

Linear Momentum Practice Quiz

Name: _____

Date: _____

$$g = 10 \text{ m/s}^2$$

Part A. Multiple Choice

- The linear momentum of an object of mass m moving with velocity $\vec{v}$ is
 - $m\vec{v}$
 - $\frac{1}{2}mv^2$
 - $\frac{p^2}{2m}$
 - $\vec{F}\Delta t$
- The impulse delivered by a net force is written most generally as
 - $\vec{F}_{\text{net}} \Delta t$
 - $\frac{d\vec{F}_{\text{net}}}{dt}$
 - $\int \vec{F}_{\text{net}} dt$
 - $\frac{1}{2}\vec{F}_{\text{net}} t^2$
- A collision is elastic when
 - the objects bounce apart instead of sticking
 - the total kinetic energy after equals the total before
 - the momentum of the system is conserved
 - each object keeps the kinetic energy it arrived with
- Two objects have momenta of equal magnitude. Compared with the lighter object, the heavier one has
 - less kinetic energy
 - more kinetic energy
 - the same kinetic energy
 - a greater speed
- Two objects move in opposite directions along one line. The magnitude of the total momentum of the system equals
 - the sum of the two magnitudes
 - the difference of the two magnitudes
 - zero in every case
 - the larger of the two magnitudes
- On a graph of the momentum of an object against time, the slope at a point gives
 - the impulse delivered up to that time
 - the kinetic energy at that time
 - the net force at that time
 - the mass of the object
- On a graph of net force against time, a region lying below the time axis contributes
 - nothing to the impulse
 - a positive change in momentum
 - an increase in the mass
 - a negative change in momentum

8. The total momentum of a chosen system stays constant provided that
- A. the net external force on the system is zero
 - B. no kinetic energy is lost by the system
 - C. the internal forces come in equal and opposite pairs
 - D. every object in the system has the same mass
9. A ball falls freely toward the ground. For which system is the total momentum constant?
- A. the ball alone
 - B. the ball and the air it moves through
 - C. the ball and the Earth
 - D. the ball and the ground, but not the rest of the Earth
10. In a collision in a plane, conservation of momentum supplies
- A. one equation, so a second principle is always needed
 - B. three equations, one for each direction in space
 - C. no equations unless the collision is elastic
 - D. two equations, one for each component in the plane
11. Two carts approach each other on a level track. Which outcome removes the most kinetic energy from the system?
- A. they stick together and move off as one
 - B. they bounce apart elastically
 - C. they bounce apart with a small loss
 - D. the outcome does not matter, only the masses do
12. The total momentum of a system of two objects is zero. Which statement is correct?
- A. both objects must be at rest
 - B. the total kinetic energy must be zero also
 - C. the two masses must be equal
 - D. the total kinetic energy can be large
13. For a system whose mass is changing, $\vec{F}_{\text{net}} = m\vec{a}$ gives the wrong answer because
- A. the acceleration of such a system cannot be defined
 - B. the derivative of $m\vec{v}$ has a term in dm/dt
 - C. momentum is a vector quantity and acceleration is not one
 - D. Newton's third law fails whenever mass is added
14. Two students analyze one collision between two carts. One reports that momentum is conserved and the other reports that it is not, and neither has made an error. The explanation is that
- A. they chose different systems, so different forces are external
 - B. one worked before the collision and the other after it
 - C. momentum is conserved only in elastic collisions
 - D. one of them used the wrong value for a mass
15. A collision loses kinetic energy. The momentum of the system is still conserved because
- A. kinetic energy and momentum are always conserved together
 - B. the collision must then be perfectly inelastic
 - C. the lost energy leaves as heat, which carries no momentum
 - D. momentum conservation needs only a zero net external force

16. A 2.5 kg cart moves west at 4.0 m/s. The magnitude of its momentum is
- A. 0.63 kg·m/s
 - B. 6.5 kg·m/s
 - C. 10 kg·m/s
 - D. 20 kg·m/s
17. A 3.0 kg cart is at rest on a level track. A constant net force of 6.0 N acts on it for 4.0 s. Its speed at the end is
- A. 2.0 m/s
 - B. 8.0 m/s
 - C. 12 m/s
 - D. 24 m/s
18. A 2.0 kg cart moving at 6.0 m/s strikes a stationary 4.0 kg cart and the two stick together. Their common speed is
- A. 1.5 m/s
 - B. 6.0 m/s
 - C. 3.0 m/s
 - D. 2.0 m/s
19. A 3.0 kg object moves along the x axis with $x(t) = 2t^3$ meters, with t in seconds. Its momentum at $t = 2.0$ s is
- A. 24 kg·m/s
 - B. 48 kg·m/s
 - C. 72 kg·m/s
 - D. 144 kg·m/s
20. The net force on an object is $F(t) = 12t^2$ N, with t in seconds, acting from $t = 0$ to $t = 2.0$ s. The impulse delivered is
- A. 32 N·s
 - B. 16 N·s
 - C. 24 N·s
 - D. 96 N·s
21. The momentum of a cart is $p(t) = 3t^2 + 2t$ kg·m/s, with t in seconds. The net force on the cart at $t = 2.0$ s is
- A. 8.0 N
 - B. 14 N
 - C. 16 N
 - D. 32 N
22. A 6.0 kg object at rest breaks into two pieces. A 2.0 kg piece moves east at 9.0 m/s. The speed of the other piece is
- A. 4.5 m/s
 - B. 2.3 m/s
 - C. 9.0 m/s
 - D. 18 m/s
23. A single external force $F(t) = 9t^2$ N acts on a 4.0 kg cart from $t = 0$ to $t = 2.0$ s. Taking the cart as the system, its change in momentum is
- A. 12 kg·m/s
 - B. 18 kg·m/s
 - C. 24 kg·m/s
 - D. 72 kg·m/s

24. Friction from the track slows a 5.0 kg cart from 8.0 m/s to 5.0 m/s in 2.0 s. Taking the cart alone as the system, the average external force on it is
- A. 7.5 N, forward
 - B. 15 N, backward
 - C. 30 N, backward
 - D. 7.5 N, backward
25. A 1.0 kg ball moving at 8.0 m/s strikes a stationary 3.0 kg ball and the two stick together. The kinetic energy lost is
- A. 8.0 J
 - B. 24 J
 - C. 16 J
 - D. 32 J
26. Object X has mass $4m$ and speed v . Object Y has mass m and speed $4v$. The ratio of the kinetic energy of Y to that of X is
- A. 1
 - B. 2
 - C. 4
 - D. 16
27. Sand falls vertically onto a conveyor belt at a steady 8.0 kg/s while the belt is held at a constant 3.0 m/s. The power delivered by the horizontal force on the belt is
- A. zero
 - B. 24 W
 - C. 36 W
 - D. 72 W
28. A 2.0 kg puck slides east at 10 m/s and strikes a stationary 2.0 kg puck. Afterward the first puck moves at 6.0 m/s at 53° north of east. The second puck moves at
- A. 6.0 m/s at 37° south of east
 - B. 8.0 m/s at 53° south of east
 - C. 8.0 m/s at 37° south of east
 - D. 10 m/s due east
29. A 1.0 kg ball moving east at 6.0 m/s collides elastically head on with a stationary 3.0 kg ball. Afterward the 1.0 kg ball moves at
- A. 3.0 m/s west
 - B. 1.5 m/s west
 - C. 1.5 m/s east
 - D. 3.0 m/s east
30. A 2.0 kg cart moving at 4.0 m/s strikes a stationary 6.0 kg cart and the two stick together. The fraction of the original kinetic energy that remains is
- A. $\frac{1}{8}$
 - B. $\frac{1}{4}$
 - C. $\frac{1}{2}$
 - D. $\frac{3}{4}$

Part B. Reasoning

1. Momentum and kinetic energy both describe how much motion an object has. State how each one depends on the speed, and say which of the two carries a direction.
2. Write the general definition of the impulse delivered by a net force, and say what has to be true before it collapses to $F\Delta t$.
3. State the condition that guarantees the total momentum of a chosen system does not change, and name the result from Topic 4.2 that it comes from.
4. Define an elastic collision, and say what the word elastic hands you when it appears in a problem.
5. Explain why $\vec{F}_{\text{net}} = m\vec{a}$ is a special case of $\vec{F}_{\text{net}} = d\vec{p}/dt$ rather than a separate law.
6. A ball of mass m arrives at a wall at speed v . Compare the magnitude of the impulse the wall delivers when the ball stops with the case where the ball rebounds at the same speed.
7. Sand falls vertically onto a conveyor belt that is held at a constant speed. Explain why a horizontal force is needed even though nothing on the belt is accelerating.
8. Say what the area under a graph of net force against time represents, and what a region of that graph below the time axis contributes.
9. Explain why the forces that the parts of a system exert on each other cannot change the total momentum of that system.
10. Two students watch the same cart collision. One says the momentum is conserved and the other says it is not, and neither has made an arithmetic error. Explain how both can be correct.

11. Puck A slides east and strikes a stationary puck B on a frictionless table. Explain what conservation of momentum tells you at once about the north and south motion afterward.
12. Explain how the velocity of the center of mass of two carts behaves while they collide, and say what decides it.
13. Two carts collide and the total kinetic energy of the system afterward is less than before. Explain what happened to the momentum and what happened to the missing kinetic energy.
14. Two objects of different mass have equal momenta. Explain which one carries more kinetic energy, and give the relationship that settles it.
15. A car is built so that its front end crumples in a crash. Using the impulse integral, explain what the crumple zone does and does not change.
16. Starting from $\vec{J} = \int \vec{F} dt$, explain what the average force over an interval means and what information is thrown away by using it.
17. In a two dimensional collision, explain why the two component equations constrain the outcome without determining it, and say what has to be added.
18. A ball falls freely toward the ground. Describe the momentum of the ball alone and the momentum of the ball together with the Earth, and explain why both descriptions are correct.
19. Of all the collisions that start from the same two objects moving in the same two ways, explain why the perfectly inelastic one removes the most kinetic energy. Use $K = p^2/2m$ in your answer.

20. Two carts of momentum $6 \text{ kg}\cdot\text{m/s}$ each move toward each other on a track. Give the momentum of the system, explain the mistake that gives twelve, and say what the kinetic energy of the system is doing meanwhile.

Part C. Problems

1. A 1.5 kg cart rolls west along a level track at 6.0 m/s.

(a) Calculate the magnitude of the momentum of the cart.

(b) A second cart has three times the mass of the first and half its speed. Calculate the magnitude of the momentum of the second cart.

2. A 0.30 kg ball is released from rest and falls for 1.2 s before it reaches the floor. Take $g = 10 \text{ m/s}^2$ and ignore the air.

(a) Calculate the magnitude of the impulse gravity delivers to the ball during the fall.

(b) The ball then rebounds straight up at 8.0 m/s. Calculate the magnitude of the change in its momentum during the bounce.

3. A 4.0 kg cart moving east at 5.0 m/s strikes a 6.0 kg cart at rest on a level frictionless track, and the two stick together.

(a) Calculate the speed of the pair after the collision.

(b) Calculate the magnitude of the impulse delivered to the 6.0 kg cart.

4. A 2.0 kg cart moving at 5.0 m/s collides elastically with a second 2.0 kg cart at rest on a level frictionless track.

(a) Calculate the speed of the second cart after the collision.

(b) Calculate the total kinetic energy of the system after the collision.

5. A 2.0 kg cart at rest on a level frictionless track is pushed by a net force $F(t) = 12t$ N from $t = 0$ to $t = 3.0$ s, with t in seconds.

(a) Derive an expression for the impulse delivered between 0 and T , then calculate it for $T = 3.0$ s.

(b) Calculate the speed of the cart at $t = 3.0$ s.

6. A 1.5 kg object at rest on a level frictionless surface is acted on by a net force $F(t) = 9t^2$ N from $t = 0$ to $t = 2.0$ s, with t in seconds.

(a) Derive an expression for the impulse delivered between 0 and T , then calculate it for $T = 2.0$ s.

(b) Calculate the speed of the object at $t = 2.0$ s.

7. A 3.0 kg object moves along a straight line and its momentum is $p(t) = 5t^2 + 2t$ kg·m/s, with t in seconds.

(a) Derive an expression for the net force on the object as a function of time, then calculate it at $t = 3.0$ s.

(b) Calculate the speed of the object at $t = 3.0$ s.

8. Sand falls vertically onto a horizontal conveyor belt at a steady 4.0 kg/s. The belt is held at a constant 2.5 m/s.

(a) Derive an expression for the horizontal force needed to keep the belt at constant speed, in terms of v and dm/dt , then calculate it.

(b) Calculate the power delivered by that force.

9. A 3.0 kg cart moving east at 4.0 m/s strikes a 1.0 kg cart at rest on a level frictionless track. After the collision the 3.0 kg cart is still moving east, at 2.0 m/s.

(a) Derive an expression for the final velocity of the 1.0 kg cart in terms of the two masses and the velocities, then calculate it.

(b) Calculate the magnitude of the impulse delivered to the 1.0 kg cart.

10. A 12 kg object at rest on a frictionless surface is split apart by a spring released inside it. It breaks into a 4.0 kg piece and an 8.0 kg piece that move in opposite directions along one line. The 4.0 kg piece leaves at 6.0 m/s.

(a) Derive an expression for the speed of the 8.0 kg piece in terms of the two masses and the speed of the lighter piece, then calculate it.

(b) Calculate the total kinetic energy of the two pieces.

11. A 2.0 kg puck slides east at 6.0 m/s across a frictionless table and strikes a 2.0 kg puck at rest. After the collision the first puck moves at 3.0 m/s along a direction 60° north of east.

(a) Calculate the speed of the second puck after the collision.

(b) Calculate the angle of the second puck's velocity, measured south of east.

12. On a level track a 5.0 kg cart moves east at 3.0 m/s while a 2.0 kg cart moves west at 2.5 m/s.

(a) Calculate the momentum of the two cart system.

(b) Derive an expression for the velocity of the center of mass of the system, then calculate it.

13. An object has a momentum of magnitude 12 kg·m/s.

(a) Derive an expression for the kinetic energy of the object in terms of its momentum and its mass, then calculate it for a mass of 3.0 kg.

(b) Calculate the kinetic energy of a 6.0 kg object carrying the same momentum.

14. A 3.0 kg cart moving at 4.0 m/s strikes a stationary 6.0 kg cart on a level frictionless track, and the two stick together.

(a) Derive an expression for the kinetic energy of the pair after the collision in terms of m_1 , m_2 and v_1 , then calculate it.

(b) Calculate the kinetic energy lost in the collision.

15. A 2.0 kg cart moving at 9.0 m/s collides elastically with a 4.0 kg cart at rest on a level frictionless track. The motion stays along one line.

(a) Derive an expression for the final velocity of the 2.0 kg cart in terms of the two masses and the initial speed, then calculate it.

(b) Derive an expression for the final velocity of the 4.0 kg cart in the same quantities, then calculate it.

16. An open cart is pulled along level rails so that it keeps a constant speed of 3.0 m/s. Grain pours into it from a hopper at a steady 2.0 kg/s. Ignore friction in the wheels.

(a) Derive an expression for the horizontal force that must be applied to the cart, in terms of v and dm/dt , then calculate it.

(b) Calculate the kinetic energy carried by the grain that has landed during the first 10.0 s.

17. A 5.0 kg object at rest on a level frictionless surface is acted on by a net force along one line. The force rises along a straight line from 0 at $t = 0$ to 20 N at $t = 2.0$ s, holds steady at 20 N until $t = 5.0$ s, then falls along a straight line to 0 at $t = 6.0$ s.

(a) Calculate the total impulse delivered to the object.

(b) Calculate the speed of the object at $t = 6.0$ s.

18. A 0.050 kg dart travels horizontally at 200 m/s and embeds itself in a 0.95 kg block of clay resting on a frictionless table.

(a) Derive an expression for the speed of the dart and block together in terms of the two masses and the dart's speed, then calculate it.

(b) Calculate the kinetic energy lost in the collision.

19. A 50 kg student stands on a 25 kg cart, both at rest on level frictionless rails. The student then walks along the cart and ends up moving at 1.0 m/s east as measured from the ground.

(a) Derive an expression for the velocity of the cart in terms of the two masses and the student's velocity, then calculate it.

(b) Calculate the total kinetic energy of the student and the cart.

20. Object A has mass m and speed v . Object B has mass $4m$ and the same kinetic energy as A. Take $m = 2.0$ kg and $v = 6.0$ m/s.

(a) Derive an expression for the speed of B in terms of v , then calculate it.

(b) Calculate the magnitude of the momentum of B.

AP Physics C: Mechanics, Equation Sheet

The constants, conventions and equations on this sheet are those the College Board provides on the AP Physics exam reference information.

CONSTANTS AND CONVERSION FACTORS

$$G = 6.67 \times 10^{-11} \text{ m}^3/(\text{kg} \cdot \text{s}^2) = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$$

universal gravitational constant

$$g = 9.8 \text{ m/s}^2$$

magnitude of the acceleration due to gravity at the surface of the Earth

$$g = 9.8 \text{ N/kg}$$

magnitude of the gravitational field strength at the surface of the Earth

CONVENTIONS

- The frame of reference of any problem is assumed to be inertial unless otherwise stated.
- Air resistance is assumed to be negligible unless otherwise stated.
- Springs and strings are assumed to be ideal unless otherwise stated.

PREFIXES

Factor	Prefix	Symbol
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

UNIT SYMBOLS

hertz	Hz
newton	N
joule	J
second	s
kilogram	kg
watt	W
meter	m

TRIGONOMETRIC FUNCTIONS AT COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin \theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos \theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan \theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

GEOMETRY AND TRIGONOMETRY

Rectangle

$$A = bh$$

Triangle

$$A = \frac{1}{2}bh$$

Circle

$$A = \pi r^2$$

$$C = 2\pi r$$

$$s = r\theta$$

Rectangular solid

$$V = \ell wh$$

Cylinder

$$V = \pi r^2 \ell$$

$$S = 2\pi r \ell + 2\pi r^2$$

Sphere

$$V = \frac{4}{3}\pi r^3$$

$$S = 4\pi r^2$$

Right triangle

$$a^2 + b^2 = c^2$$

$$\sin \theta = a/c$$

$$\cos \theta = b/c$$

$$\tan \theta = a/b$$

KINEMATICS

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

$$\Delta x = \int v_x(t) dt$$

$$\Delta v_x = \int a_x(t) dt$$

CENTER OF MASS

$$\vec{x}_{\text{cm}} = \frac{\sum m_i \vec{x}_i}{\sum m_i}$$

$$\vec{r}_{\text{cm}} = \frac{\int \vec{r} dm}{\int dm}$$

$$\lambda = \frac{d}{d\ell} m(\ell)$$

$$\vec{v}_{\text{cm}} = \frac{\sum \vec{p}_i}{\sum m_i} = \frac{\sum m_i \vec{v}_i}{\sum m_i}$$

FORCE AND TRANSLATIONAL DYNAMICS

$$\vec{a}_{\text{sys}} = \frac{\sum \vec{F}}{m_{\text{sys}}} = \frac{\vec{F}_{\text{net}}}{m_{\text{sys}}}$$

$$\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt}$$

$$|\vec{F}_g| = G \frac{m_1 m_2}{r^2}$$

$$|\vec{F}_f| \leq |\mu \vec{F}_N|$$

$$\vec{F}_s = -k\Delta \vec{x}$$

$$a_c = \frac{v^2}{r} = r\omega^2$$

$$T = \frac{1}{f}$$

WORK, ENERGY AND POWER

$$K = \frac{1}{2}mv^2$$

$$W = \int_a^b \vec{F} \cdot d\vec{r}$$

$$\Delta K = \sum W_i = \sum F_{\parallel, i} d_i$$

$$\Delta U = - \int_a^b \vec{F}_{\text{cf}}(r) \cdot d\vec{r}$$

AP PHYSICS C: MECHANICS

$$F_x = -\frac{dU(x)}{dx}$$

$$U_s = \frac{1}{2}k(\Delta x)^2$$

$$U_G = -G\frac{m_1 m_2}{r}$$

$$\Delta U_g = mg\Delta y$$

$$P_{\text{avg}} = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t}$$

$$P_{\text{inst}} = \frac{dW}{dt}$$

LINEAR MOMENTUM

$$\vec{p} = m\vec{v}$$

$$\vec{J} = \int_{t_1}^{t_2} \vec{F}_{\text{net}}(t) dt = \Delta \vec{p}$$

TORQUE AND ROTATIONAL DYNAMICS

$$\omega = \frac{d\theta}{dt}$$

$$\alpha = \frac{d\omega}{dt}$$

$$\omega = \omega_0 + \alpha t$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$$

$$v = r\omega$$

$$a_T = r\alpha$$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$I_{\text{tot}} = \sum I_i = \sum m_i r_i^2$$

$$I = \int r^2 dm$$

$$I' = I_{\text{cm}} + Md^2$$

$$\alpha_{\text{sys}} = \frac{\sum \tau}{I_{\text{sys}}} = \frac{\tau_{\text{net}}}{I_{\text{sys}}}$$

ENERGY AND MOMENTUM OF ROTATING SYSTEMS

$$K_{\text{rot}} = \frac{1}{2}I\omega^2$$

$$W = \int \tau \cdot d\theta$$

$$\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$$

$$\Delta L = \int \tau dt$$

$$\Delta x_{\text{cm}} = r\Delta\theta$$

OSCILLATIONS

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$T_s = 2\pi\sqrt{\frac{m}{k}}$$

$$T_p = 2\pi\sqrt{\frac{\ell}{g}}$$

$$T_{\text{phys}} = 2\pi\sqrt{\frac{I}{mgd}}$$

$$x = x_{\text{max}} \cos(\omega t + \phi)$$

VECTORS

$$\vec{A} \cdot \vec{B} = AB \cos \theta$$

$$|\vec{A} \times \vec{B}| = AB \sin \theta$$

$$\vec{r} = (A\hat{i} + B\hat{j} + C\hat{k})$$

$$\vec{C} = \vec{A} + \vec{B}$$

$$\vec{C} = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j}$$

CALCULUS

$$\frac{df}{dx} = \frac{df}{du} \frac{du}{dx}$$

$$\frac{d}{dx}(x^n) = nx^{n-1}$$

$$\frac{d}{dx}(e^{ax}) = ae^{ax}$$

$$\frac{d}{dx}(\ln ax) = \frac{1}{x}$$

$$\frac{d}{dx}[\sin(ax)] = a \cos(ax)$$

$$\frac{d}{dx}[\cos(ax)] = -a \sin(ax)$$

$$\int x^n dx = \frac{1}{n+1}x^{n+1}, n \neq -1$$

$$\int e^{ax} dx = \frac{1}{a}e^{ax}$$

$$\int \frac{dx}{x+a} = \ln|x+a|$$

$$\int \cos(ax) dx = \frac{1}{a}\sin(ax)$$

$$\int \sin(ax) dx = -\frac{1}{a}\cos(ax)$$

IDENTITIES

$$\log(a \cdot b^x) = \log a + x \log b$$

$$\sin^2 \theta + \cos^2 \theta = 1$$

$$\sin(2\theta) = 2 \sin \theta \cos \theta$$

$$\frac{\sin \theta}{\cos \theta} = \tan \theta$$

WHAT THE LETTERS MEAN

a	acceleration
d	distance
E	energy
f	frequency
F	force
I	rotational inertia
J	impulse
k	spring constant
K	kinetic energy
ℓ	length
L	angular momentum
m	mass
M	mass
p	momentum
P	power
r	radius, distance, or position
t	time
T	period
U	potential energy
v	velocity or speed
W	work
x	position or distance
y	vertical position
α	angular acceleration
θ	angular position
λ	linear mass density
μ	coefficient of friction
τ	torque
ϕ	phase angle
ω	angular frequency or angular speed