

Impulse in physics: $J = F\Delta t = \Delta p$, the units, the graph, and why a longer time means a smaller force

Impulse	$J = F \times \Delta t$	a force times the time it acts; a vector in the force's direction
Impulse-momentum theorem	$J = \Delta p = mv - mu$	the impulse delivered equals the change in momentum
Average force	$F = \Delta p \div \Delta t$	Newton's second law in its original form
Units	$N \cdot s = kg \cdot m/s$	the same unit for impulse and momentum
Varying force	area under the force-time graph	triangle-shaped blow: $\frac{1}{2} \times \text{peak} \times \text{duration}$

Impulse against momentum

	Momentum $p = mv$	Impulse $J = F\Delta t$
what	what a moving body has	what changes momentum
belongs to	an object at an instant	an interaction over an interval
zero when	the object is at rest	no force, or no time
conserved?	yes, in a closed system	no: it is a transfer

Same Δp , longer Δt , smaller F : the safety table

Design	What it lengthens	Result
airbag	the time the head and chest take to stop	force on the body down to survivable
crumple zone	the car's stopping time, 0.01 s to about 0.1 s	force on occupants down about ten times
seat belt	the body's stopping time; spreads the force	
bent knees on landing	the body's stopping time	force on legs and spine down several times
hands moving back when catching	the ball's stopping time	the sting goes
gloves, helmets, mats, bubble wrap	the stopping time	
follow-through in sport (the reverse)	the CONTACT time, so $F\Delta t$ is larger	a bigger Δp : a faster ball, same force

Sign step: when an object bounces back, the velocities have opposite signs and Δp is the SUM of their sizes: a 2 kg ball at 6 m/s rebounding at 4 m/s has $\Delta p = 2 \times (4 - (-6)) = 20 \text{ N}\cdot\text{s}$.

From

sciencewithshobha.com/blog/impulse-in-physics-the-impulse-formula-j-f-delta-t-the-impulse-momentum-theorem-airbags-and-follow-through-with-worked-examples-and-a-printable-sheet/ · 1-on-1 online physics and chemistry, free 30-minute first class.

Worked examples and practice

The question	The working	The answer
0.45 kg football kicked from rest to 20 m/s: impulse	0.45×20	9 N·s
the kick lasts 0.01 s: average force	$9 \div 0.01$	900 N
0.145 kg baseball in at 40 m/s, out at 50 m/s: impulse	$0.145 \times (50 - (-40))$	13.05 N·s
contact 0.7 ms: average force	$13.05 \div 0.0007$	18,600 N
1,200 kg car at 20 m/s stops in 0.1 s (crumple zone)	$24,000 \div 0.1$	240,000 N
rigid car, 0.01 s	$24,000 \div 0.01$	2,400,000 N
60 g egg at 4 m/s: floor 0.005 s, cushion 0.1 s	$0.24 \div 0.005$; $0.24 \div 0.1$	48 N; 2.4 N
2 kg ball at 6 m/s rebounds at 4 m/s: impulse	2×10	20 N·s
70 kg person lands at 5 m/s: 0.5 s bent knees, 0.05 s locked	$350 \div 0.5$; $350 \div 0.05$	700 N; 7,000 N

Practice

- [] 1. 40 N for 3 s: impulse?
- [] 2. The trolley is 8 kg, from rest: final speed?
- [] 3. 0.06 kg tennis ball served from rest at 50 m/s: impulse; force if contact is 4 ms?
- [] 4. 0.16 kg puck at 10 m/s stopped in 0.02 s: force?
- [] 5. 0.2 kg ball hits a wall at 8 m/s, rebounds at 8 m/s: impulse?
- [] 6. The same ball rebounds at 5 m/s: impulse?
- [] 7. 1,500 kg car stops from 25 m/s in 2 s: braking force?
- [] 8. Force-time triangle, peak 600 N, base 0.04 s: impulse?
- [] 9. 75 kg skydiver lands at 6 m/s: force with a 0.6 s roll against a 0.06 s stiff landing?
- [] 10. In one sentence with $F = \Delta p / \Delta t$: why pull the hands back when catching?

Answers

- 1) 120 N·s 2) 15 m/s 3) 3 N·s; 750 N 4) 80 N 5) 3.2 N·s 6) 2.6 N·s 7) 18,750 N 8) 12 N·s 9) 750 N against 7,500 N 10) Δp is fixed, so a longer Δt means a smaller F on the hands

Sketch a force-time graph for a bat hitting a ball and shade the impulse