ForceForge — Flashcards

A Spark & Anvil printable flashcard deck. Quiz yourself on the ForceForge cast's curriculum — one card at a time.

How to use these cards

Fold each sheet down the middle line so the answers are hidden. Read the **question** on the left, say your answer out loud, then **unfold** to check the right side. Testing yourself — then checking — is one of the most powerful ways to remember. Get one wrong? That's the best kind of practice: try it again tomorrow.

Want real flashcards? Cut along the fold line and the rows into cards — question on one side, answer on the other.

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1. 1D kinematics — position, velocity, acceleration, and graphs

✂ Question (fold →)	Answer
A horizontal line on a velocity–time graph means the object has:	**constant velocity (zero acceleration)** — A flat v–t line means velocity isn't changing — zero acceleration.
A common misconception is that heavier objects fall faster. Ignoring air resistance, two different-mass objects dropped together:	**hit the ground at the same time** — Free-fall acceleration is independent of mass, so both fall together (Galileo's insight).
ACCELERATION is the rate of change of:	**velocity** — Acceleration measures how fast velocity changes.
The kinematic equation $v = v_0 + at$ gives:	**final velocity from initial velocity, acceleration, and time** — $v = v_0 + at$ predicts final velocity under constant acceleration.
Average velocity over an interval equals:	**displacement divided by time** — Average velocity = Δposition / Δtime (displacement over time).
In free fall (ignoring air resistance), the acceleration of a dropped object is:	**about 9.8 m/s² downward (g)** — All objects in free fall accelerate at $g \approx 9.8$ m/s² regardless of mass.
A car speeding up in the positive direction has velocity and acceleration that are:	**both positive (same direction)** — Speeding up in the + direction means velocity and acceleration point the same way (both +).
A negative slope on a position–time graph means the object is:	**moving in the negative direction** — A downward-sloping position–time line means position is decreasing — motion in the negative direction.
Speed is the magnitude of velocity, so speed:	**has no direction (it is a scalar)** — Speed is just how fast (a scalar); velocity adds direction (a vector).
Instantaneous velocity is found from a position–time graph by taking the slope of:	**the tangent line at that instant** — The tangent slope at a point gives the instantaneous velocity there.
On a velocity–time graph, the AREA under the curve represents the:	**displacement** — Velocity × time accumulates to displacement, so the area under a v–t graph is the displacement.
A car starting from rest ($v_0 = 0$) with acceleration 2 m/s² reaches, after 3 s, a velocity of:	**6 m/s** — $v = 0 + (2)(3) = 6$ m/s.
VELOCITY is the rate of change of:	**position** — Velocity measures how fast position changes (and in what direction).
Why is kinematics the starting point of physics?	**it precisely describes motion, which forces and energy then explain** — Kinematics gives the language of motion (position, velocity, acceleration) that the rest of mechanics builds on.
A steeper slope on a position–time graph indicates a:	**greater velocity** — Steeper position–time slope = larger velocity.
A car SLOWING DOWN while moving in the positive direction has:	**positive velocity and negative acceleration** — Moving + but decelerating means acceleration opposes the motion (negative).
The area under an acceleration–time graph gives the:	**change in velocity** — Acceleration × time accumulates to the change in velocity, so the area under an a–t graph is Δvelocity.

On a POSITION–time graph, the slope represents the:	**velocity** — The slope of a position–time graph is velocity (rise/run = Δposition/Δtime).
An object moving at constant velocity has a net force of:	**zero** — Constant velocity means zero acceleration, so by Newton's 2nd law the net force is zero.
An object's SPEED tells you how fast it moves; its VELOCITY adds:	**the direction of motion** — Velocity is speed with a direction (a vector); speed alone is just the magnitude.
If a velocity–time graph shows a straight line sloping upward from zero, the motion has:	**constant (uniform) acceleration** — A straight sloped v–t line means the acceleration (slope) is constant.
DISPLACEMENT differs from distance because displacement:	**includes direction (it is a vector) and is the net change in position** — Displacement is the straight-line change in position (with direction); distance is total path length.
A common misconception is that zero velocity means zero acceleration. At the TOP of a ball's toss, the velocity is zero but the acceleration is:	**g downward (gravity still acts)** — Velocity is momentarily zero at the top, but gravity keeps accelerating the ball downward at g.
On a VELOCITY–time graph, the slope represents the:	**acceleration** — The slope of a velocity–time graph is acceleration.
Reading motion graphs is a core physics skill because it lets you:	**extract velocity, acceleration, and displacement from a picture of the motion** — Graphs encode the full motion; reading slopes and areas recovers velocity, acceleration, and displacement.

2. Vectors and two-dimensional (projectile) motion

✂ Question (fold →)	Answer
A VECTOR quantity has:	**both magnitude and direction** — Vectors (velocity, force) carry magnitude and direction; scalars (speed, mass) have only magnitude.
A quantity like temperature or mass, which has no direction, is a:	**scalar** — Temperature, mass, and time are scalars — magnitude only.
In projectile motion (no air resistance), the HORIZONTAL velocity is:	**constant** — With no horizontal force, the horizontal velocity stays constant throughout the flight.
A ball thrown horizontally off a cliff and a ball dropped straight down from the same height hit the ground:	**at the same time (same vertical motion)** — Both have the same vertical free-fall, so they land simultaneously — horizontal motion doesn't change the fall time.
The path (trajectory) of a projectile (ignoring air resistance) is:	**a parabola** — Constant horizontal velocity plus accelerated vertical motion traces a parabola.
In projectile motion, the VERTICAL motion is governed by:	**gravity (constant downward acceleration g)** — Vertically, the projectile accelerates downward at g just like any free-falling object.
Two velocity vectors pointing in OPPOSITE directions add to give a resultant that is:	**the difference of their magnitudes** — Opposite vectors partly cancel, so the resultant magnitude is their difference.
The horizontal and vertical motions of a projectile are:	**independent of each other** — The two dimensions are independent: horizontal is constant-velocity, vertical is free-fall.
Why is 2D motion (projectiles) a milestone in physics?	**it shows independent dimensions and vector analysis predicting real trajectories** — Projectile motion demonstrates the power of decomposing a problem into independent vector components — a core physics move.
Air resistance is ignored in idealized projectile motion so that:	**the only force is gravity, simplifying the analysis** — Neglecting air resistance leaves gravity as the only force, giving the clean parabolic model.
At the highest point of a projectile's arc, its HORIZONTAL velocity is:	**unchanged (still moving horizontally)** — Horizontal velocity is constant, so it is unchanged even at the peak.
Two forces of 3 N and 4 N acting at right angles produce a resultant of:	**5 N** — $\sqrt{(3^2 + 4^2)} = \sqrt{25} = 5$ N (a 3-4-5 right triangle).
To add two perpendicular vectors, you can use:	**the Pythagorean theorem for the magnitude** — Perpendicular vectors combine like the legs of a right triangle: magnitude = $\sqrt{(a^2 + b^2)}$.
Displacement in 2D is found by:	**combining the x- and y-displacements as vector components** — Combine the perpendicular displacement components (Pythagorean + direction) for the net displacement.
To find the horizontal component of a launch velocity at angle θ, you use:	**the cosine of the angle** — The horizontal (adjacent) component is magnitude × cos(θ).
At the highest point of a projectile's arc, its VERTICAL velocity is:	**zero** — The vertical velocity is momentarily zero at the peak (though the horizontal velocity continues).

The maximum RANGE of a projectile on level ground occurs at a launch angle of about:	**45°** — On level ground (no air resistance), 45° gives the maximum horizontal range.
Breaking a vector into perpendicular parts gives its:	**components (x and y)** — Resolving a vector yields its x- and y-components, which are easier to work with.
To analyze projectile motion, physicists split it into:	**independent horizontal and vertical components** — Resolving the motion into independent x (constant) and y (free-fall) parts is the key technique.
A SCALAR quantity has:	**magnitude only** — A scalar (like mass, time, speed) has only a size, no direction.
The RESULTANT of two vectors is:	**the single vector equivalent to their sum** — The resultant is the vector sum — the single vector with the same total effect.
A common 2D-motion misconception is that a projectile's horizontal velocity decreases as it rises. Actually it:	**stays constant (no horizontal force acts)** — With no horizontal force, horizontal velocity is unchanged the entire flight.
A vector pointing 30° above horizontal has a vertical component found using:	**the sine of the angle** — The vertical (opposite) component is magnitude × sin(angle).
Vector thinking is powerful because it lets you:	**handle motion and forces in any direction, not just along a line** — Vectors extend physics from a line to a plane (and space), letting you combine directional quantities correctly.
The RANGE of a projectile (horizontal distance) depends on both its launch speed and:	**its launch angle** — Range depends on launch speed and angle (maximum at 45° on level ground); mass doesn't matter.

3. Newton's laws of motion — net force and acceleration

✂ Question (fold →)	Answer
A net force of 10 N on a 2 kg object produces an acceleration of:	**5 m/s²** — a = F/m = 10/2 = 5 m/s².
A 5 kg object experiences a net force of 20 N. Its acceleration is:	**4 m/s²** — a = F/m = 20/5 = 4 m/s².
If the forces on an object are balanced, the object:	**has zero acceleration (rest or constant velocity)** — Balanced (net-zero) forces mean no acceleration — the object stays at rest OR moves at constant velocity.
INERTIA is a measure of an object's:	**resistance to changes in motion (related to its mass)** — Inertia is the tendency to resist changes in motion; more mass means more inertia.
An object in equilibrium (net force zero) can be:	**at rest OR moving at constant velocity** — Zero net force means zero acceleration — the object is at rest or moves at constant velocity.
A net force in the direction OPPOSITE to motion will:	**slow the object down (decelerate it)** — A net force opposite the velocity produces acceleration that reduces the speed.
On the Moon (weaker gravity), an object's mass and weight, compared to Earth:	**mass is the same, weight is less** — Mass is intrinsic (unchanged); weight (mg) drops because g is smaller on the Moon.
Mass and weight differ because mass is __ while weight is __:	**the amount of matter; the gravitational force on it** — Mass (kg) is intrinsic; weight (N) is the gravity force and changes with g (e.g. on the Moon).
A common third-law misconception (the 'dominance' idea): when a truck hits a small car, the force on the truck is:	**equal in magnitude to the force on the car** — By Newton's third law the forces are equal and opposite — the truck and car push each other with the same magnitude.
A common misconception (the 'motion implies force' idea) is that a moving object needs a continual force. Newton's first law says:	**a moving object continues at constant velocity with NO net force** — No net force is needed to maintain motion; force is needed only to CHANGE motion. (Friction is what stops everyday objects.)
Action–reaction force pairs always act on:	**two different objects** — The two forces in a third-law pair act on the two interacting objects, never on the same one — so they never cancel on one object.
A book resting on a table has a net force of:	**zero (gravity and the normal force balance)** — Gravity down and the table's normal force up balance, giving zero net force (no acceleration).
Weight is the force of gravity on an object, calculated as:	**mass × g (W = mg)** — Weight = mg, the gravitational force; it differs from mass (the amount of matter).
Free-body diagrams are used to:	**show all the forces acting on a single object** — A free-body diagram isolates one object and draws every force on it — the setup for applying F = ma.
If the truck and car feel equal forces, why is	**the same force gives the smaller-mass car a much larger acceleration** — Equal force but smaller mass (a = F/m) means the car

the car damaged more?	accelerates much more — greater damage despite equal force.
Newton's FIRST law (inertia) says an object at rest or in uniform motion stays that way unless:	**acted on by a net (unbalanced) force** — Without a net force, an object keeps its state of motion — the law of inertia.
The NET force on an object is:	**the vector sum of all forces acting on it** — You add all forces as vectors to get the net force, which determines the acceleration.
Newton's second law can be rearranged to solve for acceleration as:	**a = F/m** — From F = ma, acceleration a = F/m.
Newton's SECOND law is written as:	**F = ma (net force = mass × acceleration)** — The net force equals mass times acceleration: F = ma.
By Newton's second law, for a given force, a larger mass produces a __ acceleration:	**smaller** — a = F/m: more mass means less acceleration for the same force.
Inertia depends on an object's:	**mass** — More mass means more inertia (more resistance to a change in motion).
The reason a seatbelt is important in a sudden stop is that your body's inertia keeps it:	**moving forward until a force stops it** — By inertia (first law), your body tends to keep moving when the car stops; the belt provides the stopping force.
Newton's laws let you PREDICT motion because they connect:	**the forces on an object to its resulting acceleration** — Knowing the net force lets you compute the acceleration and thus predict the future motion — the core of dynamics.
Why are Newton's laws the foundation of classical mechanics?	**they explain how forces cause changes in motion for everything from balls to planets** — Newton's three laws unify the behavior of all everyday and astronomical motion under force and acceleration.
Newton's THIRD law says that for every action force there is:	**an equal and opposite reaction force on the other object** — Forces come in equal-and-opposite pairs acting on the two different interacting objects.

4. Friction, normal force, and free-body analysis

✂ Question (fold →)	Answer
The friction force on a heavier object (same surfaces) is larger because the __ is larger:	**normal force** — Friction = μN, and a heavier object presses harder (larger normal force), so friction is larger.
KINETIC friction acts when surfaces are:	**sliding against each other** — Kinetic friction acts during sliding and is usually a bit less than maximum static friction.
If the applied force on a resting box is less than the maximum static friction, the box:	**does not move (static friction matches the applied force)** — Static friction adjusts to match the applied force up to its max, so the box stays put.
On an INCLINE, gravity is resolved into components along and perpendicular to the surface; the component along the incline:	**tends to slide the object down the slope** — The along-slope gravity component (mg sinθ) drives the object down the incline.
A common friction misconception is that friction depends strongly on contact AREA. In the simple model, friction depends on:	**the normal force and the surfaces, not the contact area** — In the basic model friction is μN — independent of the apparent contact area.
At TERMINAL velocity, a falling object's air resistance:	**balances gravity, giving zero net force (constant speed)** — When drag grows to equal weight, the net force is zero and the object falls at constant terminal velocity.
A heavier object generally experiences __ friction on the same surface:	**more (greater normal force)** — More weight means a larger normal force, and friction (μN) scales with the normal force.
The direction of kinetic friction on a sliding object is:	**opposite to its direction of motion** — Kinetic friction always opposes the sliding motion.
Maximum static friction is generally __ than kinetic friction:	**greater** — It usually takes more force to START sliding than to keep it sliding, so static friction's max exceeds kinetic.
Analyzing forces with free-body diagrams lets you:	**find the net force and predict the motion** — Drawing all forces and summing them gives the net force — the key to predicting acceleration.
On a flat, level surface, the normal force on a resting object equals:	**its weight (mg)** — On level ground with no vertical push, the normal force balances gravity, so N = mg.
On a level surface, doubling an object's mass roughly __ the friction force:	**doubles** — Double the mass doubles the normal force (mg), and friction (μN) scales with it.
Friction force is proportional to the:	**normal force ($F_{friction}$ = μN)** — Friction = coefficient × normal force; it does NOT depend simply on speed or contact area.
Without any friction, walking would be difficult because:	**you push backward on the ground and friction pushes you forward** — Walking relies on friction: your foot pushes back, and friction's forward reaction propels you (Newton's third law).
Lubrication reduces friction by:	**separating the surfaces, lowering the effective μ** — A lubricant keeps surfaces apart, reducing the friction coefficient.
On an incline, the NORMAL force is __ than	**less** — Only the perpendicular gravity component (mg cosθ) presses

the object's full weight:	on the surface, so N = mg cosθ < mg.
The NORMAL force is:	**the support force a surface exerts perpendicular to itself** — The normal force pushes perpendicular (normal) to the surface, supporting the object.
STATIC friction acts when surfaces are:	**not yet sliding (at rest relative to each other)** — Static friction holds surfaces in place up to a maximum before sliding begins.
Air resistance is a form of friction that acts:	**opposite to an object's motion through the air** — Air resistance (drag) opposes motion through the air, growing with speed.
A free-body diagram of a box being pushed across a floor should include:	**gravity, normal force, applied push, and friction** — All four forces act: weight down, normal up, applied force forward, friction backward.
A crate on the verge of sliding is held by __ friction at its maximum value:	**static** — Just before sliding, static friction reaches its maximum; beyond that, the crate slides (kinetic friction).
The coefficient of friction μ depends on:	**the two surfaces in contact** — μ is a property of the pair of surfaces (rough vs smooth), not the object's mass or speed.
Friction converts kinetic energy into:	**heat (thermal energy)** — Friction dissipates mechanical energy as heat, which is why brakes and rubbed hands get warm.
FRICTION is a force that:	**opposes relative motion between surfaces** — Friction resists sliding, acting opposite to the direction of (attempted) motion.
Why is understanding friction and forces essential in engineering?	**controlling friction and forces is key to designing safe, functional machines and structures** — From brakes to bridges to tires, engineers must control friction and forces for safety and function.

5. Momentum and impulse

✂ Question (fold →)	Answer
A moving object with zero velocity has a momentum of:	**zero** — p = mv, so zero velocity gives zero momentum.
The direction of an object's momentum is:	**the same as its velocity** — Momentum p = mv points the same way as the velocity.
A common misconception is confusing momentum with kinetic energy. Momentum (p = mv) is a vector, while kinetic energy (½mv²) is:	**a scalar (no direction)** — Momentum is a vector (mv); kinetic energy is a scalar (½mv²) — they're different quantities.
Impulse and momentum share the same units because impulse equals a:	**change in momentum** — Impulse = Δp, so both are measured in kg·m/s (equivalently N·s).
Why is momentum a cornerstone concept in physics?	**it is conserved in interactions, making collisions and rocket motion predictable** — Conservation of momentum predicts the outcomes of collisions, explosions, and rocket propulsion.
A heavy truck and a light car with the same velocity: the truck has __ momentum:	**more** — Same velocity but more mass gives the truck more momentum (p = mv).
Crumple zones in cars protect passengers by:	**extending the collision time to reduce the force** — A crumple zone lengthens the stopping time, lowering the peak force for the same momentum change.
If a force of 5 N acts for 3 s, the impulse delivered is:	**15 N·s** — Impulse = F·Δt = 5 × 3 = 15 N·s.
Airbags reduce injury by:	**increasing the collision time, reducing the force on the passenger** — By extending the stopping time, airbags lower the peak force for the same momentum change.
Impulse can be increased by increasing either the force OR the:	**time the force acts** — Impulse = F·Δt, so a bigger force or a longer time (or both) increases it.
A 2 kg object moving at 4 m/s has a momentum of:	**8 kg·m/s** — p = mv = 2 × 4 = 8 kg·m/s.
Doubling an object's velocity (same mass) __ its momentum:	**doubles** — Momentum p = mv is proportional to velocity, so doubling v doubles p (unlike KE, which quadruples).
The units of momentum are:	**kg·m/s** — Momentum = mass (kg) × velocity (m/s) = kg·m/s.
Momentum is especially useful for analyzing:	**collisions and interactions between objects** — Momentum shines in collisions, where it is conserved, making otherwise complex interactions predictable.
An impulse of 10 N·s on a 2 kg object at rest gives it a velocity of:	**5 m/s** — Impulse = Δp = mΔv, so Δv = 10/2 = 5 m/s.
A follow-through in sports (e.g. a golf swing) increases the ball's speed by:	**increasing the contact time, delivering more impulse** — A longer follow-through extends contact time, increasing impulse and thus the ball's momentum.

The impulse delivered to an object equals the area under a:	**force–time graph** — Since impulse = F·Δt, the area under a force–time curve gives the impulse.
MOMENTUM is defined as:	**mass times velocity (p = mv)** — Momentum p = mv is a vector — mass times velocity.
The impulse–momentum relationship is powerful because it connects:	**the force and time of an interaction to the resulting change in motion** — It lets you design safety systems and analyze impacts by relating force, time, and momentum change.
A ball bouncing back off a wall undergoes a __ momentum change than one that stops at the wall:	**larger** — Reversing direction changes momentum more than merely stopping (Δp is larger), so a bounce needs more impulse.
IMPULSE is defined as:	**force times the time it acts (impulse = F·Δt)** — Impulse is the product of force and the time interval over which it acts.
To stop a fast-moving object gently (small force), you should:	**extend the stopping time** — Since F·Δt = Δp, a longer stopping time means a smaller force for the same momentum change.
The impulse–momentum theorem states that impulse equals the:	**change in momentum** — F·Δt = Δp: an impulse changes an object's momentum by that amount.
A longer contact time for the same change in momentum means the force is:	**smaller** — Since F·Δt = Δp, spreading the same Δp over more time lowers the force — the principle behind airbags.
Momentum is a VECTOR quantity, so it has:	**both magnitude and direction** — Because velocity has direction, momentum does too.

6. Collisions and conservation of momentum

✂ Question (fold →)	Answer
A common collision misconception is that momentum is only conserved in elastic collisions. Actually momentum is conserved in:	**all collisions in a closed system (elastic and inelastic)** — Momentum is conserved regardless of collision type; only kinetic energy depends on elasticity.
If a moving ball hits an identical stationary ball ELASTICALLY head-on, the moving ball:	**stops and the other moves off at the original speed** — For equal masses in a head-on elastic collision, velocities are exchanged — the incoming ball stops.
An explosion is like a collision in reverse: total momentum after the explosion equals:	**the total momentum before (often zero)** — If a stationary object explodes, the fragments' momenta must sum to zero (conserved from the initial rest).
The total momentum of a system is found by:	**adding the momenta of all objects as vectors** — Total momentum is the vector sum of each object's momentum.
An INELASTIC collision conserves:	**momentum but not kinetic energy** — Momentum is always conserved; in an inelastic collision some kinetic energy becomes heat/deformation.
Why is conservation of momentum one of the deepest principles in physics?	**it holds universally in closed systems, from subatomic particles to galaxies** — Conservation of momentum is a fundamental, universal law that constrains every interaction in a closed system.
Conservation of momentum applies to a collision when:	**no external forces act on the colliding objects** — Momentum is conserved for the system whenever external forces are negligible.
In a closed system (no external forces), total momentum is:	**conserved (unchanged)** — With no external force, the total momentum before an interaction equals the total after.
Two ice skaters pushing off each other move apart with:	**equal and opposite momenta (total stays zero)** — Starting at rest, the skaters gain equal and opposite momenta, keeping the total at zero.
An ELASTIC collision conserves:	**both momentum and kinetic energy** — In a perfectly elastic collision, both momentum and kinetic energy are conserved.
A perfectly elastic collision is an idealization because real collisions usually:	**lose some kinetic energy to sound, heat, and deformation** — Real collisions are somewhat inelastic; perfect elasticity is an idealization.
To solve a collision problem, you set the total momentum before equal to the total momentum after and:	**solve for the unknown velocity** — Writing p_before = p_after (as vectors) and solving yields the unknown velocity.
Two equal-mass carts, one moving and one at rest, collide and stick. Their common speed afterward is:	**half the original speed** — Momentum conserved: mv = (2m)v', so v' = v/2 — half the original speed.
A PERFECTLY INELASTIC collision is one where the objects:	**stick together and move as one afterward** — In a perfectly inelastic collision the objects couple and move together, losing the most kinetic energy.
	vehicle safety, particle physics, and astronomy — Momentum

Analyzing collisions with momentum conservation is essential in fields like:	conservation underlies crash analysis, particle collisions, and celestial interactions.
In any collision (elastic or inelastic), the quantity ALWAYS conserved is:	**momentum** — Momentum conservation holds for all collisions in a closed system; kinetic energy is conserved only if elastic.
In a rocket, momentum is conserved as it expels gas backward, so the rocket:	**gains forward momentum** — Expelling gas backward gives the rocket equal forward momentum — propulsion by momentum conservation.
Momentum is conserved in a car crash system, but individual cars still get damaged because:	**kinetic energy is transformed into deformation and heat** — Total momentum is conserved, but the lost kinetic energy goes into crumpling metal and heat.
When two objects stick together in a collision, kinetic energy is:	**reduced (some becomes heat and deformation)** — Perfectly inelastic collisions lose the most kinetic energy to heat and deformation, though momentum is conserved.
In an isolated system, an external force is one that:	**comes from outside the system and can change the total momentum** — Momentum is conserved only when NO external force acts; internal collision forces don't change the total.
A lighter skater pushed off from a heavier one moves away:	**faster than the heavier skater** — Equal and opposite momenta with less mass means the lighter skater has the greater speed ($p = mv$).
Kinetic energy is MOST reduced in a:	**perfectly inelastic collision (objects stick)** — Sticking together loses the most kinetic energy (to heat/deformation), while momentum is still conserved.
In a two-dimensional collision, momentum is conserved:	**separately in each direction (x and y)** — Momentum is a vector, so it is conserved independently in each perpendicular direction.
A recoiling rifle demonstrates conservation of momentum because:	**the bullet's forward momentum equals the rifle's backward momentum** — The system starts at rest, so the forward bullet momentum must be balanced by the backward rifle momentum.
Conservation of momentum is powerful because it lets you predict outcomes:	**without knowing the messy details of the forces during the collision** — You can predict post-collision velocities from the conservation law alone, bypassing the complex internal forces.

7. Work, kinetic energy, and potential energy

✂ Question (fold →)	Answer
If you do 100 J of work in 5 s, your power output is:	**20 W** — Power = work/time = 100/5 = 20 W.
A 3 kg object lifted 2 m gains a gravitational PE of about ($g \approx 10$ m/s^2):	**60 J** — PE = mgh = 3 × 10 × 2 = 60 J.
The unit of power is the:	**watt (W)** — Power is measured in watts (1 W = 1 J/s).
In physics, WORK is done when a force:	**causes displacement in the direction of the force** — Work = force × displacement (in the force's direction); no displacement means no work.
Kinetic energy depends on the SQUARE of the speed, so doubling the speed makes KE:	**four times larger** — $KE = \frac{1}{2}mv^2$; doubling v gives $2^2 = 4$ times the kinetic energy.
Why are work and energy such powerful concepts in physics?	**energy accounting predicts motion and is conserved across all its forms** — Tracking energy — and using its conservation — predicts outcomes across mechanics, thermodynamics, and beyond.
If you hold a heavy box still (no movement), the work you do on it is:	**zero (no displacement)** — Physics work requires displacement; holding something still does zero work on it, however tiring.
A 2 kg object moving at 3 m/s has a kinetic energy of:	**9 J** — $KE = \frac{1}{2}mv^2 = \frac{1}{2}(2)(3^2) = \frac{1}{2}(2)(9) = 9$ J.
Elastic potential energy is stored in:	**a stretched or compressed spring (or elastic object)** — Deforming an elastic object (stretching/compressing) stores elastic potential energy.
More powerful machines can do the same work in:	**less time** — Power is work/time, so higher power does the same work faster (in less time).
Gravitational potential energy depends on height, mass, and:	**the strength of gravity (g)** — PE = mgh depends on mass, height, and the gravitational field strength g.
POWER is defined as the:	**rate of doing work (work per unit time)** — Power = work/time; it measures how fast energy is transferred.
The formula for work (force along the motion) is:	**W = F·d** — Work equals force times the displacement in the force's direction: W = Fd.
A common energy misconception is that energy is 'used up.' In physics, energy is:	**transformed from one form to another, not destroyed** — Energy changes form (e.g. chemical → kinetic → heat) but the total is conserved — never truly 'used up.'
The work–energy theorem is useful because it lets you find speed changes:	**from the net work, without tracking the detailed forces over time** — Relating net work to ΔKE gives a shortcut to final speeds without solving the full time-dependent motion.
GRAVITATIONAL potential energy is:	**stored energy due to height (PE = mgh)** — Gravitational PE = mgh — energy stored by raising an object against gravity.

KINETIC ENERGY is the energy of:	**motion (½mv^2)** — Kinetic energy KE = ½mv^2 is the energy an object has due to its motion.
The work done by a force perpendicular to the motion is:	**zero** — Only the force component along the displacement does work; a perpendicular force does none.
Doing POSITIVE work on an object (force along its motion) makes its kinetic energy:	**increase** — A force in the direction of motion adds kinetic energy (positive work speeds it up).
Lifting an object higher increases its gravitational potential energy because:	**PE = mgh grows with height h** — Greater height h means more stored gravitational potential energy (mgh).
The unit of both work and energy is the:	**joule (J)** — Work and energy are both measured in joules (1 J = 1 N·m).
Doing NEGATIVE work on an object (force opposite to motion) causes its kinetic energy to:	**decrease** — A force opposing motion (like friction) removes kinetic energy — negative work slows the object.
The work–energy theorem states that the net work done on an object equals its:	**change in kinetic energy** — Net work = ΔKE: doing net work on an object changes its kinetic energy.
A force applied PERPENDICULAR to the motion does:	**zero work** — Only the component of force along the displacement does work; a perpendicular force does none (e.g. centripetal force).
Work done against gravity to lift an object is stored as:	**gravitational potential energy** — Lifting converts your work into the object's gravitational potential energy (mgh).

8. Conservation of energy — energy transforms, total conserved

✂ Question (fold →)	Answer
At the TOP of a roller-coaster hill (momentarily at rest), the car's energy is mostly:	**potential energy** — At the highest point, with little speed, the energy is mostly gravitational potential.
At the BOTTOM of the hill (fastest point), the car's energy is mostly:	**kinetic energy** — At the lowest, fastest point the energy is mostly kinetic.
Why is conservation of energy one of the most important principles in all of science?	**it governs every process in the universe, from machines to stars to living cells** — Conservation of energy is a universal law underlying all physical, chemical, and biological processes.
A falling object converts __ energy into __ energy:	**potential; kinetic** — As an object falls, gravitational potential energy transforms into kinetic energy.
Energy conservation lets you find a final speed WITHOUT knowing the path, as long as:	**you know the change in height (and friction is negligible)** — For conservative forces like gravity, only the height change matters — the specific path doesn't affect the energy result.
The 'conservation' in conservation of energy means the total amount is:	**constant (never created or destroyed) in an isolated system** — Conserved means the total stays constant — energy only changes form.
For a frictionless roller coaster, the total mechanical energy (KE + PE) is:	**constant throughout the ride** — Without friction, mechanical energy (KE + PE) is conserved — it just shifts between the two forms.
A pole vaulter converts kinetic energy (the run-up) into __ at the top of the vault:	**gravitational potential energy** — The vaulter's running kinetic energy (via the pole's elastic energy) becomes gravitational potential energy at the peak.
Energy transformations are never 100% efficient in real machines because some energy is:	**converted to heat (and other unusable forms)** — Real machines lose some input energy to heat/friction, so useful output is less than input — but total energy is conserved.
A battery stores energy as __ energy and releases it as electrical energy:	**chemical** — A battery stores chemical potential energy and converts it to electrical energy.
Tracking energy through its transformations is a powerful problem-solving tool because:	**conservation lets you relate start and end states without the details in between** — Conservation of energy connects initial and final states directly, bypassing the messy intermediate dynamics.
At the halfway point of a frictionless drop, an object's energy is:	**part kinetic and part potential (their sum unchanged)** — Partway down, some PE has become KE; the total (KE + PE) is still conserved.
Total energy (all forms) in an isolated system is:	**always conserved** — While mechanical energy can convert to heat, the TOTAL energy of an isolated system is always conserved.
A common misconception is that a moving object 'has' force that gets used up. Actually a moving object has:	**kinetic ENERGY (and momentum), which transform but conserve** — Objects carry energy and momentum, not 'force'; energy transforms and is conserved rather than being 'used up.'
A hydroelectric dam converts the __ energy of stored water into electrical energy:	**gravitational potential** — Water held high has gravitational potential energy, converted to kinetic then electrical as it falls through turbines.

A solar panel converts __ energy into electrical energy:	**light (radiant)** — Solar panels transform the radiant energy of sunlight into electrical energy.
A bouncing ball that returns to a LOWER height each bounce is losing mechanical energy to:	**heat and sound (through deformation and air resistance)** — Each bounce converts some mechanical energy to heat and sound, so the ball doesn't return as high.
When you rub your hands together, mechanical (kinetic) energy is converted to:	**thermal energy (heat)** — Friction from rubbing turns the motion energy into heat.
A real pendulum eventually stops because:	**friction and air resistance convert its energy to heat** — Energy isn't destroyed — friction and air resistance gradually convert the mechanical energy to heat.
A wind turbine converts the __ energy of moving air into electrical energy:	**kinetic** — Moving air (kinetic energy) turns the blades, generating electricity.
The energy stored in food and fuel is a form of:	**chemical potential energy** — Food and fuel store chemical potential energy, released in reactions to power bodies and engines.
A swinging pendulum converts energy back and forth between:	**kinetic and potential energy** — A pendulum trades KE (fastest at the bottom) and PE (highest at the ends) continuously.
A ball dropped from height h (frictionless) hits the ground with a kinetic energy equal to its:	**initial potential energy (mgh)** — All the initial PE (mgh) converts to KE at the ground by conservation of energy.
The law of conservation of energy states that energy:	**cannot be created or destroyed, only transformed** — Energy changes form but the total amount in a closed system stays constant.
When friction IS present, some mechanical energy is converted to:	**thermal energy (heat)** — Friction transforms mechanical energy into heat, so mechanical energy alone is not conserved — but total energy is.

9. Circular motion and centripetal force

✂ Question (fold →)	Answer
If the centripetal force on an orbiting object suddenly vanished, the object would:	**fly off in a straight line (tangent to the circle)** — By inertia (Newton's first law), the object continues straight along the tangent when the inward force disappears.
The centripetal force is a NET force, meaning it is:	**provided by real forces like tension, friction, or gravity — not a new separate force** — 'Centripetal' names the ROLE of the net force; it is supplied by ordinary forces directed inward.
Period (T) of circular motion is the time to:	**complete one full revolution** — The period is the time for one complete trip around the circle.
Uniform circular motion means moving in a circle at:	**constant speed** — 'Uniform' means the speed is constant, though the direction (and velocity) keeps changing.
The net force on an object in uniform circular motion points:	**toward the center of the circle (centripetal)** — The centripetal ('center-seeking') net force points to the center, continually turning the object.
A common misconception is that a 'centrifugal' force pushes objects OUTWARD in circular motion. Actually the real net force points:	**inward (centripetal); the outward feeling is inertia, not a real force** — The outward sensation comes from inertia (the tendency to go straight); the actual net force is inward.
The velocity of an object in circular motion is directed:	**tangent to the circle** — The velocity is always tangent to the circular path (perpendicular to the radius).
For a car turning a corner, the centripetal force is usually provided by:	**friction between the tires and the road** — Static friction between tires and road supplies the inward centripetal force for the turn.
A larger radius of circular motion (same speed) requires a __ centripetal force:	**smaller** — $F = mv^2/r$: a bigger radius means less centripetal force is needed at the same speed.
Why is circular motion a conceptually important topic in physics?	**it shows that a net force changes direction (not just speed) and underlies orbits** — Circular motion deepens the force–acceleration idea (force can turn an object) and is the basis of orbital mechanics.
At the top of a vertical loop, the forces providing the centripetal force include:	**gravity and the normal (track) force, both pointing down toward the center** — At the top of a loop, gravity and the track's normal force both point downward (toward the center), providing centripetal force.
A rider feels 'pushed outward' on a spinning ride because of:	**their inertia (tendency to move straight), while the ride pushes them inward** — The rider's body tends to go straight; the ride's inward push feels like being thrown outward — but the real force is inward.
Because the centripetal force is perpendicular to the velocity, it does:	**no work (speed stays constant)** — A force perpendicular to motion does no work, so uniform circular motion keeps constant speed.
A satellite in circular orbit is kept in orbit by:	**gravity acting as the centripetal force** — Earth's gravity supplies the inward centripetal force that keeps a satellite in circular orbit.
Halving the radius of circular motion (same speed) __ the required centripetal force:	**doubles** — $F = mv^2/r$: halving r doubles the centripetal force.

The centripetal force formula is:	**F = mv²/r** — The centripetal force needed is $F = mv^2/r$.
A ball on a string swung in a circle is kept moving in the circle by the:	**tension in the string (pointing inward)** — The string's inward tension provides the centripetal force.
An object moving in a circle at constant speed is accelerating because:	**its direction (and thus velocity) is constantly changing** — Velocity is a vector; a changing direction means changing velocity, so there is acceleration even at constant speed.
Which quantity is CONSTANT in uniform circular motion?	**the speed (magnitude of velocity)** — The speed is constant, but the velocity's direction (and thus the velocity vector and acceleration direction) constantly change.
Circular motion illustrates that acceleration can occur:	**without any change in speed (just a change in direction)** — Uniform circular motion is the key example that acceleration means changing velocity — which includes changing direction alone.
Understanding centripetal force is essential for designing:	**safe curves, orbits, and rotating machinery** — Road curves, satellite orbits, centrifuges, and turbines all rely on correctly providing centripetal force.
The centripetal force required increases when the object's speed:	**increases ($F \propto v^2$)** — Centripetal force $F = mv^2/r$ grows with the square of the speed.
A rider at the bottom of a Ferris wheel feels heavier because the seat must provide:	**an upward force greater than their weight (to also supply centripetal force)** — At the bottom, the seat supports the weight AND provides the upward centripetal force, so it pushes harder — you feel heavier.
Doubling the speed of an object in a circle of the same radius multiplies the required centripetal force by:	**4** — $F = mv^2/r$ depends on v^2, so doubling v gives $2^2 = 4$ times the force.
Centripetal acceleration is directed:	**toward the center of the circle** — Centripetal acceleration points to the center, matching the centripetal force direction.

10. Universal gravitation and orbits

✂ Question (fold →)	Answer
The reason all objects fall with the same acceleration g (ignoring air resistance) is that:	**the greater gravitational force on a heavier object is exactly offset by its greater inertia** — Force ∝ mass, but acceleration = force/mass, so mass cancels — all objects accelerate at g.
The gravitational force provides the __ force that keeps a planet in orbit:	**centripetal** — Gravity supplies the inward centripetal force that curves a planet's path into an orbit.
The gravitational field strength g near a planet's surface depends on the planet's:	**mass and radius** — $g = GM/R^2$ depends on the planet's mass M and radius R — a bigger, denser planet has stronger surface gravity.
Weight and mass are related by:	**W = mg** — Weight (a force) equals mass times the gravitational field strength: W = mg.
The gravitational constant G is:	**a universal constant that sets the strength of gravity everywhere** — G is a fundamental universal constant in $F = Gm_1m_2/r^2$, the same throughout the universe.
A satellite in a HIGHER orbit moves __ than one in a lower orbit:	**slower** — Higher orbits have weaker gravity and require less speed, so higher satellites orbit more slowly.
Gravity is the WEAKEST of the fundamental forces, yet it dominates on astronomical scales because it:	**is always attractive and adds up over huge masses** — Unlike electric forces (which cancel), gravity is always attractive, so it accumulates across enormous masses to shape the cosmos.
Newton's law of universal gravitation says every mass attracts every other mass with a force that:	**increases with the masses and decreases with distance** — Gravitational force grows with the product of the masses and falls off with distance ($F = Gm_1m_2/r^2$).
Kepler's laws describe:	**the motion of planets in their orbits** — Kepler's three laws describe planetary orbital motion (ellipses, equal areas, period–radius relation).
Tides on Earth are primarily caused by:	**the Moon's gravitational pull (and the Sun's)** — The Moon's (and Sun's) gravity pulls unevenly on Earth's oceans, creating tidal bulges.
Escape velocity is the minimum speed needed to:	**break free of a planet's gravity without further propulsion** — Escape velocity is the speed at which an object's kinetic energy can overcome gravitational binding and escape.
The value $g \approx 9.8\ m/s^2$ is the:	**gravitational field strength (acceleration due to gravity) near Earth's surface** — g is the acceleration gravity gives near Earth's surface — the local field strength.
Why is universal gravitation one of the most profound ideas in science?	**it revealed that one simple law governs motion from falling apples to galaxies** — A single inverse-square law unifies falling objects, planetary orbits, and galactic structure — a landmark of scientific unification.
Newton's great insight was that the force pulling an apple down is the SAME force that:	**keeps the Moon in orbit** — Newton unified terrestrial and celestial motion: the same gravity that drops an apple holds the Moon in orbit.
The Moon stays in orbit rather than	**Earth's gravity continuously provides the centripetal force** — Earth's gravity pulls the Moon inward as the needed centripetal force, keeping it

flying away because:	in orbit.
Your WEIGHT would decrease if you moved to a location where:	**the gravitational field is weaker (e.g. higher altitude or the Moon)** — Weight (mg) depends on the local gravitational field g, which weakens with altitude or on a smaller body.
An orbit is essentially the result of an object:	**falling toward a body while moving fast enough sideways to keep missing it** — Newton's insight: an orbiting object continuously falls toward the planet but moves sideways fast enough to keep 'missing' the surface.
Tripling the distance between two masses reduces the gravitational force to:	**one-ninth** — $F \propto 1/r^2$: tripling r divides the force by $3^2 = 9$.
Gravitational force follows an INVERSE-SQUARE law, so doubling the distance makes the force:	**one-quarter as strong** — $F \propto 1/r^2$: doubling r divides the force by $2^2 = 4$.
Understanding gravitation lets scientists:	**predict planetary orbits, plan spacecraft trajectories, and understand the cosmos** — Gravitation predicts orbits and eclipses, enables space missions, and explains the structure of the universe.
An astronaut in orbit feels weightless because they and their spacecraft:	**fall together at the same rate (free fall)** — Both fall together, so there's no support force — the sensation of weightlessness (though gravity still acts).
A common misconception is that there is NO gravity in space (e.g. on the ISS). Actually astronauts float because they are:	**in free fall (continuously falling around Earth), not free of gravity** — Orbiting astronauts are in constant free fall; gravity is still strong — they just fall around Earth, feeling weightless.
The gravitational force between two objects depends on the __ of their masses:	**product** — $F = Gm_1m_2/r^2$ — the force is proportional to the PRODUCT of the two masses.
The gravitational force between two objects is __ if their masses increase:	**stronger** — $F = Gm_1m_2/r^2$ grows with the masses, so bigger masses attract more strongly.
Planets orbit the Sun in paths that are:	**ellipses (with the Sun at one focus)** — Kepler's first law: orbits are ellipses with the Sun at one focus (nearly circular for many planets).

11. Oscillation and simple harmonic motion

✂ Question (fold →)	Answer
A playground swing pushed at just the right times illustrates:	**resonance (driving at the natural frequency)** — Timing pushes to the swing's natural frequency builds up amplitude — an everyday resonance example.
At the equilibrium point of an oscillator, the restoring force is:	**zero** — At equilibrium the displacement is zero, so the restoring force (∝ displacement) is zero — but the speed is maximum.
The frequency of oscillation is measured in:	**hertz (Hz)** — Frequency (cycles per second) is measured in hertz.
Understanding oscillations and SHM is essential because they:	**model repeating phenomena from clocks and springs to atoms and waves** — Oscillatory motion underlies timekeeping, music, structural vibrations, and wave physics.
A mass on a spring oscillates faster (higher frequency) if the spring is:	**stiffer (larger spring constant)** — A stiffer spring (larger k) provides a stronger restoring force, raising the oscillation frequency.
The RESTORING force in an oscillator always points:	**toward the equilibrium position** — The restoring force pushes the system back toward equilibrium, driving the oscillation.
A mass–spring oscillator with MORE mass oscillates with a __ period:	**longer** — More mass has more inertia, slowing the oscillation and lengthening the period.
A larger amplitude in an ideal (small-angle) pendulum changes the period by:	**essentially nothing (period is independent of amplitude for small swings)** — For small swings, the period is independent of amplitude (isochronism) — a key property of SHM.
A common oscillation misconception is that a heavier pendulum bob swings with a longer period. Actually the period:	**does not depend on the bob's mass (for a simple pendulum)** — A simple pendulum's period depends on length and g, not the bob's mass.
Why is simple harmonic motion a foundational model in physics?	**many systems near equilibrium behave like SHM, making it broadly applicable** — Near a stable equilibrium, most systems approximate SHM, so it's a universal model across physics.
Energy in SHM transforms between:	**kinetic energy (at the center) and potential energy (at the extremes)** — SHM continually trades kinetic energy (fastest at center) and potential energy (stored at the extremes).
A frequency of 2 Hz corresponds to a period of:	**0.5 s** — T = 1/f = 1/2 = 0.5 s.
Simple harmonic motion (SHM) occurs when the restoring force is:	**proportional to the displacement from equilibrium** — SHM arises when the restoring force is proportional to (and opposite) the displacement (like an ideal spring).
Frequency and period are related by:	**f = 1/T** — Frequency is the reciprocal of the period: f = 1/T.
DAMPING in a real oscillator causes the:	**amplitude to decrease over time** — Damping (like friction/air resistance) gradually reduces the amplitude, eventually stopping the oscillation.
A stiffer spring stores __ elastic potential	**more** — A larger spring constant means more restoring force and

energy for the same stretch:	more stored energy for a given stretch.
In SHM, the speed of the oscillator is greatest at the:	**equilibrium position (center)** — The oscillator moves fastest as it passes through equilibrium, where all energy is kinetic.
At the extremes of oscillation, the restoring force is:	**maximum** — At maximum displacement the restoring force is largest (it's proportional to displacement).
An OSCILLATION is a motion that:	**repeats back and forth around an equilibrium position** — Oscillations are repetitive back-and-forth motions about an equilibrium point (like a pendulum or spring).
FREQUENCY is:	**the number of cycles per second (the inverse of the period)** — Frequency $f = 1/T$ counts cycles per second, measured in hertz (Hz).
RESONANCE occurs when a system is driven at its:	**natural frequency, producing large-amplitude oscillations** — Driving a system at its natural frequency builds up large-amplitude oscillations — resonance.
The PERIOD of an oscillation is the time for:	**one complete cycle** — The period T is the time to complete one full oscillation cycle.
For an ideal pendulum (small swings), the period depends on:	**the length of the pendulum and gravity** — A pendulum's period depends on its length and g, not on the bob's mass or (for small swings) amplitude.
AMPLITUDE is the:	**maximum displacement from equilibrium** — Amplitude is how far the oscillator swings from its equilibrium position.
In SHM, the speed of the oscillator is ZERO at the:	**extremes (maximum displacement)** — At the turning points (maximum displacement), the oscillator momentarily stops before reversing.

12. Wave properties — wavelength, frequency, and speed

✂ Question (fold →)	Answer
If a wave's frequency doubles while its speed stays constant, its wavelength:	**halves** — v = fλ is fixed, so doubling f halves λ.
DIFFRACTION is the:	**spreading of a wave as it passes an edge or through an opening** — Diffraction is the bending/spreading of waves around obstacles or through gaps.
AMPLITUDE of a wave is related to its:	**energy (larger amplitude = more energy)** — Amplitude (the wave's height) reflects its energy — bigger amplitude carries more energy.
Waves are important across physics because they describe:	**light, sound, water waves, seismic waves, and more** — The wave model unifies light, sound, water, and seismic phenomena under shared properties.
A wave with frequency 5 Hz and wavelength 2 m has a speed of:	**10 m/s** — $v = f\lambda = 5 \times 2 = 10$ m/s.
A wave slows down and bends when it enters a new medium; this bending is:	**refraction** — Changing speed at a boundary bends the wave — refraction.
CONSTRUCTIVE interference occurs when two waves:	**align crest-to-crest, adding to a larger amplitude** — Crest meeting crest reinforces to a bigger wave — constructive interference.
The wave equation relating speed, frequency, and wavelength is:	**$v = f \cdot \lambda$** — Wave speed = frequency × wavelength ($v = f\lambda$).
When a wave bounces off a surface, this is called:	**reflection** — Reflection is a wave bouncing back from a boundary.
DESTRUCTIVE interference occurs when two waves:	**align crest-to-trough, canceling out** — Crest meeting trough cancels, reducing the amplitude — destructive interference.
The speed of a wave is determined mainly by the:	**medium it travels through** — Wave speed depends on the medium's properties; changing frequency changes wavelength to keep $v = f\lambda$.
The HIGHEST point of a transverse wave is called the:	**crest** — The crest is the highest point of a transverse wave; the trough is the lowest.
A LONGITUDINAL wave has its oscillation:	**parallel to the direction of wave travel** — In a longitudinal wave (like sound), the medium compresses and rarefies along the direction of travel.
WAVELENGTH is the:	**distance between two successive identical points (e.g. crest to crest)** — Wavelength is the length of one full wave cycle (crest to crest).
Light is an example of a __ wave:	**transverse (electromagnetic)** — Light is a transverse electromagnetic wave that needs no medium.
When a wave passes into a new medium and bends, this is called:	**refraction** — Refraction is the bending of a wave as it changes speed entering a new medium.
Why is the wave model one of the most powerful ideas in physics?	**the same wave properties ($v = f\lambda$, interference, refraction) describe vastly different phenomena** — A single set of wave principles explains light,

	sound, and more — a remarkable unification across physics.
FREQUENCY of a wave is the:	**number of wave cycles passing a point per second** — Frequency counts how many wave cycles pass per second (Hz).
When two waves overlap and combine, the result is called:	**interference** — Interference is the superposition of overlapping waves, adding constructively or destructively.
If wave speed is constant and frequency increases, the wavelength:	**decreases** — Since $v = f\lambda$ is fixed, a higher frequency means a shorter wavelength.
A common wave misconception is that waves carry matter along with them. Actually a wave in a medium:	**moves energy through the medium while the matter oscillates in place** — The medium's particles oscillate about fixed points; only energy propagates (e.g. a floating cork bobs but doesn't travel with the wave).
A TRANSVERSE wave has its oscillation:	**perpendicular to the direction of wave travel** — In a transverse wave (like light or a wave on a string), the medium moves perpendicular to the wave's motion.
The number of complete waves passing a point in one second is the:	**frequency** — Frequency counts full wave cycles per second.
The LOWEST point of a transverse wave is called the:	**trough** — The trough is the lowest point of a transverse wave.
A WAVE transfers __ without transferring matter:	**energy** — Waves carry energy through a medium (or space) without permanently moving the matter itself.

13. Sound — pitch, intensity, and resonance

✂ Question (fold →)	Answer
The LOUDNESS (intensity) of a sound is determined by its:	**amplitude** — Greater amplitude carries more energy, producing a louder sound.
Two sounds of the same pitch but different loudness differ in their:	**amplitude** — Same pitch means same frequency; the loudness difference is a difference in amplitude.
Sound is a __ wave:	**longitudinal (compressions and rarefactions)** — Sound travels as compressions and rarefactions of the medium along the direction of travel — a longitudinal wave.
A tuning fork produces a sound of a single, steady:	**frequency (pitch)** — A tuning fork vibrates at one natural frequency, producing a pure, steady pitch.
Why is sound a rich example of wave physics?	**it demonstrates frequency, amplitude, resonance, and the Doppler effect in everyday experience** — Sound makes abstract wave concepts (pitch, loudness, resonance, Doppler) tangible in daily life.
The intensity of sound is measured in:	**decibels (dB)** — Sound intensity/loudness is measured on the decibel (dB) scale.
A higher-frequency sound wave has a __ pitch:	**higher** — Higher frequency corresponds to higher perceived pitch.
Sound above the human hearing range is called:	**ultrasound** — Ultrasound is above ~20 kHz (used in medical imaging and by bats).
Understanding sound is essential in fields such as:	**music, medicine (ultrasound), and engineering (acoustics)** — Sound science underlies music, medical imaging, noise control, and communication.
A common sound misconception is that sound can travel through a vacuum (like in space movies). Actually:	**sound cannot travel through a vacuum — it needs a medium** — Without matter to compress, sound cannot propagate; space is silent.
Noise-canceling headphones work by producing a sound wave that:	**destructively interferes with the incoming noise** — They emit an 'anti-noise' wave out of phase with the noise, canceling it by destructive interference.
As the siren RECEDES, the pitch sounds:	**lower (waves stretched to lower frequency)** — A receding source stretches the waves, lowering the observed frequency (pitch).
The human hearing range is approximately:	**20 Hz to 20,000 Hz** — Humans typically hear from about 20 Hz to 20 kHz.
The PITCH of a sound is determined by its:	**frequency** — Higher frequency means higher pitch; lower frequency means lower pitch.
The echo you hear in a canyon is an example of sound:	**reflection** — An echo is sound reflecting off a distant surface and returning.
RESONANCE in a musical instrument occurs when:	**it vibrates strongly at its natural frequency** — Instruments are built to resonate at natural frequencies, amplifying particular notes.

Increasing a sound's amplitude while keeping frequency constant makes it:	**louder but the same pitch** — Amplitude affects loudness (not pitch), so a bigger amplitude is louder at the same pitch.
Echolocation (used by bats and sonar) works by:	**emitting sound and timing its reflection to locate objects** — Emitting sound and timing the echo reveals the distance and location of objects.
The DOPPLER effect describes the change in observed __ as a sound source moves:	**frequency (pitch)** — The Doppler effect shifts the observed frequency (pitch) up as a source approaches and down as it recedes.
Sound requires a __ to travel:	**medium (like air, water, or solids)** — Sound needs matter to propagate; it cannot travel through a vacuum.
A siren sounds higher-pitched as it APPROACHES because the sound waves are:	**compressed to a higher frequency** — An approaching source compresses the waves, raising the observed frequency (pitch).
Sound generally travels FASTEST in:	**solids** — Tightly packed particles in solids transmit sound faster than in liquids or gases.
Sound travels SLOWEST in:	**gases** — Widely spaced gas particles transmit sound more slowly than liquids or solids.
The decibel scale is logarithmic, so a 10 dB increase corresponds to:	**a tenfold increase in sound intensity** — Each 10 dB step is a 10× increase in intensity — a logarithmic scale for a huge range.
Ultrasound imaging in medicine uses sound waves that are:	**above the human hearing range** — Ultrasound (above ~20 kHz) reflects off internal structures to form images safely.

14. Electric charge, current, and Ohm's law

✂ Question (fold →)	Answer
For a fixed voltage, increasing the resistance __ the current:	**decreases** — From I = V/R, more resistance means less current at a fixed voltage.
VOLTAGE (potential difference) is the:	**energy per charge that drives current** — Voltage is the electric potential difference (energy per unit charge) that pushes charges through a circuit.
A volt (V) measures electric:	**potential difference (voltage)** — The volt is the unit of potential difference (energy per charge).
The direction of an electric field is defined as the direction of the force on a:	**positive test charge** — By convention, the field points the way a positive test charge would be pushed.
A FUSE protects a circuit by:	**melting and breaking the circuit if the current gets too high** — A fuse breaks the circuit when excessive current would otherwise cause damage or fire.
RESISTANCE opposes the flow of current and is measured in:	**ohms (Ω)** — Resistance is measured in ohms; it opposes current flow.
In a series circuit, if one bulb burns out, the others:	**go out (the single loop is broken)** — A break anywhere in a single series loop stops the current everywhere.
A device that stores electric charge is a:	**capacitor** — A capacitor stores charge (and energy) in an electric field between its plates.
Why are electric charge and current foundational to modern technology?	**controlling the flow of charge underlies all electronics, communication, and power systems** — Harnessing charge flow powers the entire electrical and electronic world.
Understanding circuits is essential because they:	**power virtually all modern electronics and appliances** — Electric circuits underlie phones, computers, lighting, and every electronic device.
Like electric charges __ and unlike charges __:	**repel; attract** — Like charges (both + or both −) repel; opposite charges attract.
A common circuit misconception is that current is 'used up' as it flows through components. Actually:	**current (charge) is conserved — the same current returns to the source in a series loop** — Charge is conserved; the current isn't 'used up' — energy is transferred, but the same current flows around a series loop.
Adding more resistors in SERIES increases the total resistance because:	**the current must pass through each one in turn** — Series resistors add up: the current faces each in sequence, so total resistance increases.
An ampere (A) measures electric:	**current** — The ampere is the unit of electric current (charge flow per second).
A 12 V battery across a 4 Ω resistor drives a current of:	**3 A** — I = V/R = 12/4 = 3 A.
Adding resistors in PARALLEL __ the total resistance:	**decreases** — Parallel resistors give more paths for current, lowering the total resistance below the smallest branch.
For a fixed resistance, increasing	**increases** — From I = V/R, more voltage drives more current at a fixed

the voltage __ the current:	resistance.
An INSULATOR resists the flow of charge because its charges are:	**tightly bound (not free to move)** — Insulators hold their charges tightly, so current does not flow easily.
Electric CURRENT is the:	**flow of electric charge** — Current is the rate of flow of electric charge, measured in amperes.
A conductor allows charge to flow easily because it has:	**many free (mobile) charges** — Conductors (like metals) have mobile electrons that carry current easily.
Ohm's law relates voltage, current, and resistance as:	**V = I·R** — Voltage = current × resistance (V = IR).
An electric FIELD around a charge:	**exerts a force on other charges placed in it** — An electric field represents the force a charge would feel at each point in space.
Electrical POWER dissipated by a device is given by:	**P = V·I (voltage × current)** — Power = voltage × current (P = VI); it measures the rate of energy transfer.
In a SERIES circuit, the current is:	**the same through every component** — In a single series loop, the same current flows through every component.
In a PARALLEL circuit, the voltage across each branch is:	**the same** — Each parallel branch has the full source voltage across it.

15. Magnetism and electromagnetic induction

✂ Question (fold →)	Answer
Moving a magnet in and out of a coil of wire will:	**induce a current in the coil** — The changing field as the magnet moves induces a current in the coil (the basis of generators).
Most of the world's electricity is generated by using motion to:	**induce a current via changing magnetic flux** — Turbines spin coils in magnetic fields, inducing current — the basis of nearly all power generation.
A GENERATOR converts __ energy into electrical energy:	**mechanical (motion)** — A generator uses mechanical motion to change magnetic flux through coils, inducing electricity.
A compass needle points north because it:	**aligns with Earth's magnetic field** — A compass is a small magnet that aligns with Earth's magnetic field, indicating direction.
The relationship between electricity and magnetism is called:	**electromagnetism** — Electricity and magnetism are unified as electromagnetism — moving charges make fields, changing fields make currents.
Wireless charging pads work using:	**electromagnetic induction between coils** — A changing field in the pad's coil induces current in the device's coil — induction without wires.
An electromagnet is made by:	**running current through a coil of wire (often around iron)** — Current through a coil creates a magnetic field; an iron core strengthens it — a controllable electromagnet.
Electromagnetic INDUCTION is the production of a current by a:	**changing magnetic field** — A CHANGING magnetic field (Faraday's law) induces a voltage and current in a nearby conductor.
Every magnet has:	**two poles (north and south)** — Magnets are dipoles with a north and a south pole.
Faster motion of a magnet through a coil induces a __ current:	**larger** — A faster-changing magnetic flux induces a larger current (Faraday's law).
The region around a magnet where its force acts is the:	**magnetic field** — A magnetic field is the region where magnetic forces act, represented by field lines from N to S.
The link 'moving charges make magnetic fields, and changing magnetic fields make currents' describes:	**the two-way connection of electromagnetism** — Electricity and magnetism each produce the other — the symmetric heart of electromagnetism.
A wire carrying current in a magnetic field experiences a:	**force (perpendicular to both the current and the field)** — A current-carrying wire in a magnetic field feels a force perpendicular to both — the motor principle.
A power plant's turbine turning a generator is an application of:	**electromagnetic induction** — The turbine spins the generator's coils in a magnetic field, inducing electricity.
A common misconception is that a steady (unchanging) magnetic field induces a current. Actually a current is induced only by a:	**changing magnetic field (or changing flux)** — Only a CHANGE in magnetic flux induces a current; a static field does not.
	the deep link between electricity and magnetism powers generators,

Why is electromagnetism one of the pillars of modern physics and technology?	**motors, light, and communication** — Electromagnetism unified electricity, magnetism, and light, enabling the technologies that define the modern world.
A moving electric charge (a current) creates a:	**magnetic field** — An electric current produces a magnetic field around it — the link between electricity and magnetism.
Like magnetic poles __ and unlike poles __:	**repel; attract** — Like poles (N–N or S–S) repel; unlike poles (N–S) attract — like electric charges.
An electric MOTOR converts electrical energy into:	**mechanical (motion) energy** — A motor uses the force on a current in a magnetic field to produce motion — the reverse of a generator.
Magnetic field lines point from a magnet's __ pole to its __ pole (outside the magnet):	**north; south** — Outside a magnet, field lines run from the north pole to the south pole.
The discovery that electricity and magnetism are linked led to:	**generators, motors, and modern power and communication technology** — Understanding electromagnetism enabled electric generators, motors, radio, and the entire electrical age.
A TRANSFORMER uses induction to:	**change the voltage of an alternating current** — Transformers use changing magnetic flux between coils to step voltage up or down for power transmission.
Induction underlies electricity generation because it lets us:	**convert mechanical motion (from steam, wind, or water) into electric current** — Nearly all electricity is generated by inducing current from mechanical motion — the heart of power plants.
If you cut a bar magnet in half, you get:	**two smaller magnets, each with a north and south pole** — You cannot isolate a single pole; cutting a magnet just makes two smaller dipoles.
Earth itself acts like a giant:	**magnet (with magnetic poles)** — Earth generates a magnetic field, acting like a huge magnet that compasses respond to.

16. Capstone — integrating forces and energy on real systems

✂ Question (fold →)	Answer
Conservation of ENERGY lets you find a final speed from a height change without:	**tracking the detailed forces along the path** — For conservative forces, only the endpoints (heights) matter — energy conservation bypasses the path details.
The net force on an object determines its:	**acceleration (F = ma)** — Newton's second law: the net force divided by mass gives the acceleration.
If a problem gives colliding masses and velocities, the most efficient tool is usually:	**conservation of momentum** — A collision with given masses and velocities is a momentum-conservation problem.
If a problem gives you a height and asks for a final speed, the most efficient tool is usually:	**conservation of energy** — A height-and-speed problem is naturally solved with energy conservation (PE ↔ KE).
To predict a system's motion, the first step is usually to:	**identify all the forces acting (draw a free-body diagram)** — Identifying every force and finding the net force is the foundation for predicting motion (F = ma).
Checking that a predicted answer's UNITS are correct is important because:	**wrong units reveal a setup error** — Verifying units (dimensional analysis) is a quick sanity check that catches many setup mistakes.
Energy and momentum are BOTH conserved in an isolated system, but they are:	**different quantities that give different information** — Energy (a scalar) and momentum (a vector) are distinct conserved quantities — using both can fully solve a problem.
Why does physics let us predict and engineer the physical world so powerfully?	**because matter obeys consistent laws of force, energy, and momentum we can quantify** — Consistent, quantifiable laws (Newton's laws, conservation of energy and momentum) make the physical world predictable and engineerable.
Predicting whether a car can safely round a curve involves:	**the centripetal force available from friction** — The maximum friction sets the centripetal force available, determining the safe cornering speed.
A roller coaster's speed at the bottom of a hill can be found using:	**conservation of energy (PE → KE)** — The potential energy at the top converts to kinetic energy at the bottom — an energy-conservation problem.
Choosing whether to use forces, energy, or momentum depends on:	**what the problem asks and what information is given** — A skilled physicist picks the most efficient principle (Newton's laws, energy, or momentum) for the given situation.
Conservation of MOMENTUM lets you predict the outcome of a collision without:	**knowing the complex internal forces during the impact** — Momentum conservation relates before and after directly, avoiding the messy internal collision forces.
The 'predict–observe–explain' habit in physics means you:	**predict the outcome, run/observe the system, then reconcile any surprise** — Predicting before observing — then explaining discrepancies — creates the cognitive conflict that dislodges misconceptions.
Combining Newton's laws with energy conservation lets	**analyze systems too complex for one principle alone** — Complex problems often need forces AND energy (or momentum) together — the full toolkit.

you:	
A simulated physics sandbox lets you:	**safely test predictions and see the consequences of changing variables** — A simulation supports safe, repeatable predict–observe–explore of how systems respond to changes.
A projectile problem integrates:	**vectors, kinematics, and (sometimes) energy** — Projectiles combine vector decomposition, kinematics, and often energy conservation.
Analyzing a real machine, an engineer must account for energy lost to:	**friction and heat (real inefficiencies)** — Real machines lose energy to friction and heat, so useful output is less than input — though total energy is conserved.
Real systems differ from idealized models mainly because of:	**friction, air resistance, and other neglected effects** — Idealized models neglect friction and air resistance; real results differ because of these effects.
Reasoning responsibly about a physics model means acknowledging that predictions:	**rely on assumptions (ideal conditions) and may differ from messy reality** — Good physics states the assumptions (frictionless, no air resistance) and expects real results to vary.
The overarching goal of physics as ForceForge presents it is to:	**predict and explain how physical systems behave using a few powerful laws** — Physics uses a small set of laws (forces, energy, momentum) to predict and explain the behavior of the physical world.
The outcome of a collision between two carts is best found using:	**conservation of momentum** — Momentum conservation predicts the post-collision velocities in a closed system.
A pendulum's motion combines ideas from:	**forces (restoring force), energy (KE↔PE), and oscillation** — A pendulum integrates a restoring force, energy exchange, and oscillation — several topics at once.
The single most important reasoning habit ForceForge builds is to:	**predict what a system will do, then run it and reconcile the result** — Predict-then-reconcile is the habit that turns physics procedures into genuine conceptual understanding.
A key habit of a good physicist is to PREDICT before calculating so that:	**a wrong calculation is caught by an unexpected result** — A prior prediction gives a reasonableness benchmark — a surprising result flags a possible error.
A good first sanity check on any physics answer is whether it:	**has reasonable units and a sensible size** — Checking units and rough magnitude quickly catches errors before trusting a result.

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