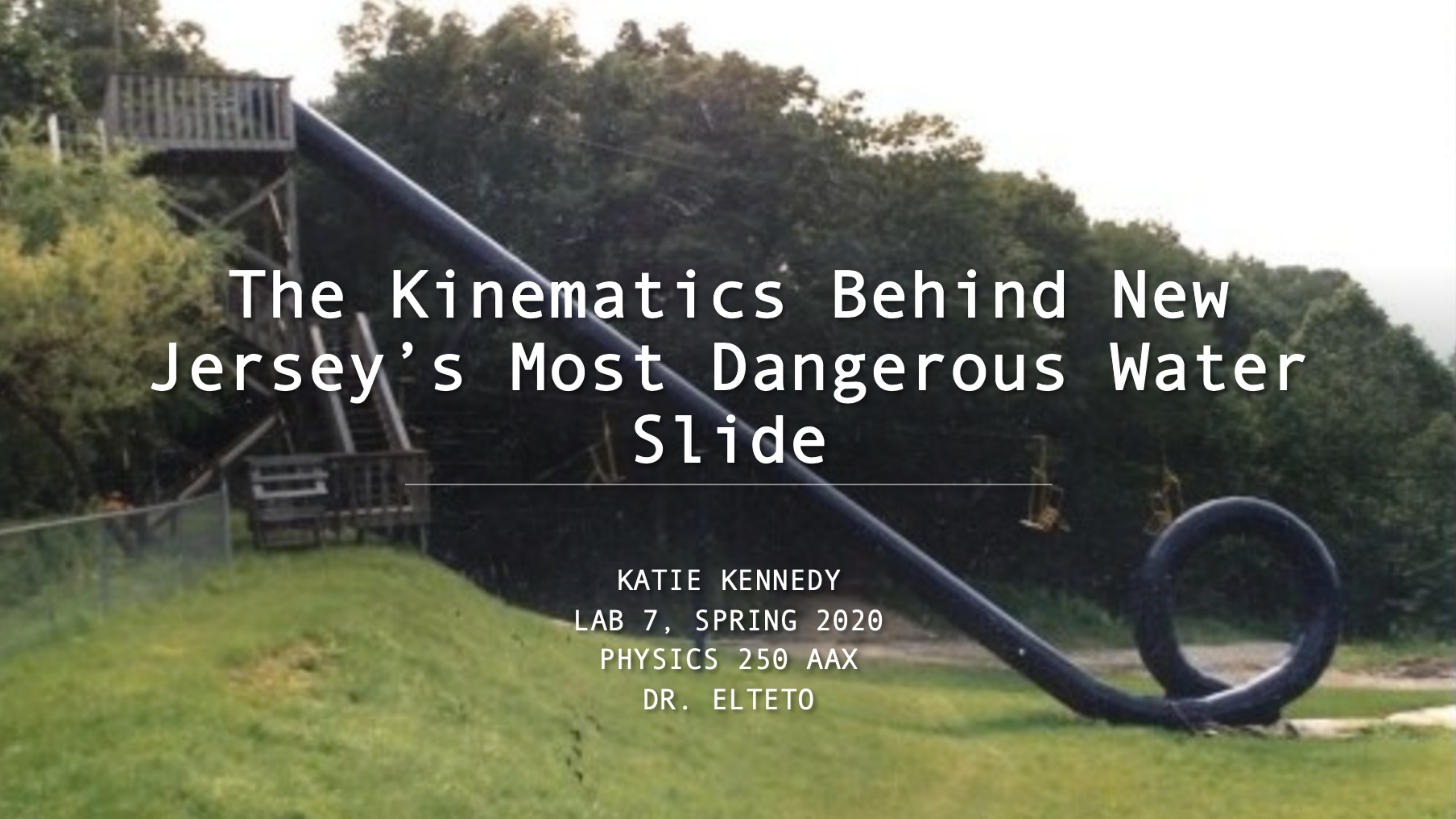

# The Kinematics Behind New Jersey’s Most Dangerous Water Slide

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PHYSICS 250 AAX
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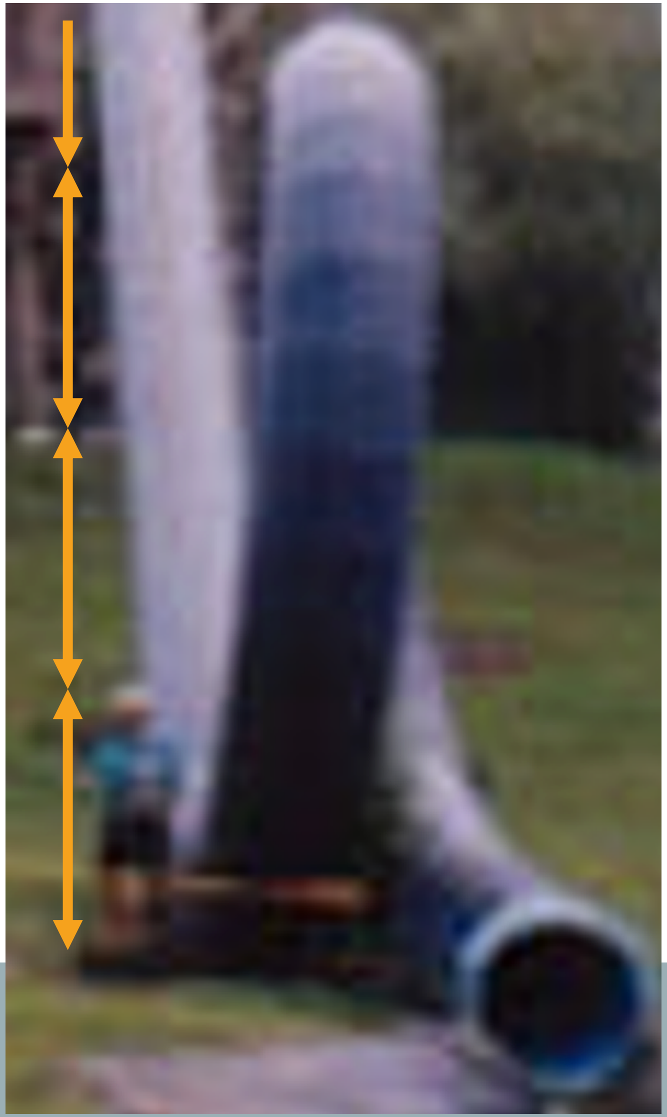
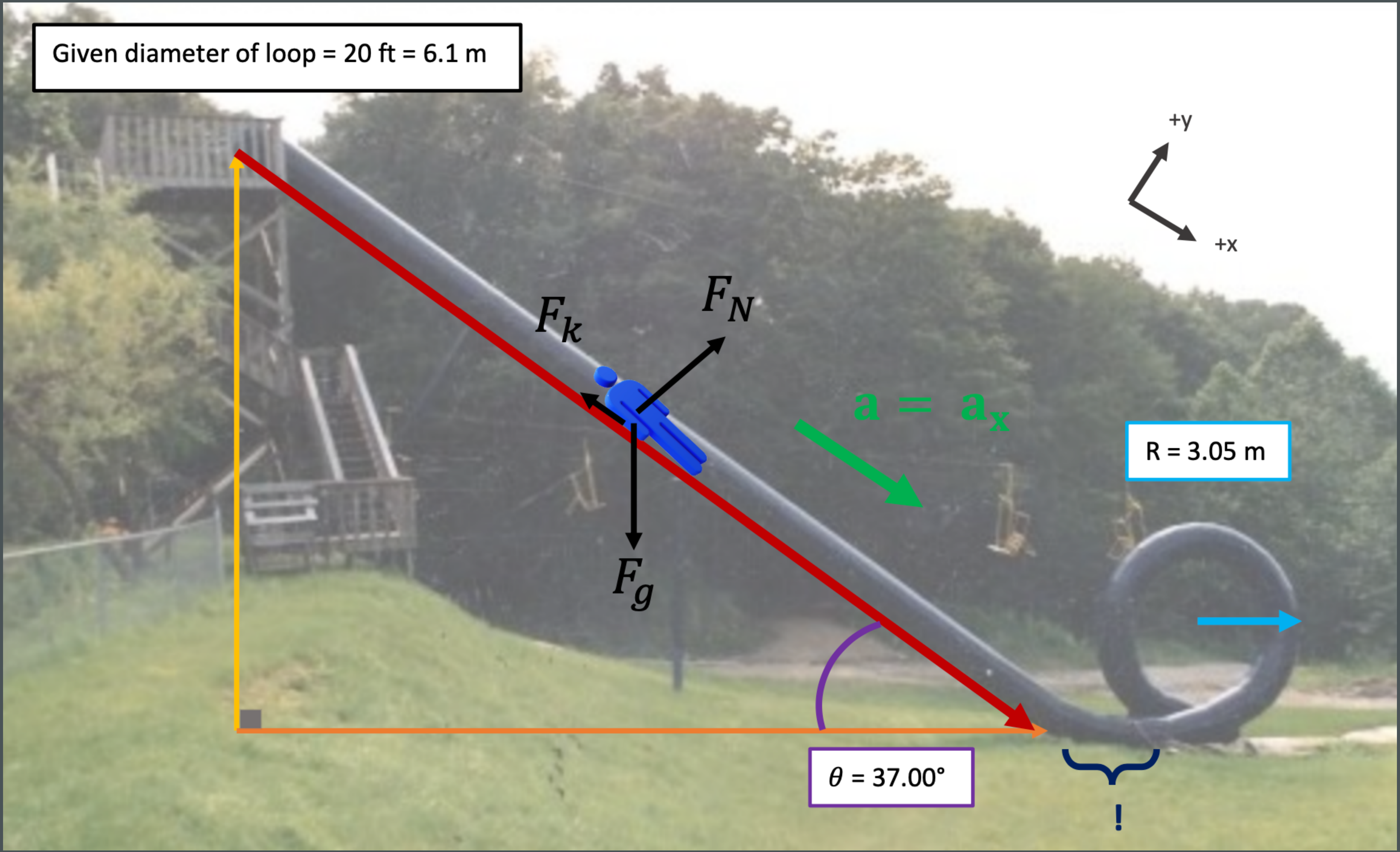
THE CANNONBALL LOOP



HEIGHT OF THE LOOP:  15-20 FT



Given diameter of loop = 20 ft = 6.1 m
+y
+x
$F_k$
$F_N$
$F_g$
$a = a_x$
R = 3.05 m
$\theta$ = 37.00°
!

# FINDING VELOCITY WHEN ENTERING THE LOOP

**Assumptions:**

1) angle measured with online protractor

2) length of straight slide part based on horizontal photo being head-on, not manipulated irregularly

3) height assumed to be 20 ft (6.1 m) for numeric calculations

4) ignoring constraint force of slide surface onto rider

*L = length of straight portion of slide*

*h = initial height of ride at top of straight slide*

$$-F_k = -\mu_k\, F_N = \frac{1}{2} m\, {v_f}^2 - mgh$$

$$W_{F_k} = -F_k \cos 180° * L = \mu_k\, mg \cos 37° * L$$

$$U_{g_i} - W_{F_k} = KE_f$$

$$mgh_{top} - L * \mu_k\, mg \cos 37° = \frac{1}{2} m {v_f}^2$$

$$\boldsymbol{V_f = \sqrt{2\, g\, h_{top} - 2\, L * \mu_k\, g * \cos 37°}}$$

$$\boldsymbol{V_f = V_{bottom\ of\ slide} = V_{entering\ loop}}$$

# REALISTIC INITIAL VELOCITY

$$V_f = \sqrt{2gh_{top} - 2\,L * \mu_k\, g * \cos 37°}$$

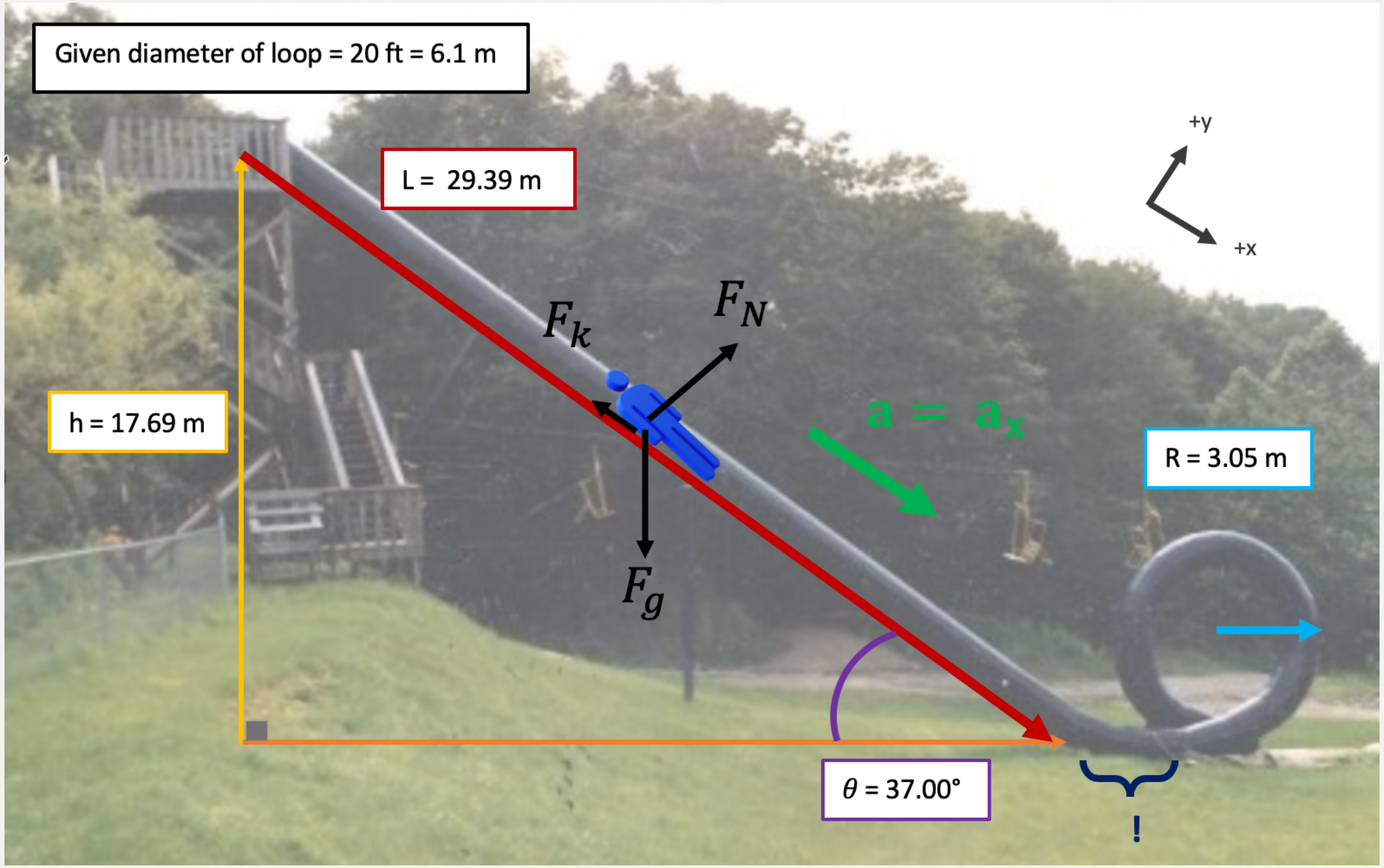
$$V_{f\ slide} = V_{i\ entering\ loop}$$

**Velocity at end of initial straight slide / beginning of loop:**

at $\mu_k = 0.10 \quad \rightarrow \quad$ **V = 17.34** $\frac{m}{s}$

at $\mu_k = 0.15 \quad \rightarrow \quad$ **V = 16.66** $\frac{m}{s}$

at $\mu_k = 0.20 \quad \rightarrow \quad$ **V = 15.96** $\frac{m}{s}$




<u>Note</u>: 16.66 $\frac{m}{s}$ is equiv. to just over 37 $mph$.

# FINDING MINIMUM VELOCITY TO THE COMPLETE LOOP

arc length $= s = 2\pi R * {}^{180°}/_{360°}$
Normal force of rider at top of loop $= 0$ N.
No acceleration in the $x$ direction at the top of the loop.

$$W_{F_k} = -\mu_k(-F_N) * s * \cos 180° = -\pi R * \mu_k F_N$$

$$KE_i + W_{F_k} = KE_f + U_g$$

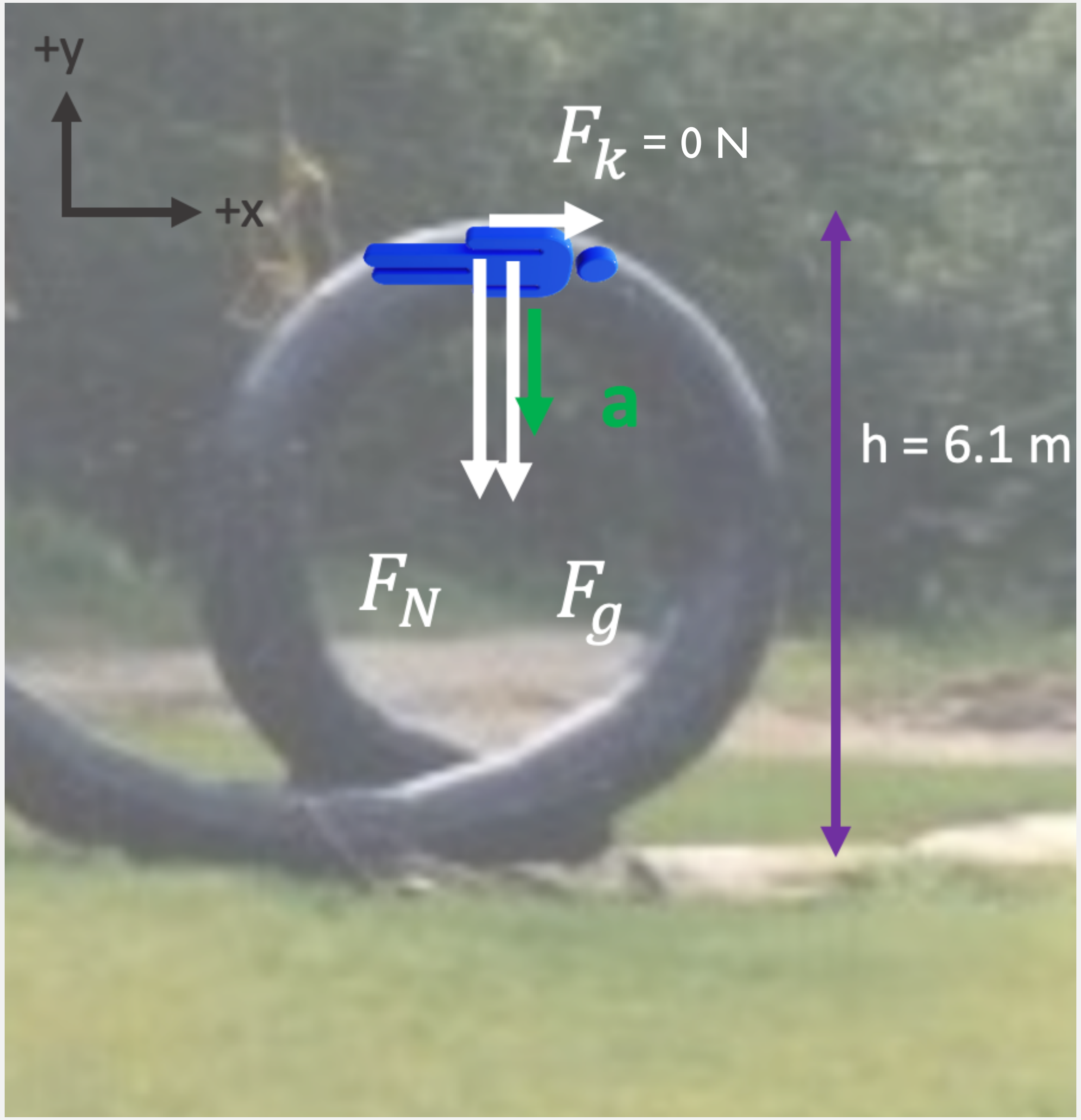
$$\frac{1}{2} m v_i^2 - \pi R * \mu_k Fn = \frac{1}{2} m v_f^2 + m g h_{loop}$$

$$\Sigma F_y = ma_y = -F_N - F_g$$

$$-\frac{m v^2}{R} = 0 - mg$$

$$V_y > \sqrt{g R} = \sqrt{9.8 \frac{m}{s^2} * 3.05 m}$$

Need a speed <u>greater</u> than: $5.47 \frac{m}{s}$ (12.24 mph)
(Requires a speed of 14.34 m/s entering loop)



# THE RIDER'S REALISTIC VELOCITY AT THE TOP OF THE LOOP

***Conservation of Energy & Circular Motion***

$$KE_i + W_{F_k} = KE_f + U_f$$

$$\frac{1}{2}\, m\, {V_i}^2 + \int_{0\,m}^{s} F_k\, ds = \frac{1}{2}\, m\, {V_f}^2 + mg\, h_{loop}$$

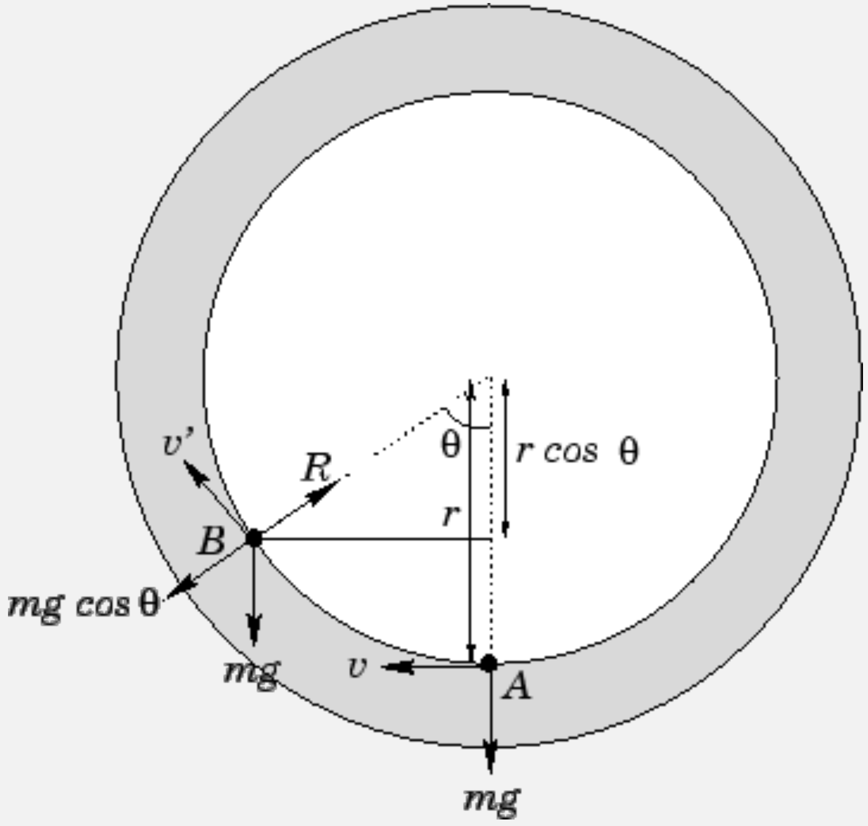
$$\frac{1}{2}\, m\, {V_i}^2 - 2\pi\, \mu_k\, mg\, R = \frac{1}{2}\, m\, {V_f}^2 + mg\, h_{loop}$$

$$V_f = \sqrt{{V_i}^2 - 4\,\pi\, \mu_k\, g\, R - 2\, g\, h_{loop}}$$

at $\mu_k = 0.10$ → **V = 11.98** $^{m}/_{s}$

at $\mu_k = 0.15$ → **V = 10.08** $^{m}/_{s}$ (a.k.a ~22.6 mph)

at $\mu_k = 0.20$ → **V = 9.10** $^{m}/_{s}$



# THE FRICTION COEFFICIENT OF PANIC

$$\mu_k = 0.4$$

**Assuming the panic starts after the straight slide ( $\mu_k = 0.15$ , $v_i = 16.66\ m/s$ ):**

$$V_{top} = \sqrt{V_i^{\,2} - 4\,\pi\,\mu_k\,g\,R - 2\,g\,h_{loop}} = 2.78\,\frac{\mathrm{m}}{\mathrm{s}}$$

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