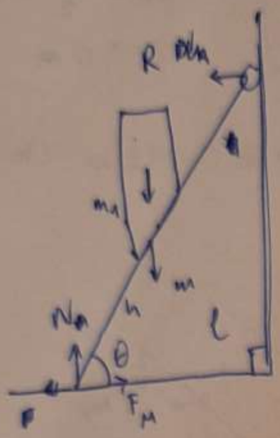
9.3.



$m = 15\,kg$
$l = 5\,m$
$\mu = 0.5$
$m_1 = 70\,kg$

$W = mg = 15 \cdot 9.81 = 145.15\,N$

$W_1 = m_1 g = 70 \cdot 9.81 = 686.7\,N$

Equilibrium :

$\Rightarrow N = W + W_f$

$\Rightarrow R = F_\mu = \mu N$

$\tau_{ladder} = W \frac{l}{2} \cos\theta \qquad \tau_{person} = W_1 h \cos\theta$

$\tau_{wall} = R\, l \sin\theta$

$\tau_{ladder} + \tau_{person} = \tau_{wall}$

$\Rightarrow W \frac{l}{2} \cos\theta + W_1 h \cos\theta = R\, l \sin\theta$

$\Rightarrow W \frac{l}{2} \cos\theta + W_1 h \cos\theta = \mu (W + W_1)\, l \sin\theta$

$$\Rightarrow h = \frac{\mu (W + W_1)\, l \sin\theta - W \frac{l}{2} \cos\theta}{W_1 \cos\theta}$$

$$= \frac{208.4625 \sin\theta - 367.875 \cos\theta}{686.7 \cos\theta}$$

9.1.

$m_{\text{~~[illegible]~~}} = 50kg$

$m_{\text{~~[illegible]~~}r} = 10kg$

$m_{\text{~~total~~} t} = 60kg$

depth $= 70cm = 0.7m$

H = height $= 190cm = 1.9m$

$\theta = 30°$

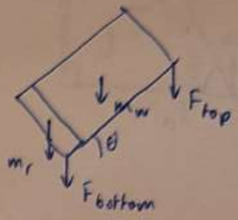
Upright orientation:

$$F_{bottom} + F_{top} = W \sin 30°$$

$$F_{top} \cdot H = W \sin 30° \; y_{com}$$

$$\Rightarrow F_{top} = \frac{60 \cdot 9.81 \cdot 0.792}{2 \cdot 1.9} \approx 123\ N \ (3s.f)$$

$$\Rightarrow F_{bottom} = \frac{60 \cdot 9.81}{2} - 123 \approx 172\ N \ (3s.f)$$



Combined center of mass:

$$y_{com} = \frac{(m_w \, y_w) + (m_r \, y_r)}{m_t}$$

$$= \frac{50 \cdot 0.95 + 10 \cdot 0}{60} \approx 0.792\ m \quad (3s.f)$$

$$y_w = \frac{1.90}{2} = 0.95\ m$$

$$y_r = 0\ m$$

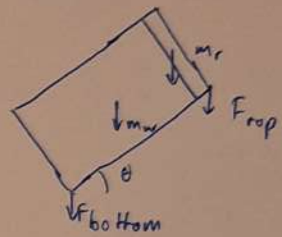
Inverse orientation:

$$F_{bottom} + F_{top} = W \sin 30°$$

$$F_{bottom} \, \cancel{F_{top}} \; H = W \sin 30° \, (H - y_{com})$$

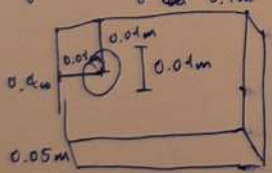
$$\Rightarrow \cancel{F_{top}} \; F_{bottom} = \frac{60 \cdot 9.81}{2 \cdot 1.9} (1.9 - 0.792) \approx 172N \ (3s.f)$$

$$F_{top} = \frac{60 \cdot 9.81}{2} - 172 \approx 123N \ (3s.f)$$



~~width = height = length = 40~~ 0.4m

9.2.



$$V_{plank} = 40 \cdot 40 \cdot 5 = 8000\ cm^3$$

$$V_{disk} = \pi r^2 \cdot 5 = \pi \cdot 5^2 \cdot 5 = 125\pi \approx 392.7\ cm^3$$

$$M_{plank} = \rho V_{plank} = \rho 8000$$

$$M_{disk} = \rho V_{disk} = \rho\ 392.7$$

$$M_{remain} = \rho 8000 - \rho 392.7 = \rho 7607.3$$

$$x_{com} = \frac{(\rho 8000 \cdot 20) - (\rho 392.7 \cdot 10)}{\rho\ 7607.3} \approx 20.5cm$$

$$y_{com} = \frac{(8000\rho \, 20) - (392.7\rho \cdot 10)}{\rho 7607.3\rho} \approx 20.5cm$$

$$\Rightarrow (x_{com}, y_{com}) \approx (20.5\ cm, 20.5\ cm)$$

```
import numpy as np
from scipy.integrate import solve_ivp


rho = 1.293 # air density
C_d = 0.295 # drag coefficient
diameter = 0.00782 # m (7.82 mm)
A = np.pi * (diameter / 2) ** 2 # cross sectional area of bullet
m_bullet = 0.00603 # mass of bullet
v_initial = 1330 * 1000 / 3600 # initial velocity
target_height = 500 # height of the target


g = 9.81


def drag_force(v):
return 0.5 * rho * C_d * A * v**2


def equations_with_theta(theta):
def equations(t, y):
x, y_pos, v_x, v_y = y
v = np.sqrt(v_x**2 + v_y**2)
F_drag = drag_force(v)
F_drag_x = F_drag * (v_x / v)
F_drag_y = F_drag * (v_y / v)
dxdt = v_x
dydt = v_y
dvxdt = -F_drag_x / m_bullet
dvydt = -g - F_drag_y / m_bullet
return [dxdt, dydt, dvxdt, dvydt]
return equations
```

```
def reach_target_height(t, y):
return y[1] - target_height
reach_target_height.terminal = True


def minimum_distance(theta_degrees):
theta = np.radians(theta_degrees)
initial_conditions = [0, 0, v_initial * np.cos(theta), v_initial * np.sin(theta)]

solution = solve_ivp(
equations_with_theta(theta), [0, 100], initial_conditions,
dense_output=True, events=reach_target_height
)

if solution.status == 1:
distance = solution.y[0, -1]
return distance
else:
return None


angle_1, angle_2 = None, None
for angle in range(1, 90):
dist = minimum_distance(angle)
if dist:
if angle_1 is None:
angle_1 = angle
elif angle_2 is None:
angle_2 = angle
break
```

```
print(f"Two angles for hitting the target: {angle_1}° and {angle_2}°")
print(f"Minimum distance to hit the window with drag included: {minimum_distance(angle_1):.3f} m")
```

Output:

Two angles for hitting the target: 38° and 39°

Minimum distance to hit the window with drag included: 834.230 m