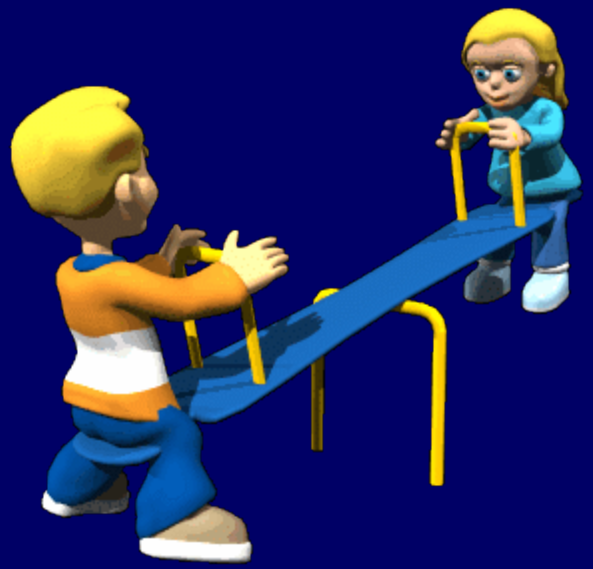
Static Equilibrium



AP Physics

Chapter 9

Static Equilibrium

8.4 Torque

8.4 Torque

Rotational Dynamics – the causes of rotational motion

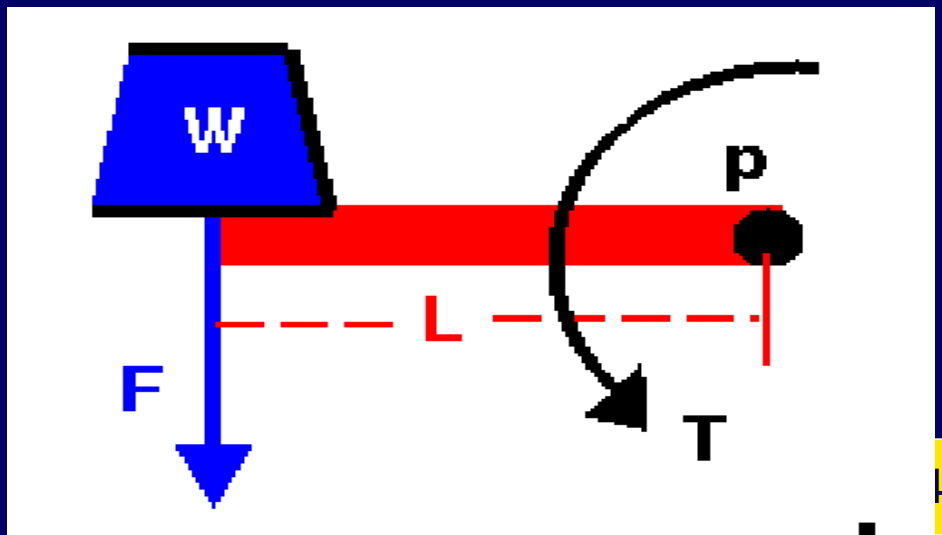
Caused by Torque, or a force applied at a distance from the pivot point

$$\tau = Fr$$

τ=torque (Nm)

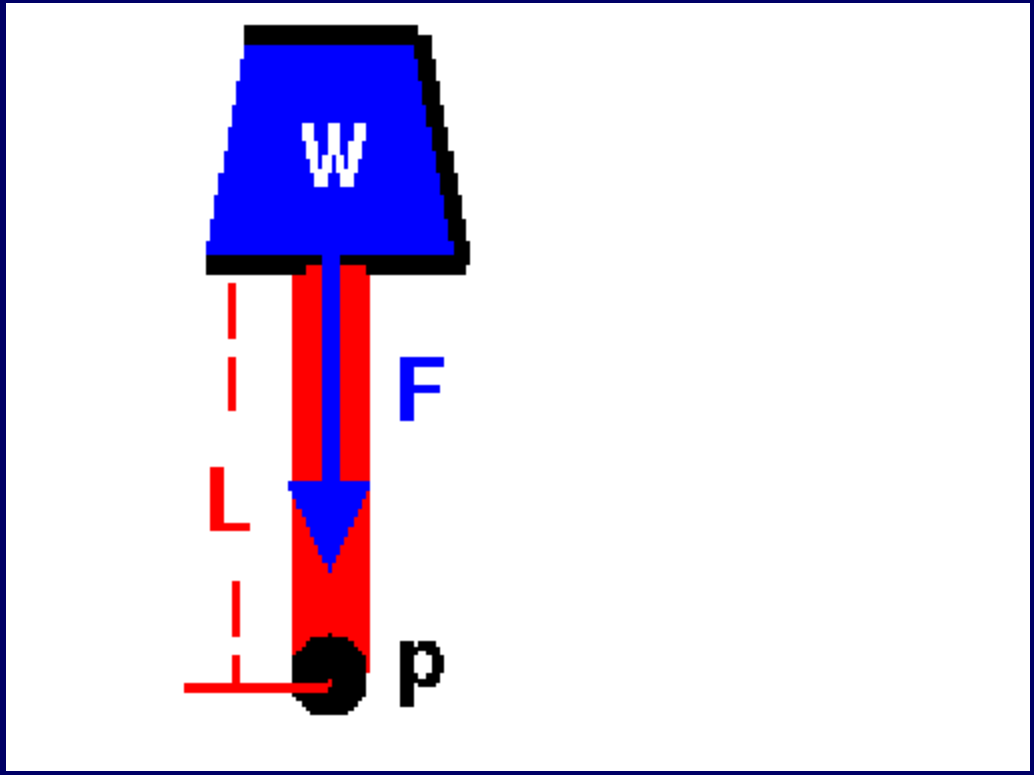
F=force (N)

r=torque arm (m)



8.4 Torque

Force causes no rotation if it is applied at the pivot point



8.4 Torque

If the force is applied at an angle then only the perpendicular component matters

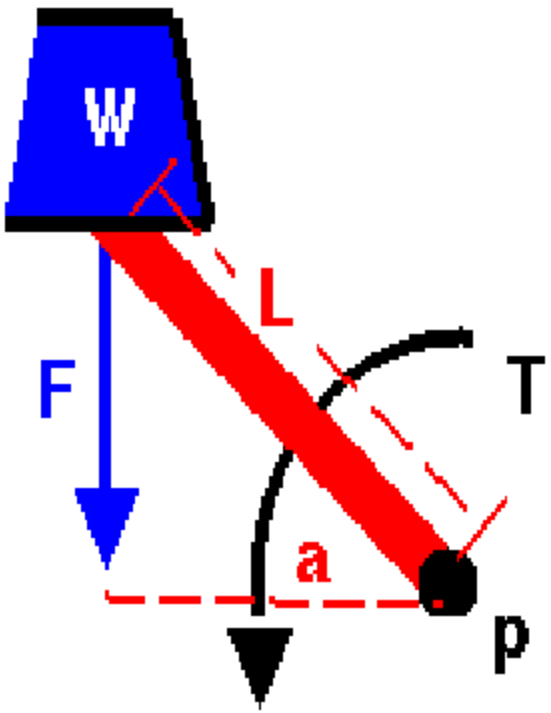
So

$$\tau = Fr\sin\theta$$

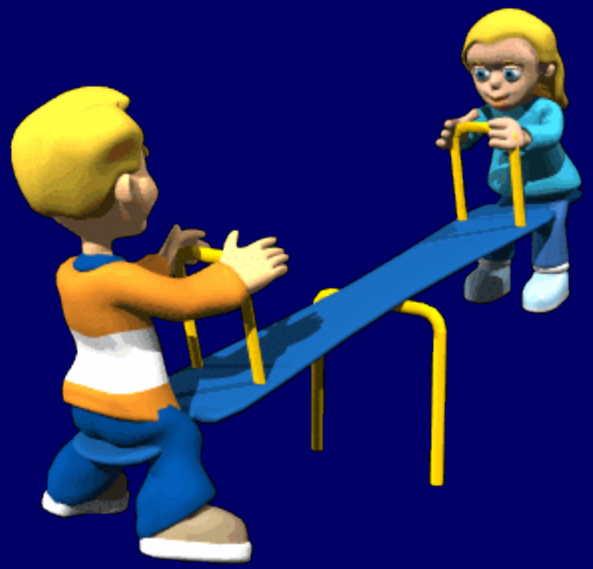
θ must be the angle

Between the force

And the torque arm



Static Equilibrium



9.1 The Conditions of Equilibirum

9.1 The Conditions for Equilibrium

Two Conditions

1. The sum of all forces is zero mathematically

$$\Sigma F_x = 0$$

$$\Sigma F_y = 0$$

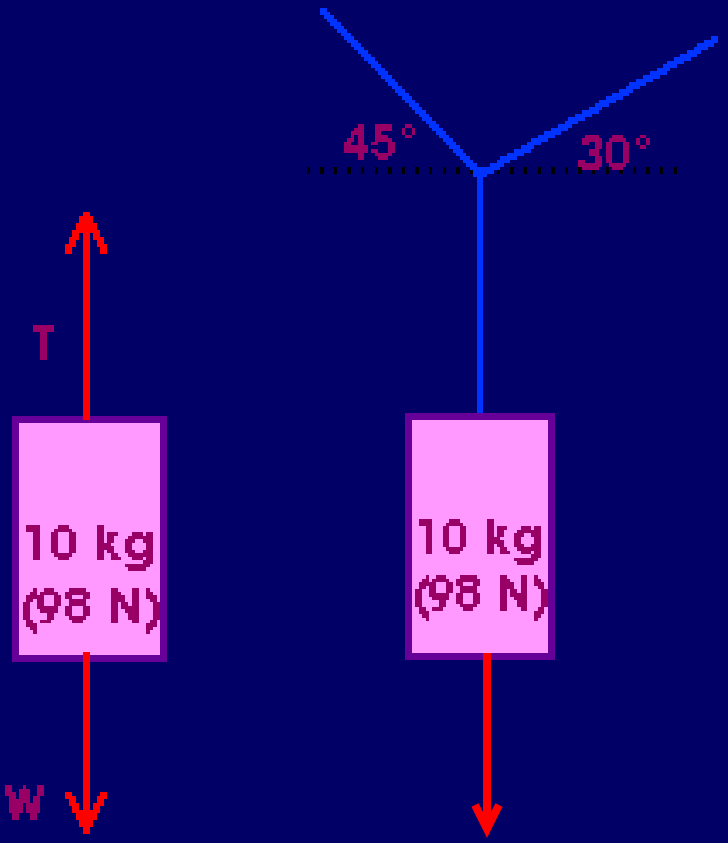
$$\Sigma F_z = 0$$

examples

Called

Translational

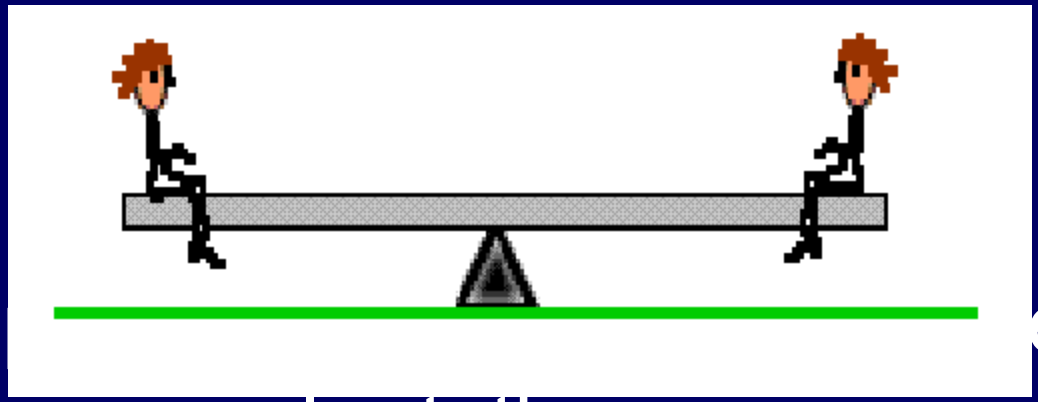
equilibrium



9.1 The Conditions for Equilibrium

2. The second condition for equilibrium – the sum of all torques equals zero

$$\Sigma\tau = 0$$



The pivot point can be chosen to be anywhere you like since there is no real rotation

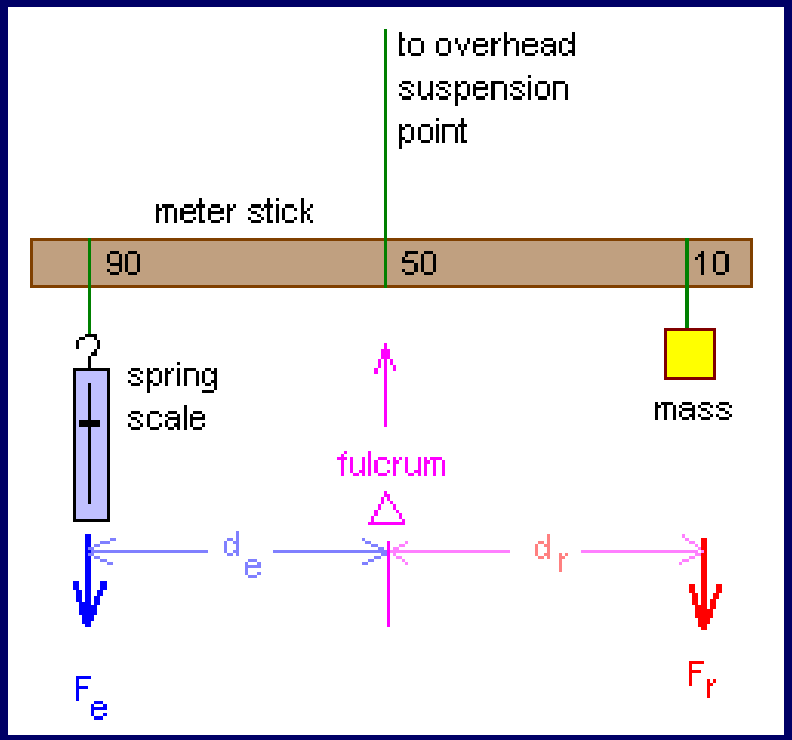
9.1 The Conditions for Equilibrium

Counterclockwise is considered positive torque

Clockwise negative torque

Mass – negative torque

Spring scale – positive torque



9.1 The Conditions for Equilibrium

Steps in Problem Solving

- Make a free body diagram
- Choose a coordinate system and resolve the forces into their components
- Write down the equilibrium equations for the forces
- Write down the torque equilibrium equation
- Solve

9.1 The Conditions for Equilibrium

Example: A happy 50 kg dude stands 2 m from the left side of a 5 m long bridge. The bridge is supported at each end by pylons. What is the force on each pylon?

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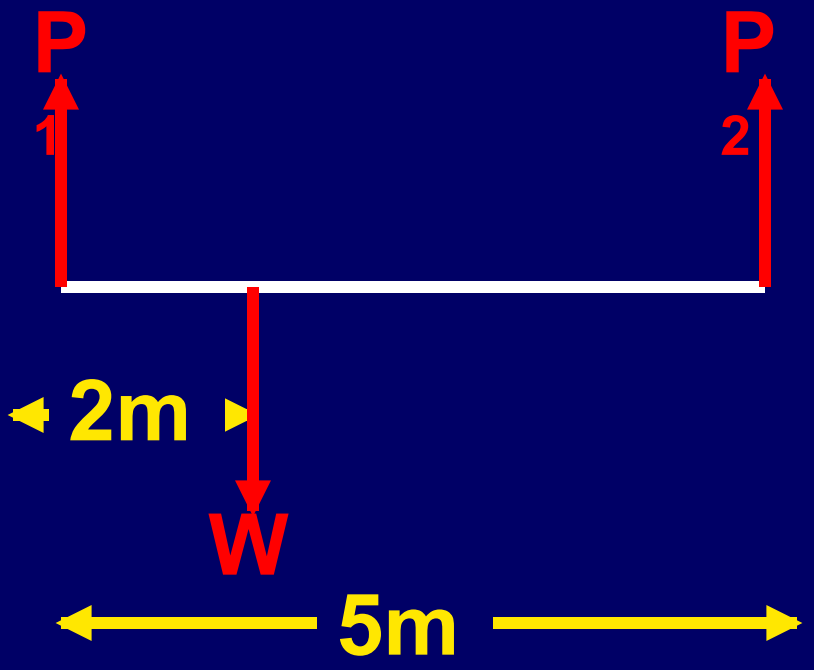
Free Body Diagram



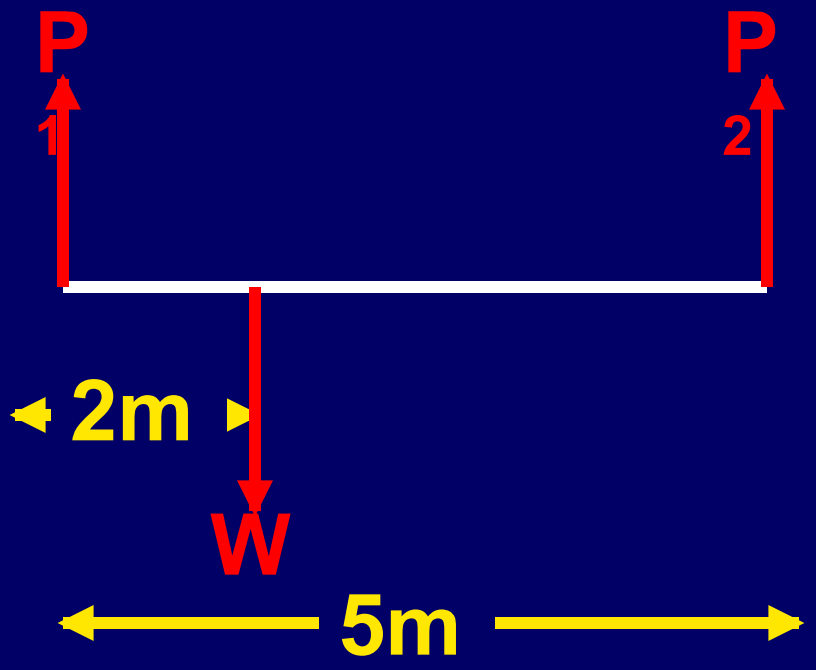
9.1 The Conditions for Equilibrium

Example: A happy 50 kg dude stands 2 m from the left side of a 5 m long bridge. The bridge is supported at each end by pylons. What is the force on each pylon?

Force Equations

$$\Sigma F_x = 0 = 0$$

$$\Sigma F_y = P_1 + P_2 - W = 0$$



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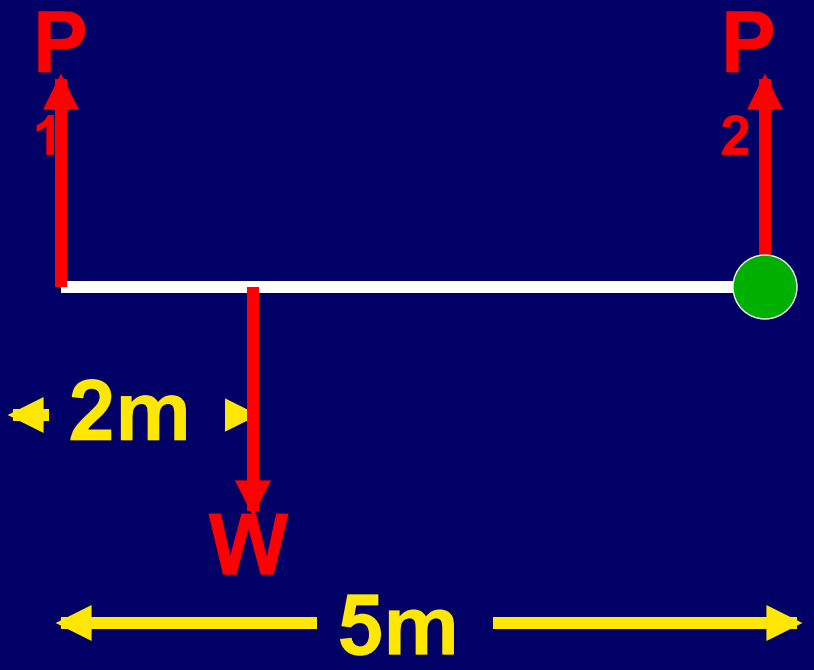
Pivot Point



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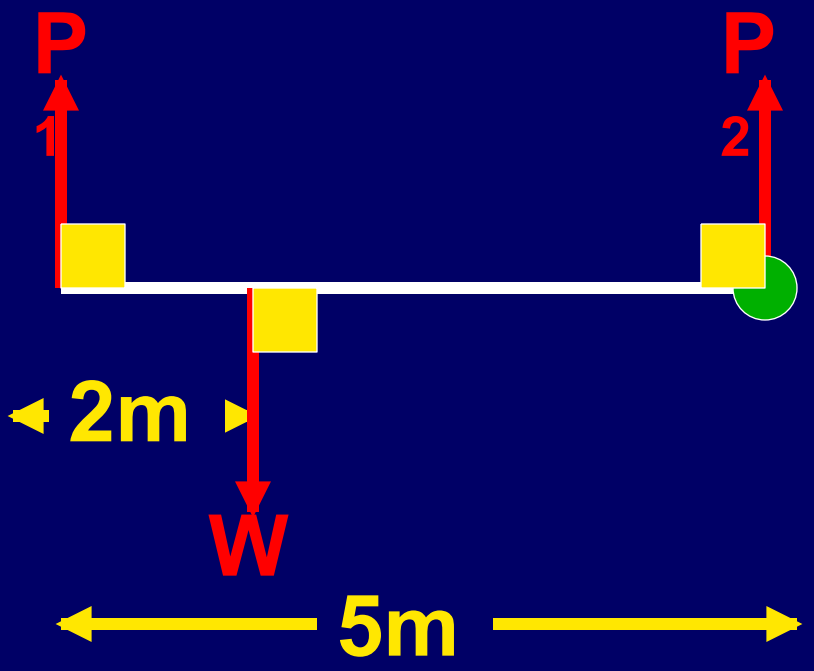
Torque Equation

Angles



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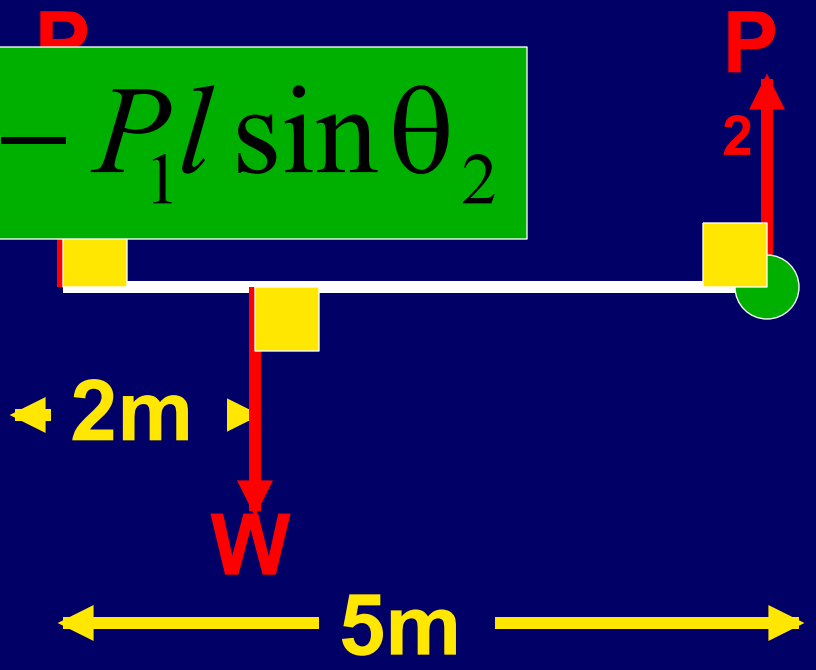
Example: A happy 50 kg dude stands 2 m from the left side of a 5 m long bridge. The bridge is supported at each end by pylons. What is the force on each pylon?

Torque Equation

$$\Sigma\tau = W\,\tfrac{3}{5}\,l\sin\theta_1 - P_1 l\sin\theta_2$$



9.1 The Conditions for Equilibrium

Example: A happy 50 kg dude stands 2 m from the left side of a 5 m long bridge. The bridge is supported at each end by pylons. What is the force on each pylon?

Solve

$$\Sigma\tau = W\,\tfrac{3}{5}\,l\sin\theta_1 - P_1 l\sin\theta_2$$

$$\Sigma\tau = (50)(9.8)\,\tfrac{3}{5}\,(5) - P_1(5)$$

$$P_1 = 294N$$

9.1 The Conditions for Equilibrium

Example: A happy 50 kg dude stands 2 m from the left side of a 5 m long bridge. The bridge is supported at each end by pylons. What is the force on each pylon?

Solve

$$P_1 = 294N$$

$$\Sigma F_x = 0 = 0$$

$$\Sigma F_y = P_1 + P_2 + W = 0$$

$$294 + P_2 - (50)(9.8) = 0$$

$$P_2 = 196N$$

9.1 The Conditions for Equilibrium

Example: A 5 m long ladder leans against a wall at a point 4 m above a cement floor. The ladder is uniform and has a mass of 12 kg. Assuming the wall is frictionless (but the floor is not) determine the forces exerted on the ladder by the floor and by the wall.

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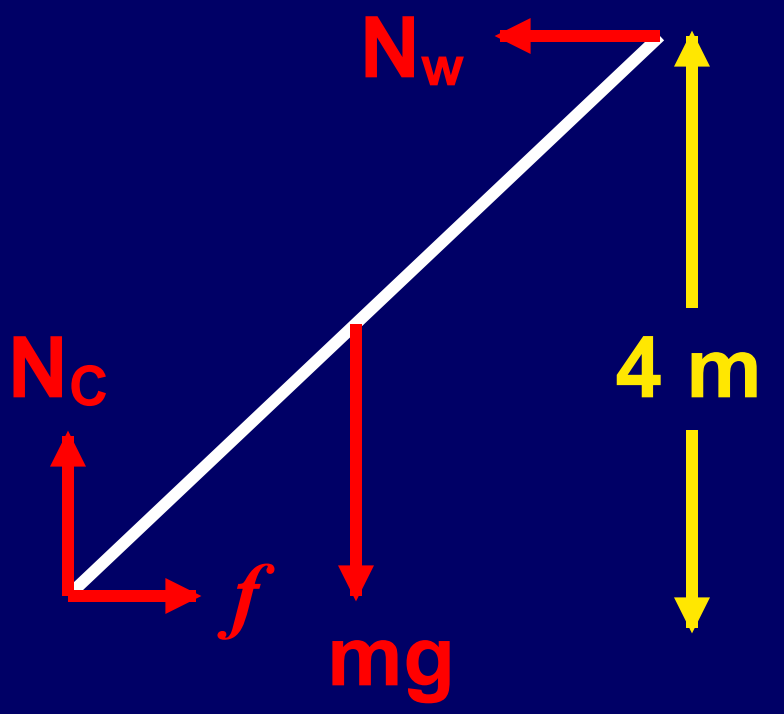
Free body diagram



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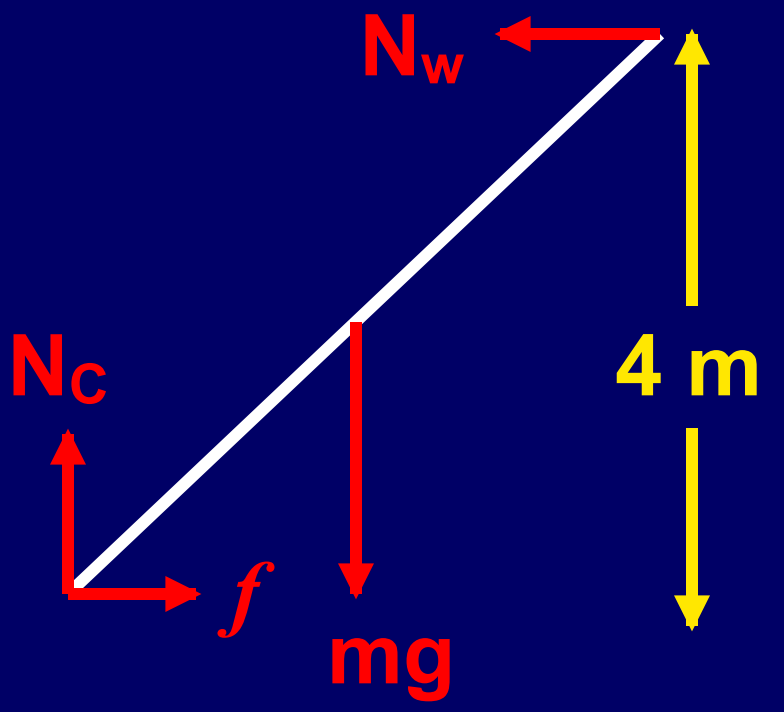
Axis?



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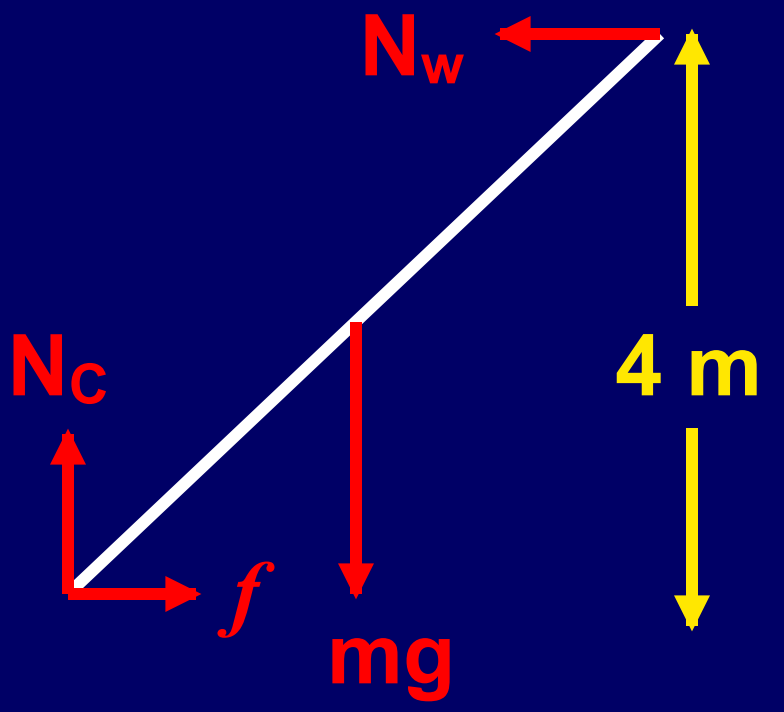
Force Equations

$$\Sigma F_x = f - N_w = 0$$

$$\Sigma F_y = N_c - mg = 0$$



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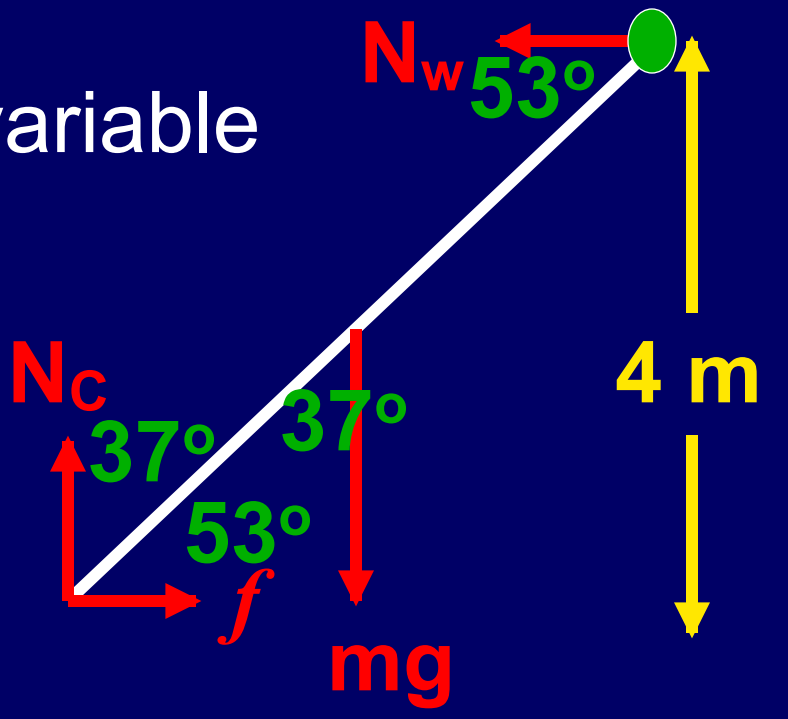
Torque Equations

Pick a pivot the eliminates variable

Calculate angles

$$\theta = \sin^{-1}\frac{y}{h}$$

$$\theta = \sin^{-1}\frac{4}{5} = 53^{o}$$



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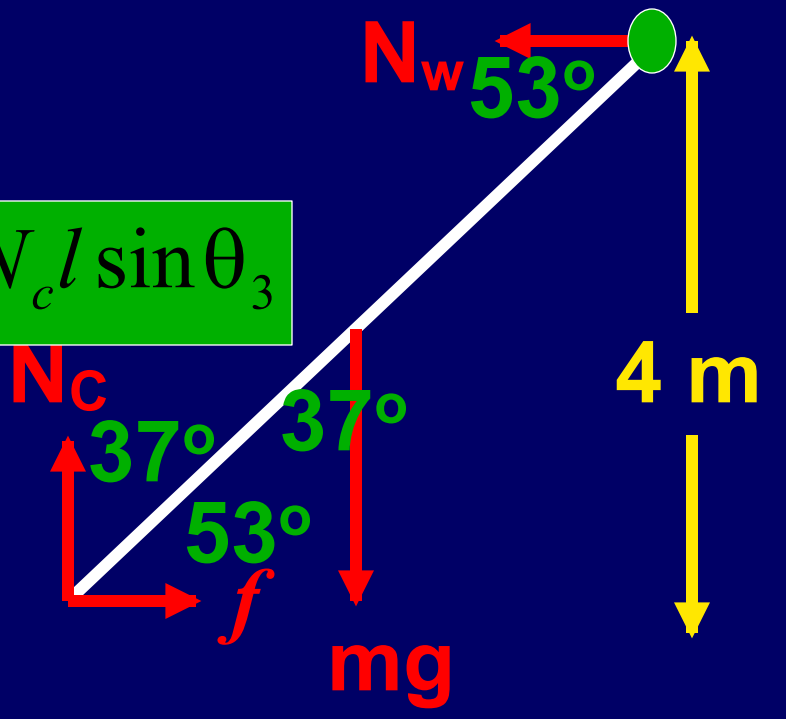
Torque Equations

Write your torque equation

$$\Sigma\tau = mg\,\tfrac{1}{2}l\sin\theta_1 + fl\sin\theta_2 - N_c l\sin\theta_3$$



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Solve

$$\Sigma\tau = mg\tfrac{1}{2}l\sin\theta_1 + fl\sin\theta_2 - N_c l\sin\theta_3$$

$$\Sigma\tau = (12)(9.8)\tfrac{1}{2}(5)\sin(37) + f(5)\sin(53) - N_c(5)\sin(37)$$

$$\Sigma\tau = 176 + 4f - 3N_c$$

$$\Sigma F_x = f - N_w = 0$$

$$\Sigma F_y = N_c - mg = 0$$

$$\Sigma F_x = f - N_w = 0$$

$$\Sigma F_y = N_c - 118 = 0$$

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Solve

$$\Sigma\tau = 176 + 4f - 3N_c$$

$$\Sigma F_x = f - N_w = 0$$

$$\Sigma F_y = N_c - 118 = 0$$

$$N_c = 118$$

$$176 + 4f - 3(118) = 0$$

$$f = 44.5N$$

$$f = 44.5N$$

$$f = N_w$$

$$N_w = 44.5N$$