DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
PRE-IB PHYSICS

GIANCOLI LESSON 8-4
TORQUE

Big Idea(s):

- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.

Enduring Understanding(s):

- A force exerted on an object can cause a torque on that object.
- A net torque exerted on a system by other objects or systems will change the angular momentum of the system.

Essential Knowledge(s):

- Only the force component perpendicular to the line connecting the axis of rotation and the point of application of the force results in a torque about that axis.
  - The lever arm is the perpendicular distance from the axis of rotation or revolution to the line of application of the force.
  - The magnitude of the torque is the product of the magnitude of the lever arm and the magnitude of the force.
  - The net torque on a balanced system is zero.

Essential Knowledge(s):

- The presence of a net torque along any axis will cause a rigid system to change its rotational motion or an object to change its rotational motion about that axis.
  - Rotational motion can be described in terms of angular displacement, angular velocity, and angular acceleration about a fixed axis.
  - Rotational motion of a point can be related to linear motion of the point using the distance of the point from the axis of rotation.
  - The angular acceleration of an object or rigid system can be calculated from the net torque and the rotational inertia of the object or rigid system.

Essential Knowledge(s):

- A torque exerted on an object can change the angular momentum of an object.
  - Angular momentum is a vector quantity, with its direction determined by a right-hand rule.
  - The magnitude of angular momentum of a point object about an axis can be calculated by multiplying the perpendicular distance from the axis of rotation to the line of motion by the magnitude of linear momentum.
  - The magnitude of angular momentum of an extended object can also be found by multiplying the rotational inertia by the angular velocity.
  - The change in angular momentum of an object is given by the product of the average torque and the time the torque is exerted.

Essential Knowledge(s):

- Torque, angular velocity, angular acceleration, and angular momentum are vectors and can be characterized as positive or negative depending upon whether they give rise to or correspond to counterclockwise or clockwise rotation with respect to an axis.

Learning Objective(s):

- The student is able to use representations of the relationship between force and torque.
- The student is able to compare the torques on an object caused by various forces.
- The student is able to estimate the torque on an object caused by various forces in comparison to other situations.

Learning Objective(s):

- The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system.
- The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction).
- The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis.

Learning Objective(s):

- The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis.
- The student is able to predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum.

Learning Objective(s):

- In an unfamiliar context or using representations beyond equations, the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object.
- The student is able to plan data collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object.

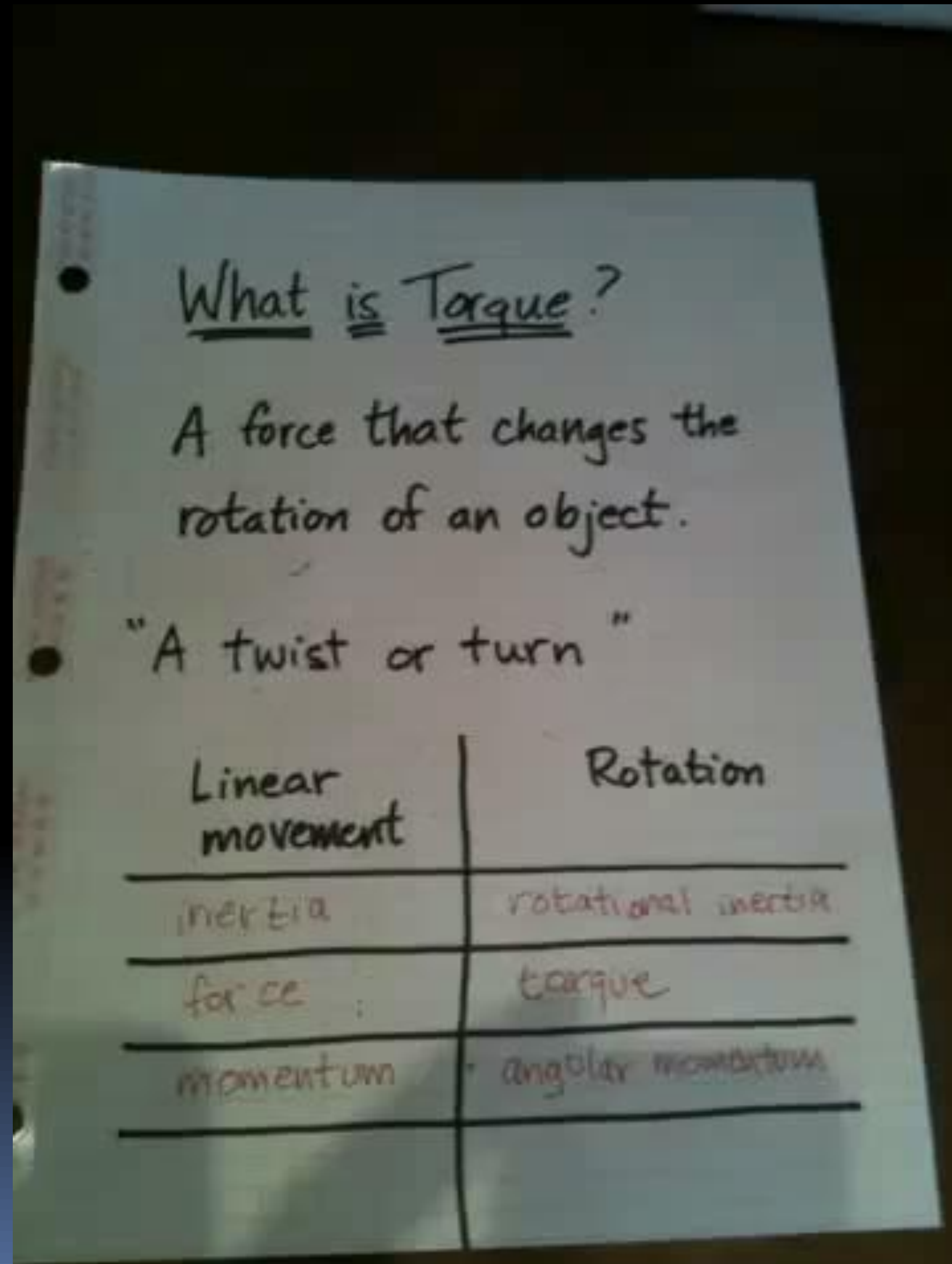
Learning Objective(s):

- The student is able to describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected objects change the angular velocity and angular momentum of the system.

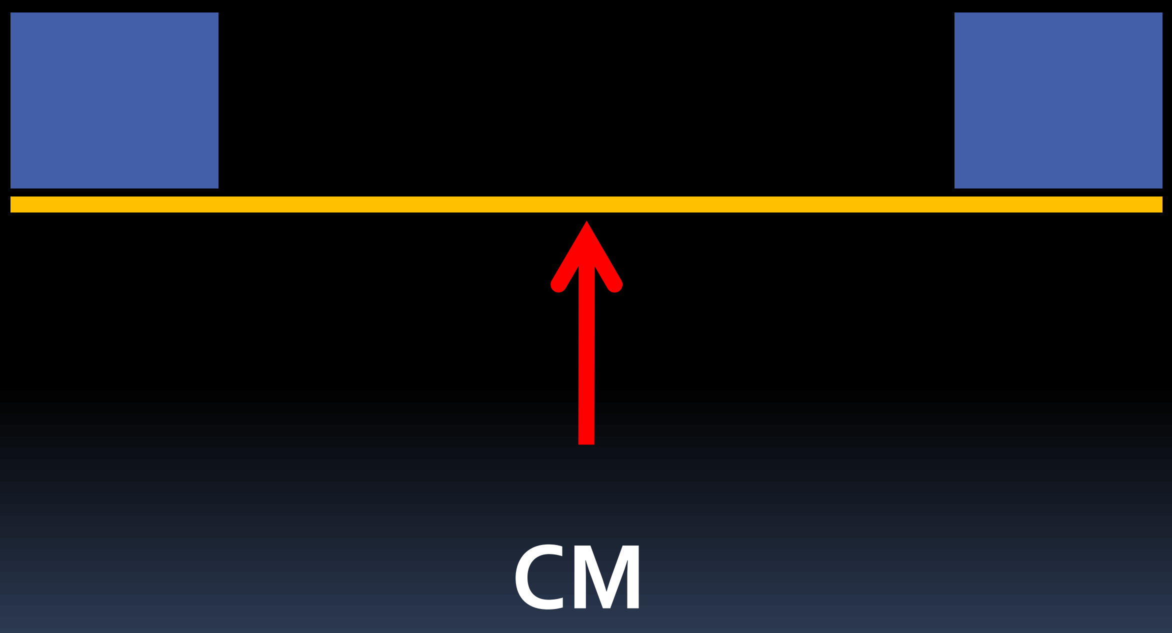
Learning Objective(s):

- The student is able to plan data collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data.

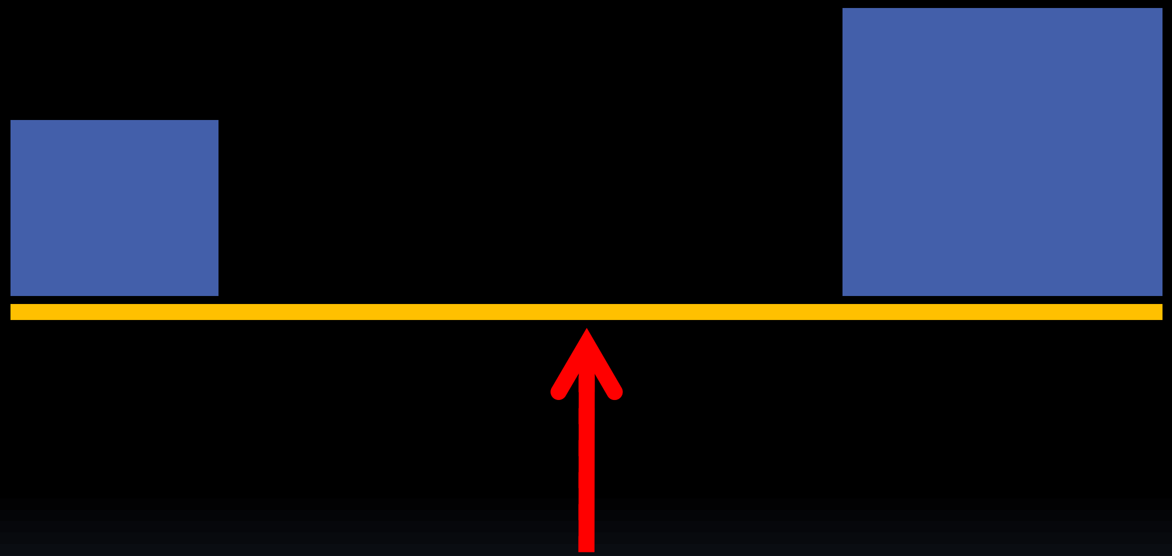
Introductory Video



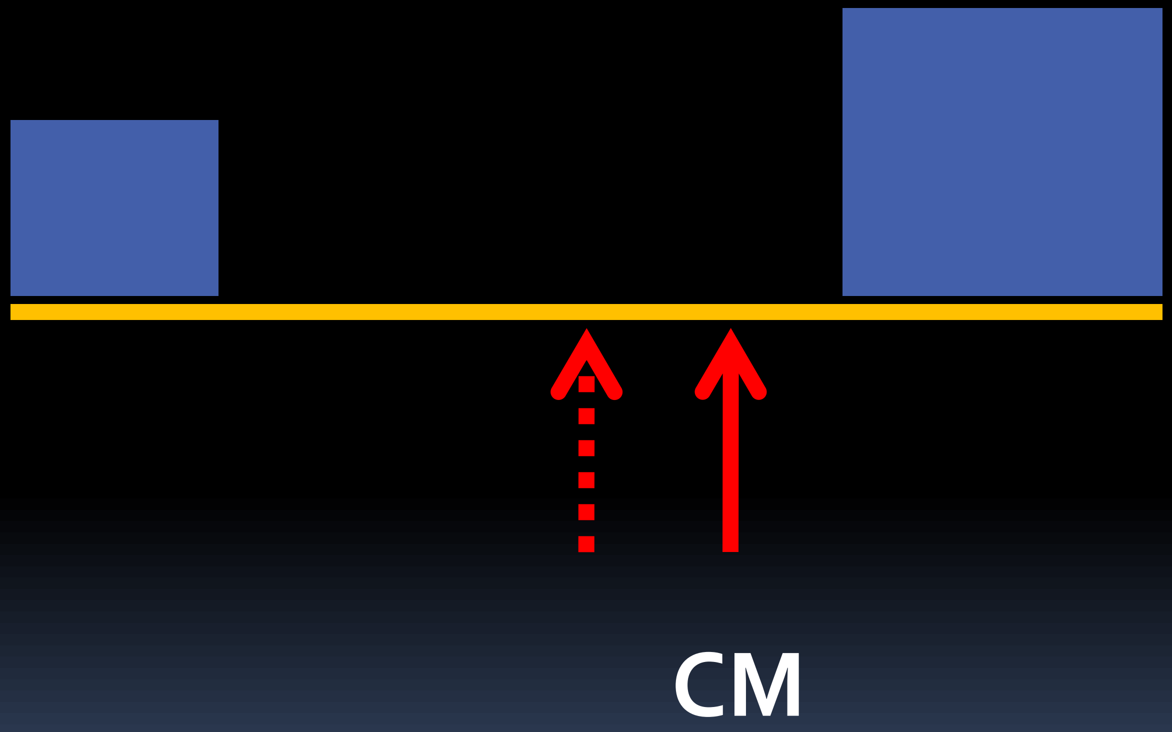
Center of Mass



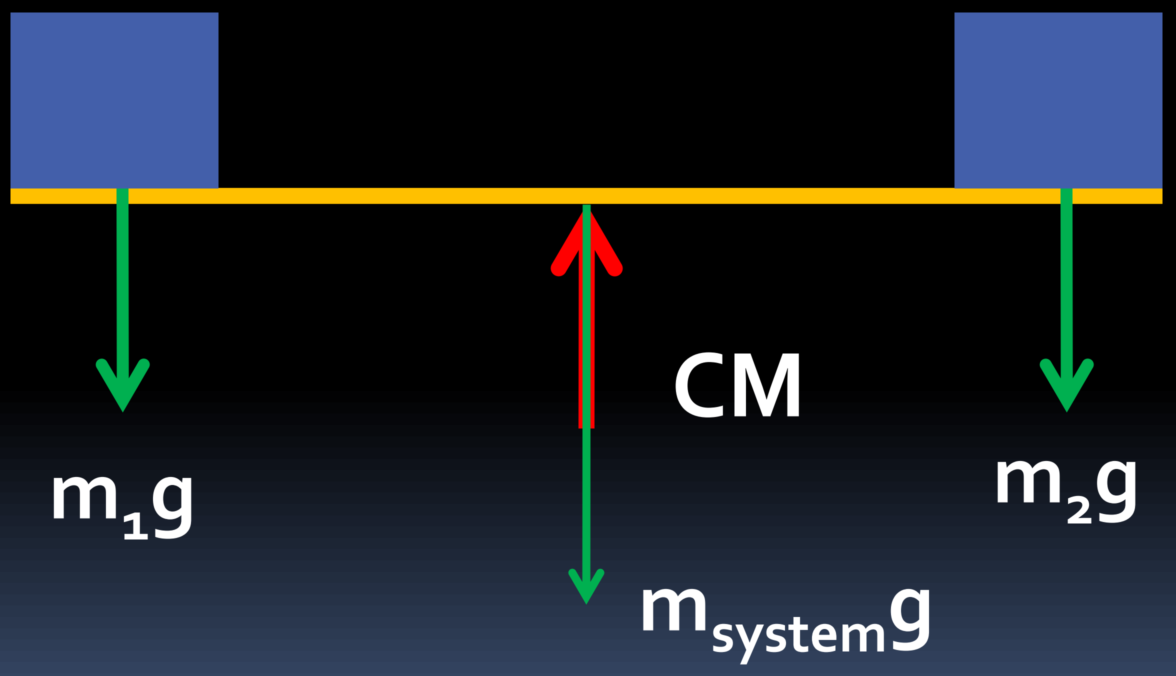
Center of Mass



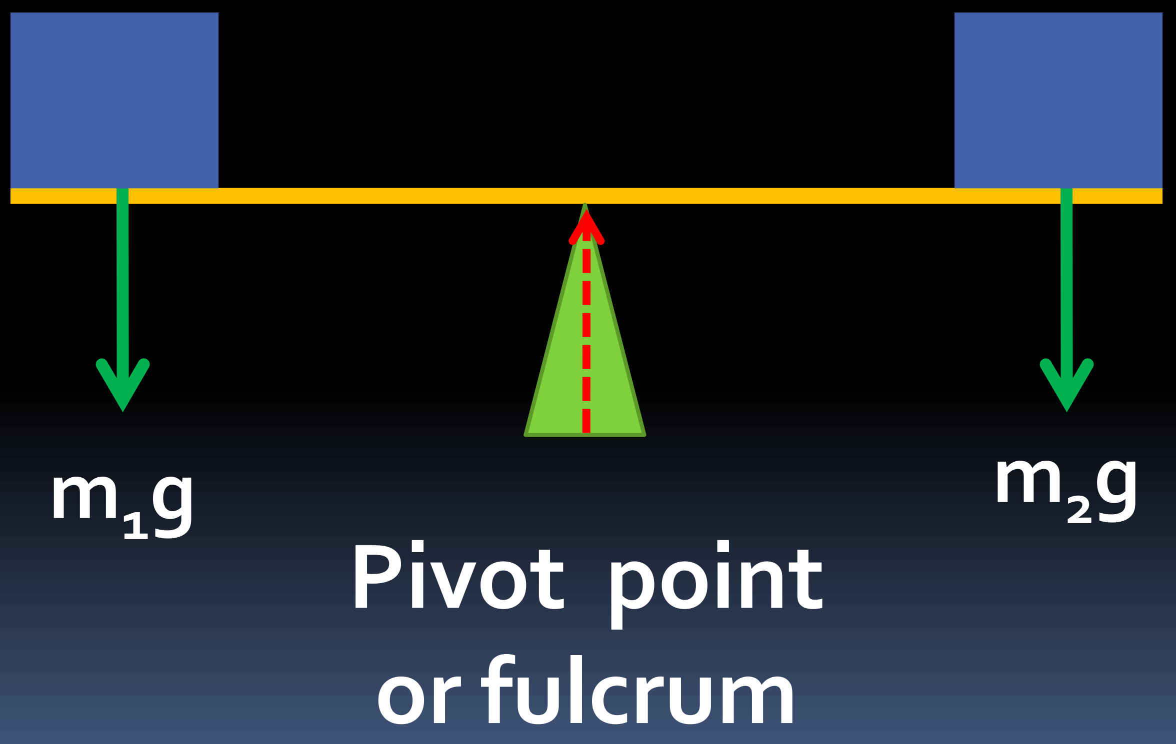
Center of Mass



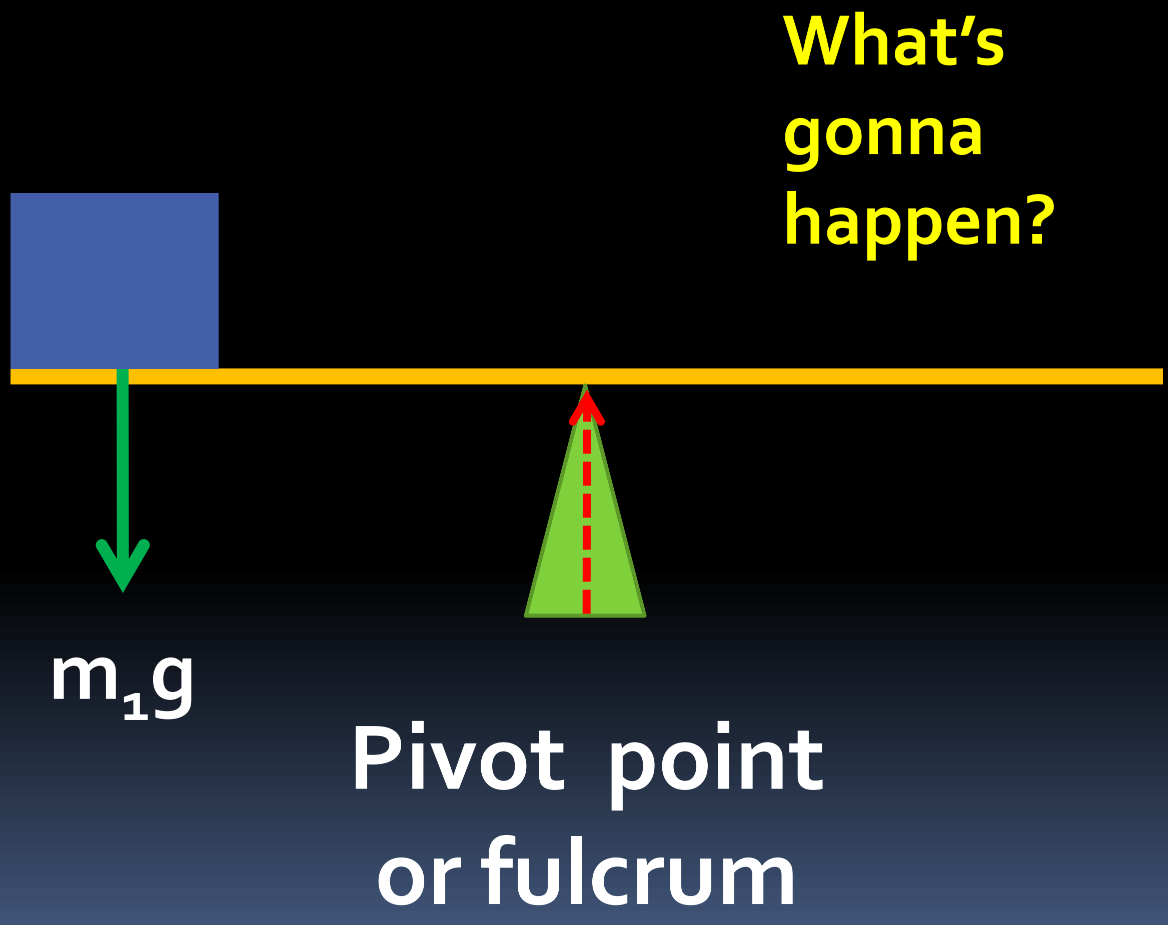
Center of Gravity



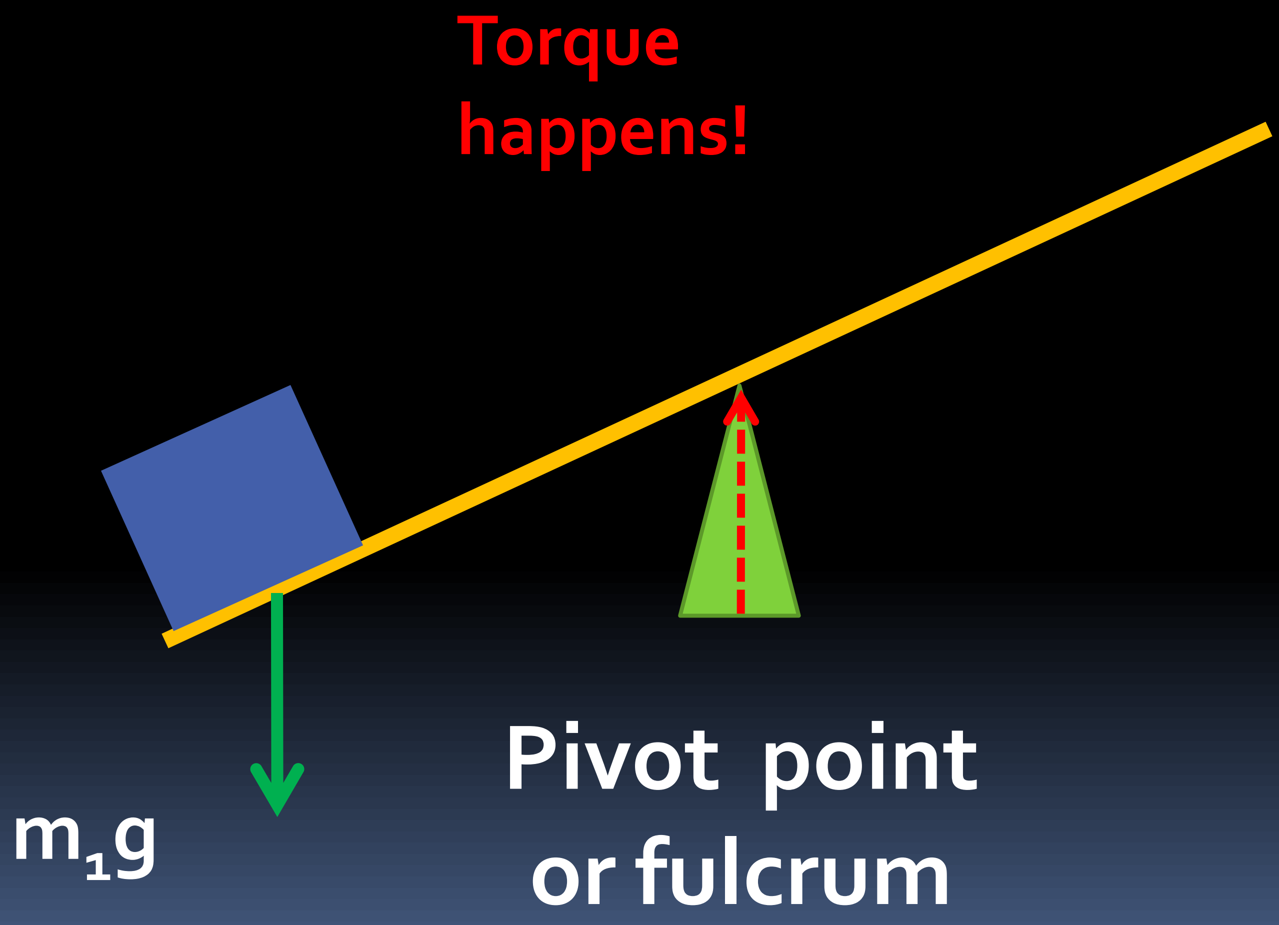
Center of Gravity



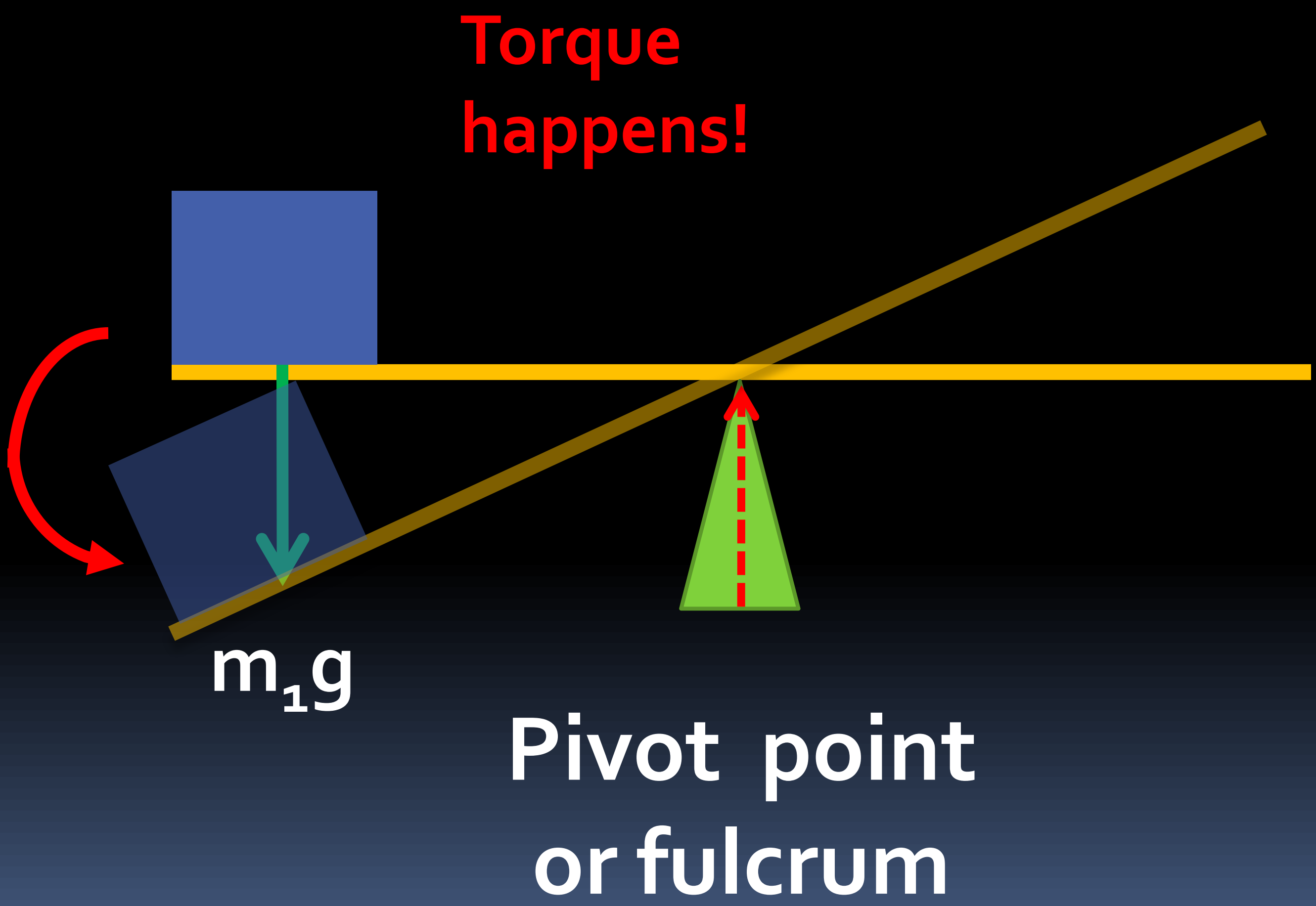
Center of Gravity



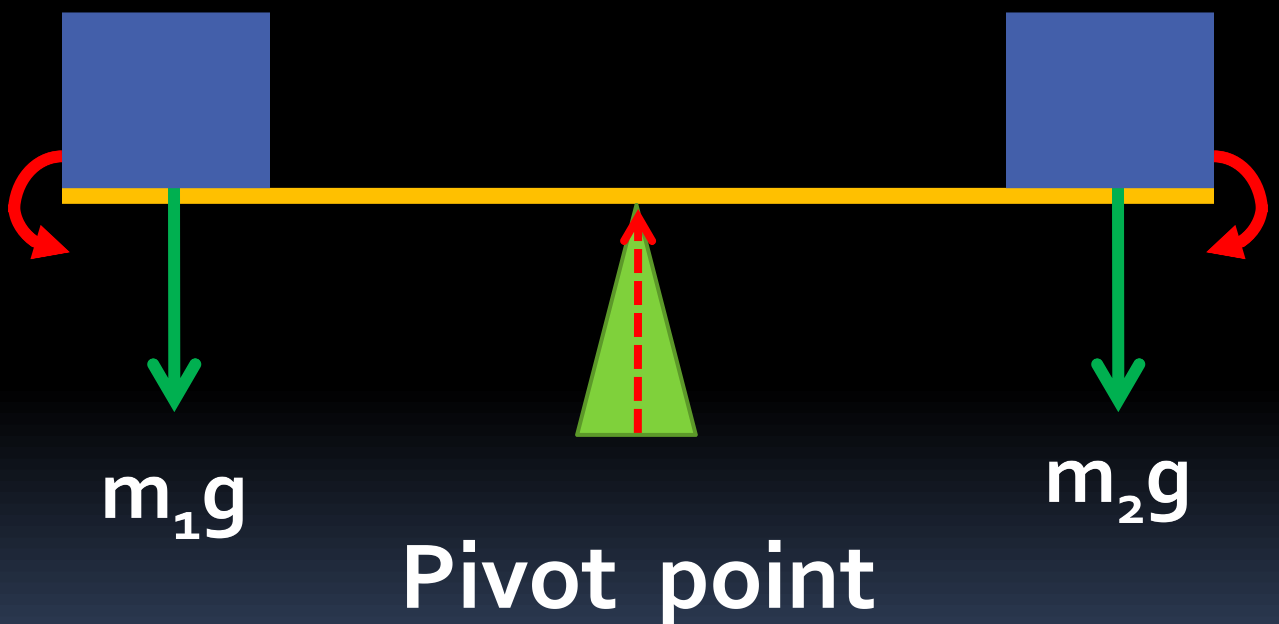
Torque



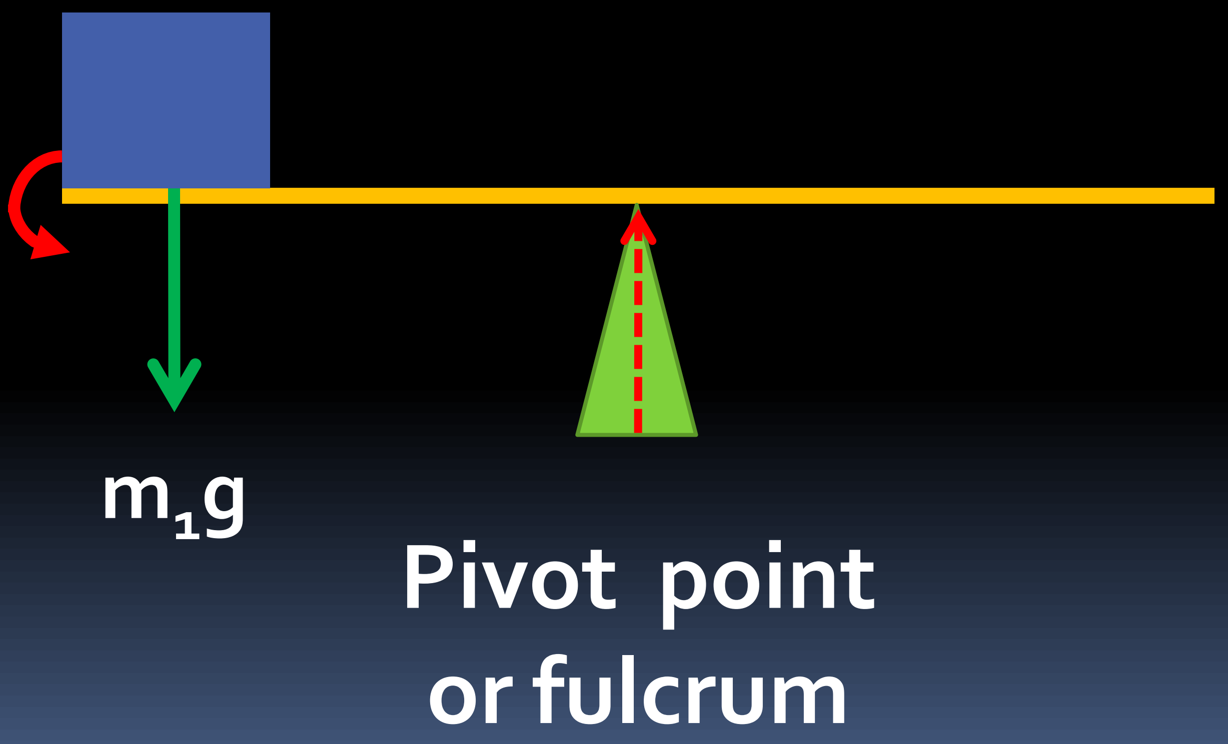
Center of Gravity



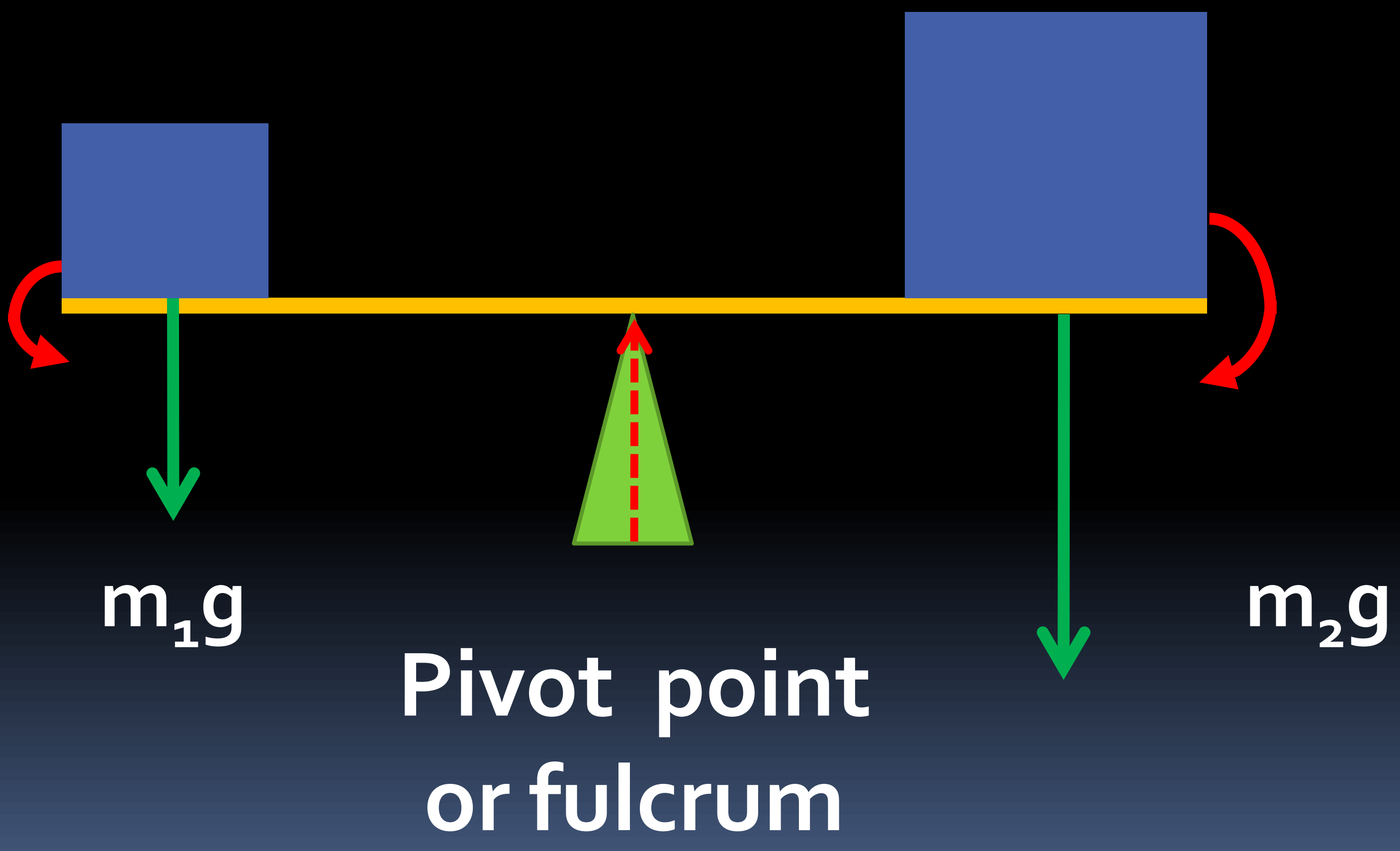
Torque – Case 1



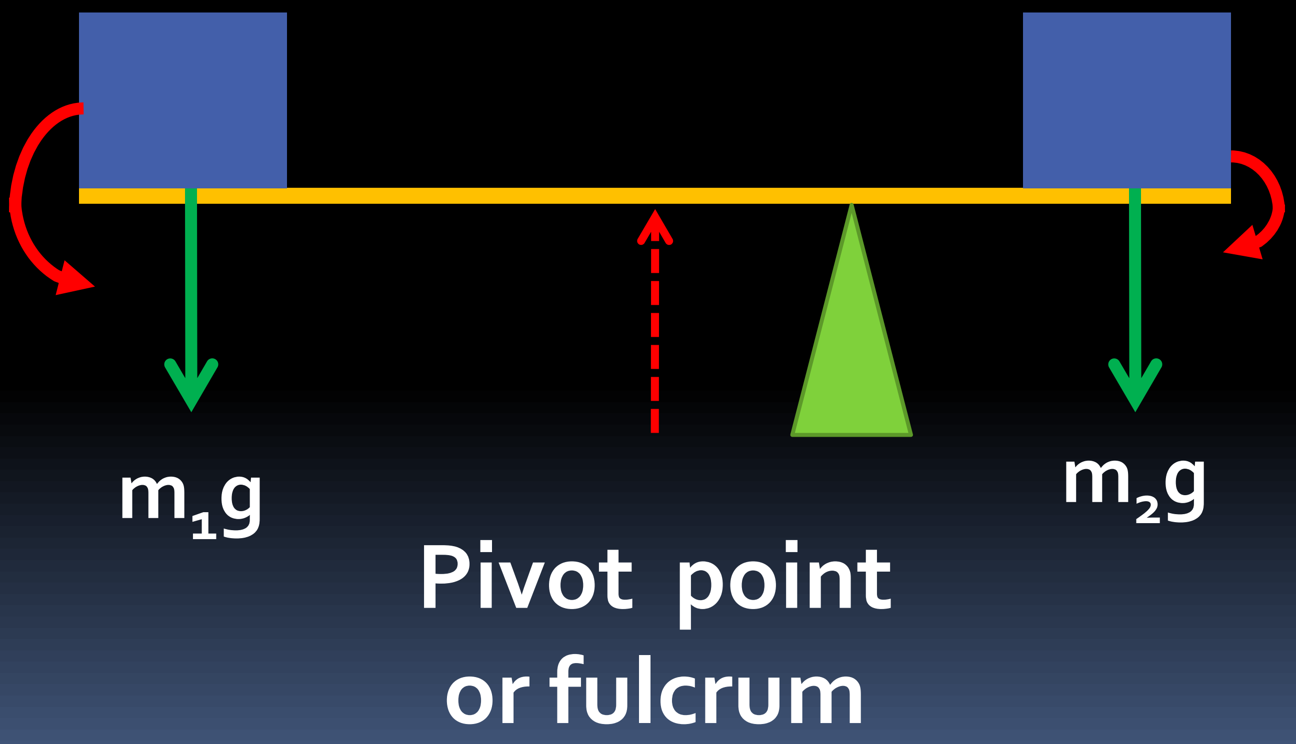
Torque – Case 2



Torque – Case 3

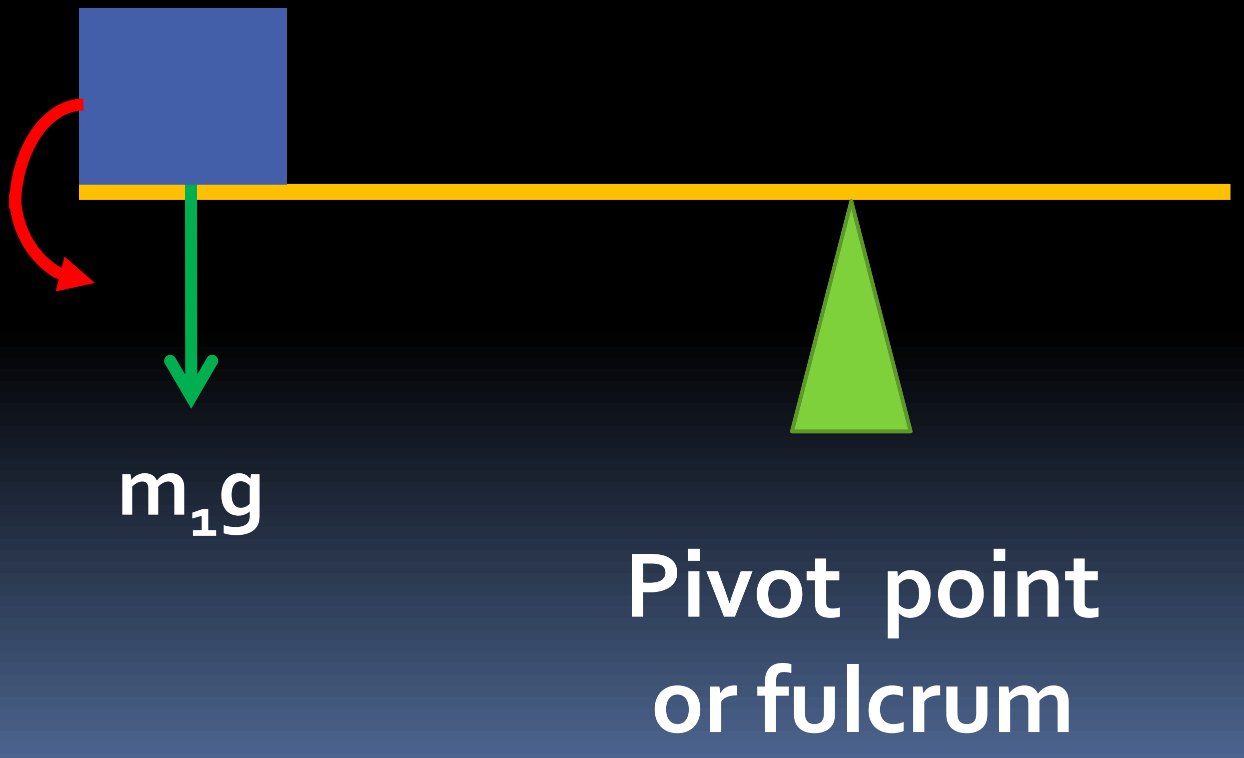


Torque – Case 4



Torque

- Torque is:
  1. The moment of the force about the axis
  2. Another name for angular acceleration

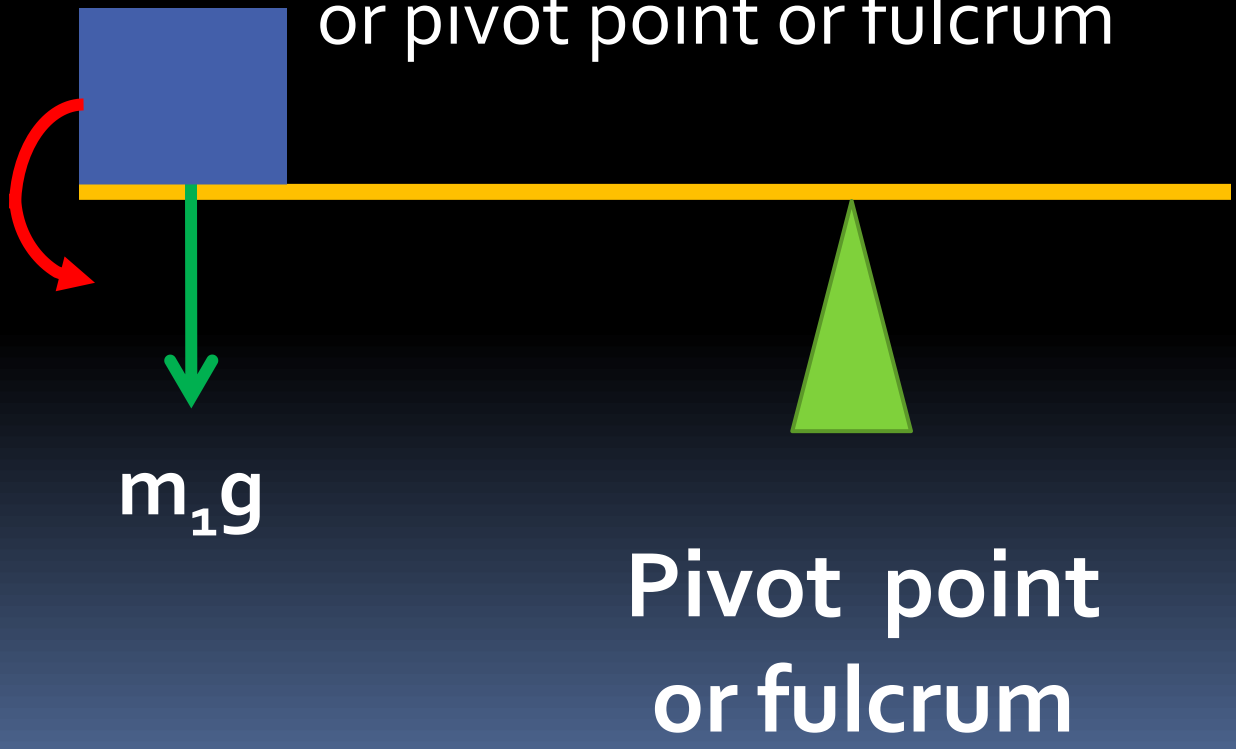


Torque Is

$$\tau = rF_{\perp}$$

- The product of the force times the lever or moment arm. The lever arm is the distance between the force and the axis of rotation

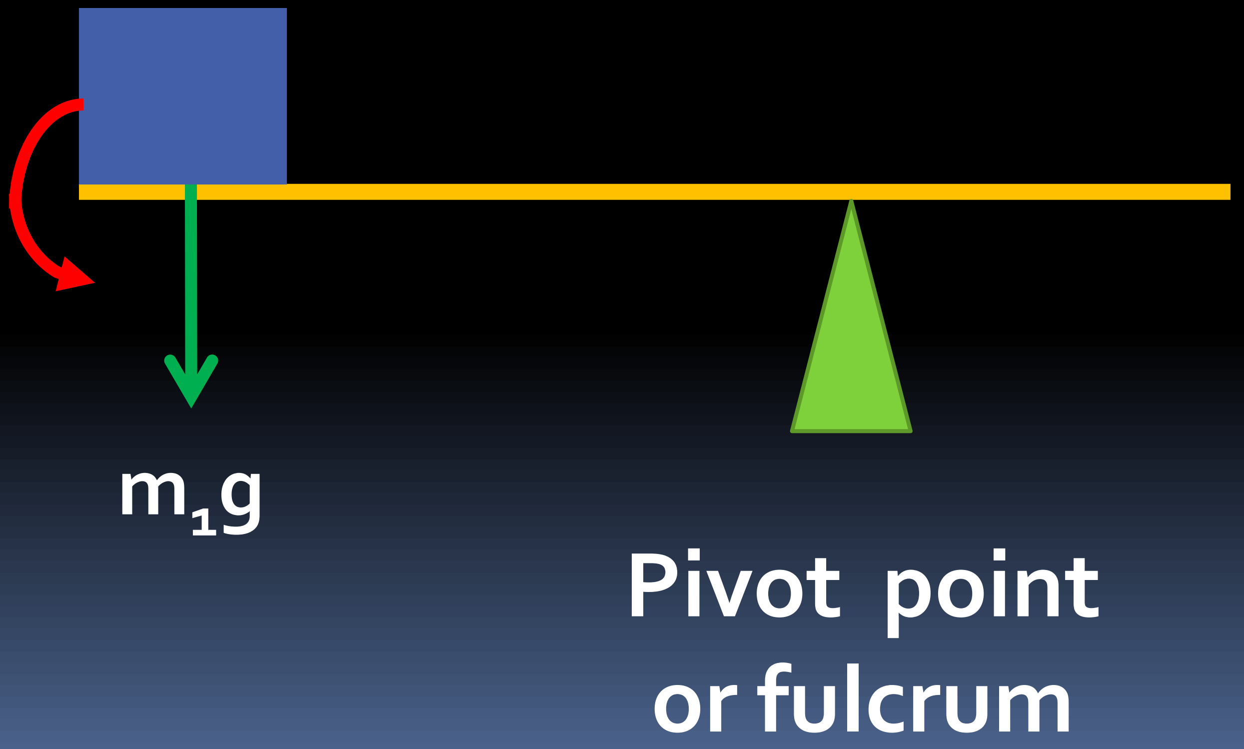
or pivot point or fulcrum



Torque

$$\tau = rF_{\perp}$$

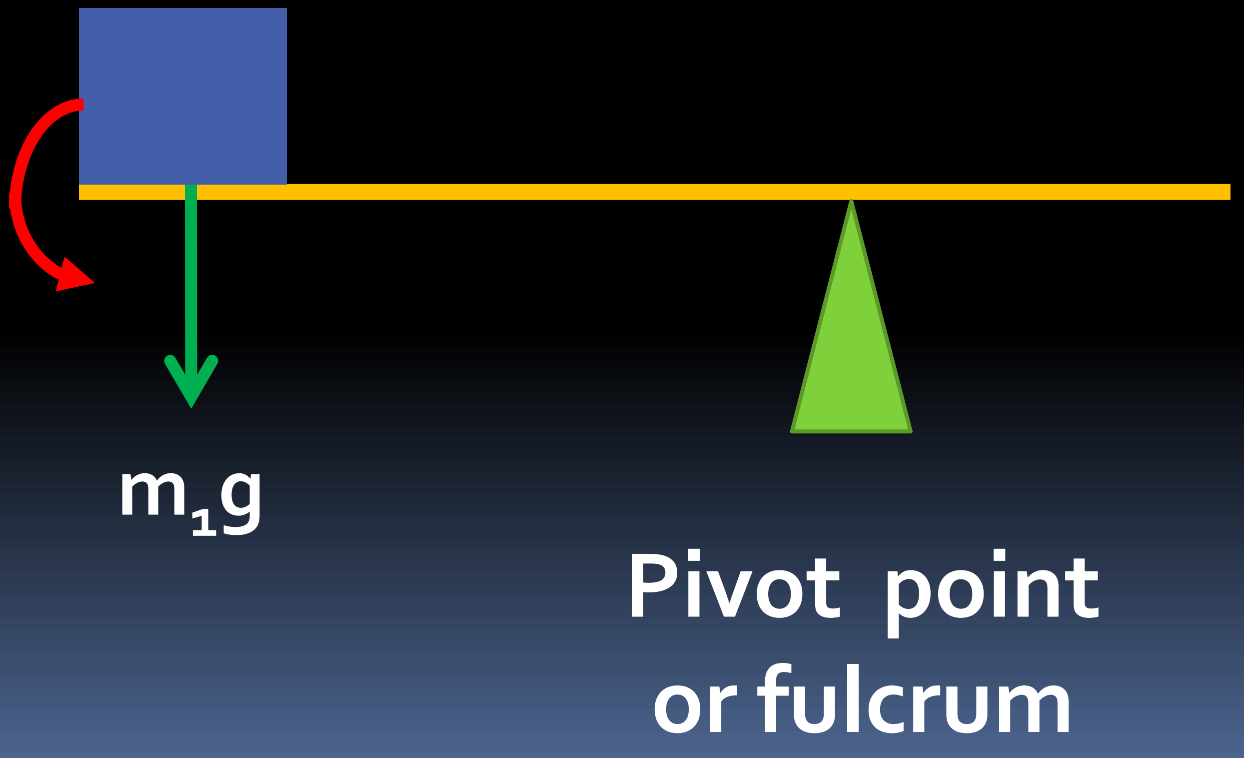
- Since torque is force times distance, it stands to reason that the units will be Newton-meters (N·m), or Joules (Work)



Torque

$$\tau = rF_{\perp}$$

- If the blue box is 10kg and 30cm from the pivot point, how much torque is produced and in what direction?



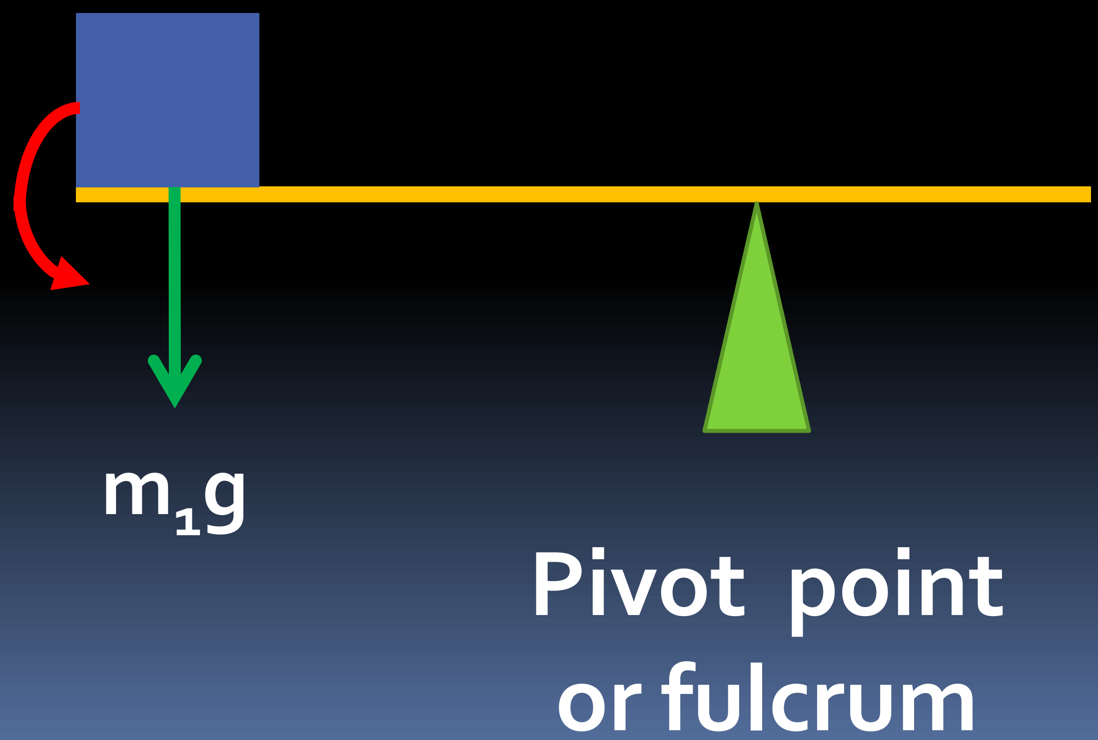
Torque

- If the blue box is 10kg and 30cm from the pivot point, how much torque is produced and in what direction?

$$\tau = rF_{\perp}$$

$$\tau = (0.30m)(10kg)(9.81)$$

$$\tau = 29.4Nm[CCW]$$



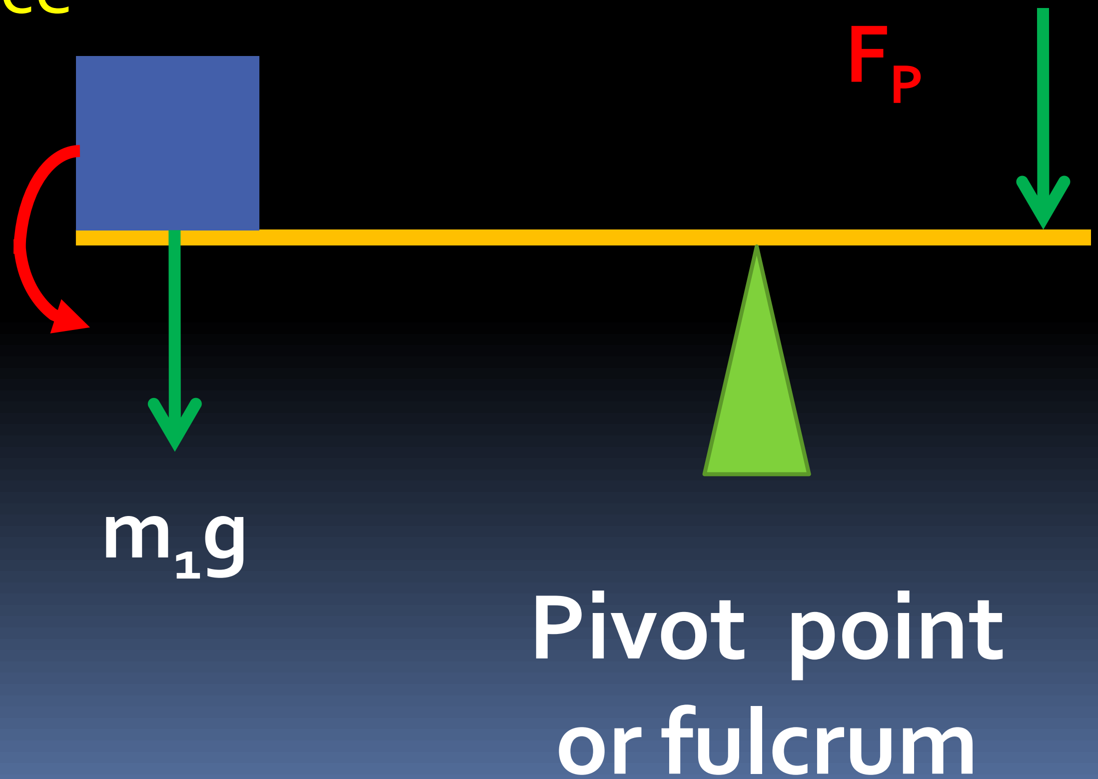
Torque

- How much force would have to be applied 10cm from the pivot to balance the box?

$$29.4Nm[CCW] = rF_{\perp}$$

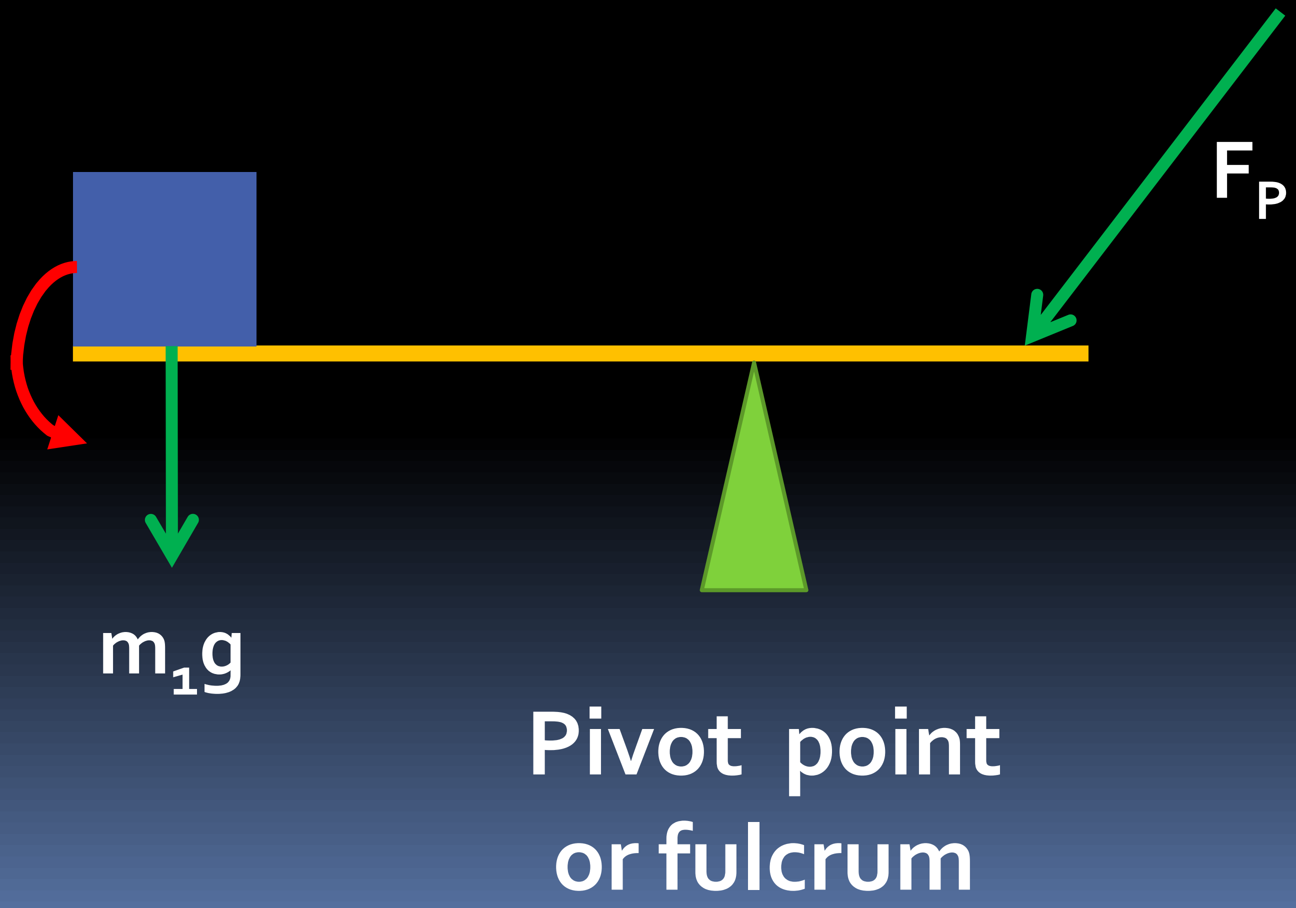
$$\frac{29.4Nm}{0.10}[CCW] = F_{\perp}$$

$$F_{\perp} = 294Nm[CW]$$



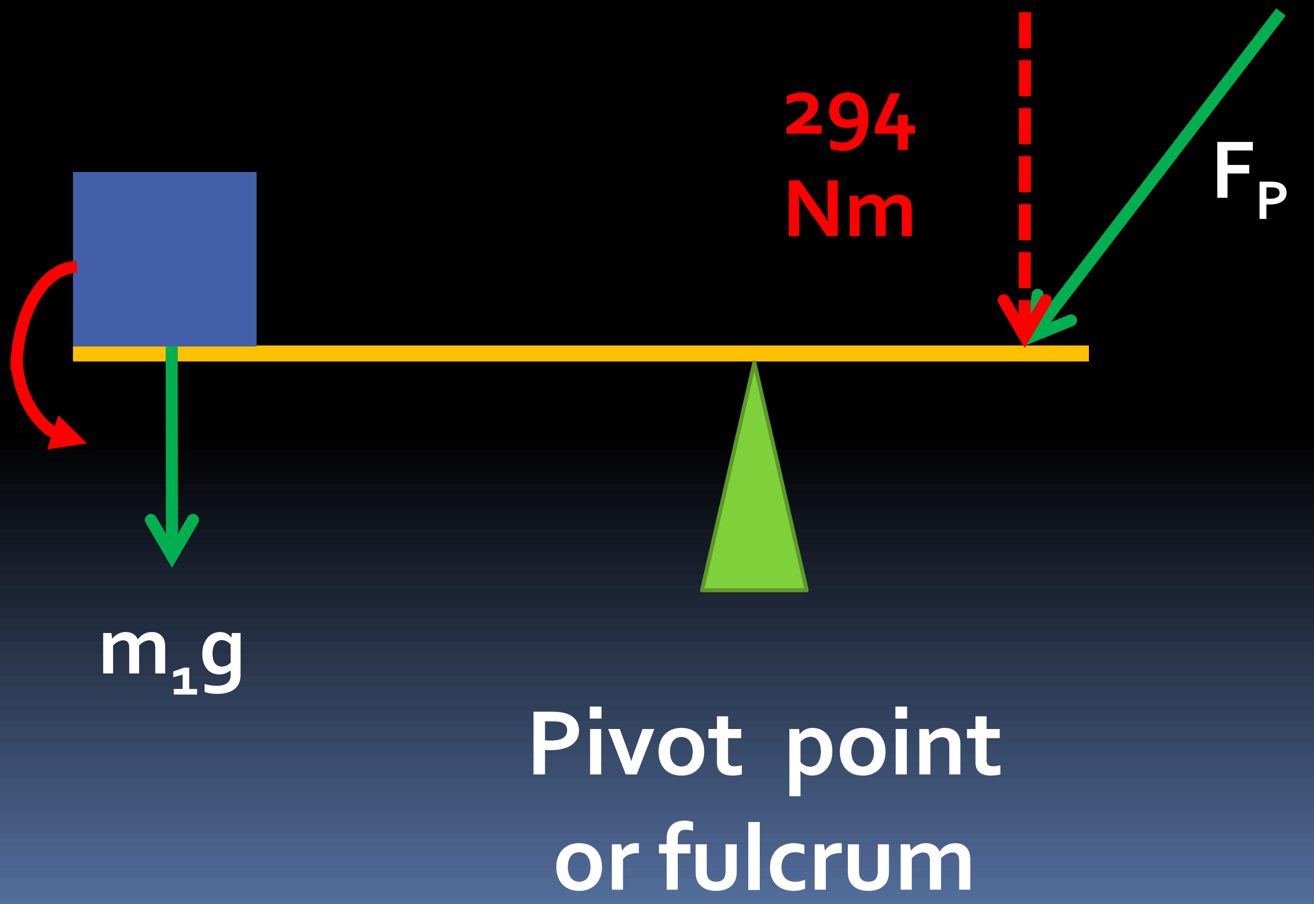
Torque

- What if the force is applied at a 45° angle?



Torque

- What if the force is applied at a 45° angle?
- You still need a vertical force of 294 Nm, so the applied force must be a lot greater.



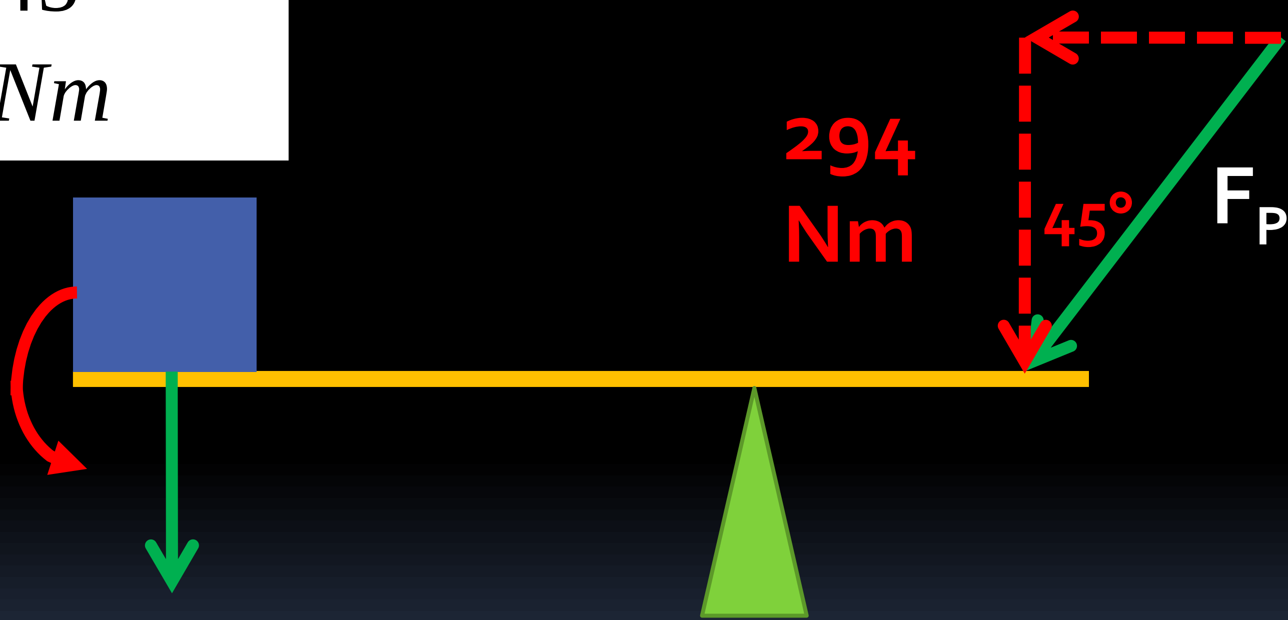
Torque

- What if the force is applied at a 45° angle?

$$\cos 45° = \frac{294\,Nm}{F_P}$$

$$F_P = \frac{294\,Nm}{\cos 45°}$$

$$F_P = 416\,Nm$$



LET'S PLAY WITH STUFF

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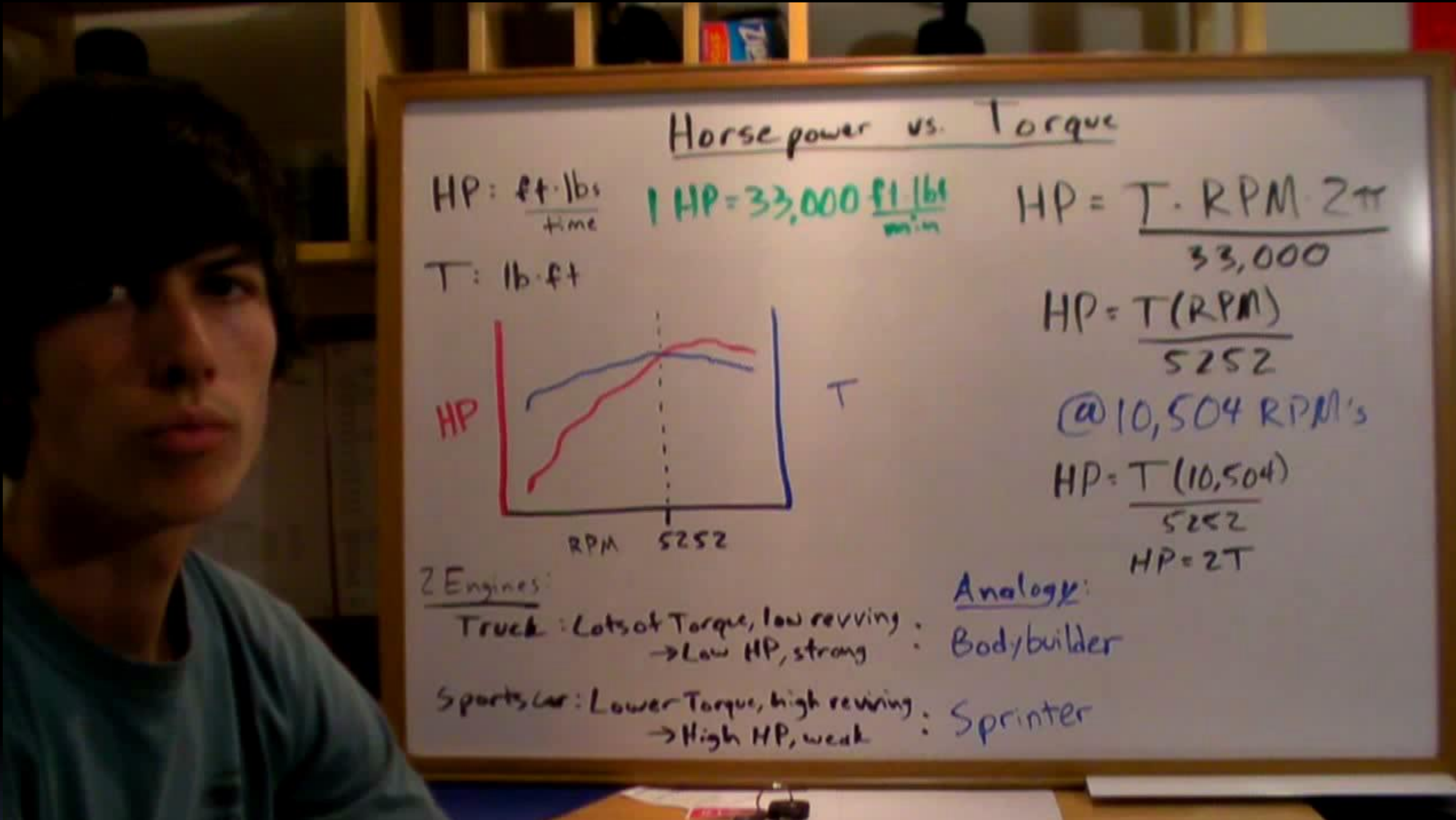
QUESTIONS?

Homework

#22-26



VIDEO: TORQUE VS. HORSEPOWER