

SI Physics - Full Discipline Demo

Torque and Equilibrium - Digital

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term to the best description.

Center of mass	State of an extended object in which net force and net torque are equal to zero	1
Line of action	The twisting force that tends to cause rotation of an object	2
Pivot point	The average position of all parts of an object or system weighted according to mass	3
Radial distance	Distance between the pivot point and point of force application	4
Static equilibrium	Axis along which a force is applied	5
Torque	Axis of an object around which the object rotates	6

Correct answers:

- 1 Static equilibrium 2 Torque 3 Center of mass 4 Radial distance
5 Line of action 6 Pivot point

Identify each statement as true or false.

True	False
1	2

A force applied parallel to the moment arm produces the largest possible torque.

The rotational velocity must be zero during static equilibrium.

Torque is a vector quantity.

Torque is positive when it induces rotation in the clockwise direction.

Correct answers:

1 The rotational velocity must be zero during static equilibrium.

Torque is a vector quantity.

2

A force applied parallel to the moment arm produces the largest possible torque.

Torque is positive when it induces rotation in the clockwise direction.

Exploration

A force applied at a 90° angle to the moment arm produces the largest possible torque.

- ☒ True
- ☐ False



Torque can be found using the equation ____.

- ☐ $\tau = rF_{\perp}$
- ☐ $\tau = r_{\perp}F$
- ☐ $\tau = rF \sin(\theta)$
- ☒ All of the above

✓

The ____ is the average position of all parts of the object or system weighted according to mass.

- ☐ center of gravity
- ☒ center of mass
- ☐ pivot point
- ☐ None of the above

✓

The moment of inertia depends on how the ____ of an object is distributed.

- ☐ gravity
- ☐ inertia
- ☒ mass
- ☐ All of the above

✓

____ is the rotational equivalent of force and causes rotational motion.

- ☐ Center of mass
- ☐ Moment of inertia
- ☒ Torque
- ☐ All of the above

✓

Static equilibrium occurs when the ____ is zero.

- ☐ net force
- ☐ net torque
- ☐ velocity
- ☒ All of the above



Exercise 1

How can two objects with different masses be in balanced equilibrium on a beam with a pivot at the beam center of mass? Refer to your measurements recorded in Data Table 1 to support your answer.

Different masses can be in equilibrium on a balance if the torques are equal and opposite. This is done by utilizing the torque equation $\tau = r \times F$. Though the gravitational forces are different, the radial distance r can be adjusted such that the torques have equal magnitudes. Assuming the objects are on different sides of the pivot point, this ensures equilibrium is reached. The mass of the bricks recorded in Data Table 7 remained constant at 20 kg, but the torque due to the bricks changed because the radial distance was changed. The system could still be balanced as the mass of the unknown objects changed by changing the position of the bricks. The bricks moved closer to the pivot point as the mass of the object decreased with the smallest mass object (5 kg) having the bricks located the closest to the pivot point (0.25 m).

Describe how torque and equilibrium determine the mass of an unknown object.

Equilibrium requires that the torque due to all forces acting on a balance add up to zero. Therefore, the torque due to the weight of a single object resting on the balance can be determined if the torques due to any other objects acting on the balance are known. Once the torque due to the weight of the unknown object is determined, the mass can be found using the definition of torque $\tau = r \times F$, and the definition of weight $F = w = mg$ and solving for the mass.

Data Table 1: Determining the Mass of a Mystery Object
(SAMPLE ANSWER BELOW)

Mystery object	Object distance (m)	Brick mass (kg)	Brick distance (m)	Brick torque (Nm)	Object mass (kg)	F _{object} (N)	F _{bricks} (N)	F _{pivot point} (N)

A	1.00	20	1.00	-196.20	20	-196.20	-196.20	392.40
B	1.00	20	0.25	-49.05	5	-196.20	-49.05	245.25
C	1.00	20	0.75	-147.15	15	-196.20	-147.15	343.35
D	1.00	20	0.50	-98.10	10	-196.20	-98.10	294.30

Competency Review

_____ is calculated by finding the product of the applied force and the radial distance.

- ☐ Center of mass
- ☐ Moment of inertia
- ☒ Torque ✓
- ☐ All of the above

The _____ spans the distance from the _____ to the location of the applied force.

- ☒ moment arm; pivot point ✓
- ☐ moment of inertia; center of mass
- ☐ torque; center of mass
- ☐ None of the above

A net force of zero is the only requirement for static equilibrium.

- ☐ True
- ☒ False ✓

Torque can be calculated if the _____ and angular acceleration are known.

- ☐ mass
- ☐ moment arm
- ☒ moment of inertia ✓
- ☐ None of the above

Torque is the rotational equivalent of force and causes translational motion.

- ☐ True
- ☒ False

✓

A door is pushed with a force of 5 N at a distance of 30 cm from the hinge. The torque is ____.

- ☐ 6 N/m
- ☐ 150 N m
- ☒ 1.50 N m
- ☐ None of the above

✓

A 40 cm ruler with non-uniform mass is hung from its center of mass, at 21 cm. A force is applied at the 40 cm mark of the ruler. The length of the moment arm is ____.

- ☐ 40
- ☒ 19
- ☐ 21
- ☐ None of the above

✓

A 30 cm ruler is found to have a center of mass of 15.6 cm. The percent error of the center of mass is ____, if the ruler is assumed to have uniform mass.

- ☐ 0.48%
- ☐ 0.52%
- ☒ 4%
- ☐ None of the above

✓

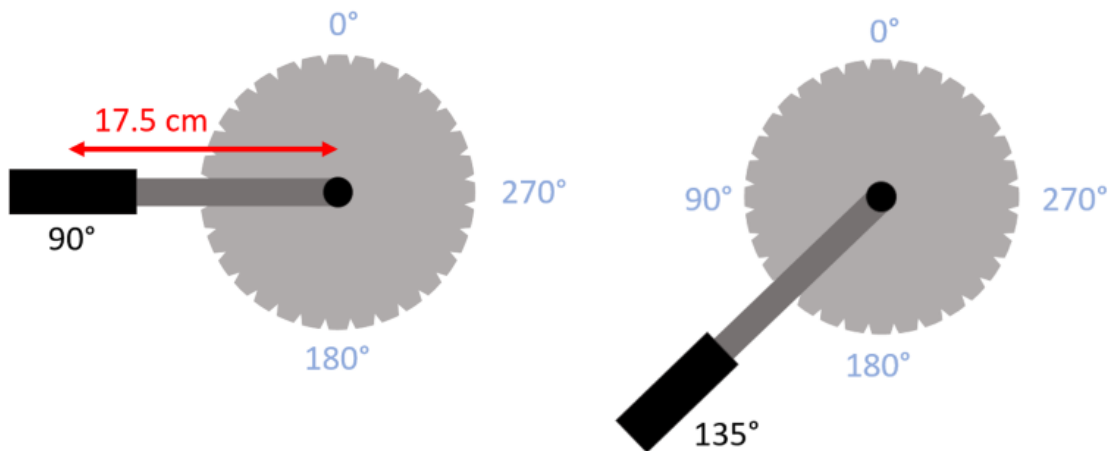
A seesaw sits in static equilibrium. A child with a mass of 30 kg sits 1 m away from a pivot point. Another child sits 0.75 m away from the pivot point on the opposite side. The second child's mass is ____ kg.

- ☐ 20
- ☐ 30
- ☒ 40
- ☐ None of the above



Extension Questions

In cycling, the torque generated about the crank axis is determined by the magnitude of the force from a foot pushing the pedal as well as the angle between the crank arm and the force vector. The diagram shows the 17.5 cm crank pedal at two positions: 90 degrees and 135 degrees. What is the torque at each of the points if the foot applies a force of 800 N? Which position creates the larger torque? Note: Use the angle between the force application and crank arm in your calculations.



(SAMPLE ANSWER BELOW)

At 90 degrees, the torque is: $\tau = r * F * \sin(90) = 0.175 * 800 * 1 = 140 \text{ N}\cdot\text{m}$. At 135 degrees, the torque is: $\tau = r * F * \sin(135 - 90) = 0.175 * 800 * \sin(45) = 99 \text{ N}\cdot\text{m}$. Thus, the 90 degree position yields the greater torque. Note: The angle for the second calculation is 135-45 degrees due the geometry of the system. You must use the angle between the applied force and the crank. $\sin(135)$ would give the component of the force parallel to the crank arm.