P5 Forces

What's the science story?

Engineers analyse forces when designing a great variety of machines and instruments, from road bridges and fairground rides to atomic force microscopes. Anything mechanical can be analysed in this way. Recent developments in artificial limbs use the analysis of forces to make movement possible.

Previous knowledge:

Year 7 Forces 1 – The basics

· forces as pushes or pulls, arising from the interaction between 2 objects

· using force arrows in diagrams, adding forces in 1 dimension, balanced and unbalanced forces

· moment as the turning effect of a force

· forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction

between surfaces, with pushing things out of the way; resistance to motion of air and water

· forces measured in newtons, measurements of stretch or compression as force is changed

Year 8 Pressure

· atmospheric pressure, decreases with increase of height as weight of air above decreases with height · pressure in liquids, increasing with depth; upthrust effects, floating and sinking · pressure measured by ratio of force over area – acting normal to any surface

Speed · speed and the quantitative relationship between average speed, distance and time (speed = distance ÷ time) · the representation of a journey on a distance-time graph · relative motion: trains and cars passing one another

Year 9 Forces 2

opposing forces and equilibrium: weight held by stretched spring or supported on a compressed surface · force-extension linear relation; Hooke's Law as a special case · work done and energy changes on deformation · non-contact forces: gravity forces acting at a distance on Earth and in space, forces between magnets, and forces due to static electricity

Keywords

Vector
Balanced
scalar
unbalanced
work

KS4 P5 Forces

vector

arrow

contact

non-contact

weight

mass

gravity

gravitational field

gravitational field strength

newtons

kilograms

centre of mass

newton meter

equation

joule

newton-metre

frictional forces

temperature

compressing

stationary

elastic

deformation

running

cycling

equation

non-uniform

scalar

displacement

vector

speed

average

walking

resultant
stationary
uniform
resistive
driving
interact
reaction-action
balanced
inertia

acceleration

resultant force

mass

inversely proportional

equation

estimate

inertial mass

ratio

Stopping distance

Thinking distance

Braking distance

Reaction time

road

vehicle

work

temperature

deceleration

estimate

inelastic

directly proportional
limit of proportionality

spring constant

extension

newton

elastic potential energy

work

linear

non-linear

Working scientifically skills:

WS1	Scientific methods
WS2	Draw/Interpret diagrams
WS3	Make predictions
WS8	Method
WS9	Variables
WS10	Selecting equipment
WS11	Hazards
WS12	Errors
WS13	Constructing tables
WS14	Graphs
WS15	Data
WS16	Using equations
WS17	Make conclusions
WS18	Converting units
WS19	Prefixes and powers

Assessments:

End of unit test (summative)
Exit tickets x 2/3 (formative)

- **Forces**
- **Acceleration 1**
- **Acceleration 2**

Lesson No. and Title	Learning objectives	AQA Specification	Practical equipment

1. Describing forces	4 – To say the difference between scalar and vector quantities 6 – To categorise forces as contact or non-contact 8 – To describe the interactions between pairs of objects which produce a force on each object	**6.5.1.1 Scalar and vector quantities** **Content** Scalar quantities have magnitude only. Vector quantities have magnitude and an associated direction. A vector quantity may be represented by an arrow. The length of the arrow represents the magnitude, and the direction of the arrow the direction of the vector quantity. **6.5.1.2 Contact and non-contact forces** **Content** A force is a push or pull that acts on an object due to the interaction with another object. All forces between objects are either: • contact forces – the objects are physically touching • non-contact forces – the objects are physically separated. Examples of contact forces include friction, air resistance, tension and normal contact force. Examples of non-contact forces are gravitational force, electrostatic force and magnetic force. Force is a vector quantity. Students should be able to describe the interaction between pairs of objects which produce a force on each object. The forces to be represented as vectors.	Demo https://spark.iop.org/introduction-electric-forces

2. Gravity	4 – Describe the difference between weight and mass. (A01) 5 – Give factors that determine the weight of an object. (A01) 6 – Calculate weight of an object by recalling the formula. (A02)	**6.5.1.3 Gravity** **Content** Weight is the force acting on an object due to gravity. The force of gravity close to the Earth is due to the gravitational field around the Earth. The weight of an object depends on the gravitational field strength at the point where the object is. The weight of an object can be calculated using the equation: weight = mass × gravitational field strength [$W = m\,g$] weight, *W*, in newtons, N mass, *m*, in kilograms, kg gravitational field strength, *g*, in newtons per kilogram, N/kg (In any calculation the value of the gravitational field strength (*g*) will be given.) The weight of an object may be considered to act at a single point referred to as the object's 'centre of mass'. The weight of an object and the mass of an object are directly proportional. Weight is measured using a calibrated spring-balance (a newtonmeter).	demo: large mass, newtonmeter that can measure force of large mass, large displacement can the mass can fit in, beaker to collect water from displacement can, balance class prac: selection of objects with masses labelled, newtonmeters

3. Resultant forces	4 – Calculate the resultant of two forces that act in a straight line Higher – Show how a single force van be resolved into two components acting at right angles to each other Higher – Use vector diagrams to illustrate resolution of forces and equilibrium situations	6.5.1.4 Resultant forces **Content** A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force. Students should be able to calculate the resultant of two forces that act in a straight line. (HT only) Students should be able to: • describe examples of the forces acting on an isolated object or system • use free body diagrams to describe qualitatively examples where several forces lead to a resultant force on an object, including balanced forces when the resultant force is zero. (HT only) A single force can be resolved into two components acting at right angles to each other. The two component forces together have the same effect as the single force. (HT only) Students should be able to use vector diagrams to illustrate resolution of forces, equilibrium situations and determine the resultant of two forces, to include both magnitude and direction (scale drawings only).	

4. Work done and energy transfer	4 – Say when work is done and describe the energy transfer involved 6 – Apply the equation for work done	**6.5.2 Work done and energy transfer** **Content** When a force causes an object to move through a distance work is done on the object. So a force does work on an object when the force causes a displacement of the object. The work done by a force on an object can be calculated using the equation: work done = force × distance (moved along the line of action of the force) [$W = F s$] work done, W, in joules, J force, F, in newtons, N distance, s, in metres, m One joule of work is done when a force of one newton causes a displacement of one metre. 1 joule = 1 newton-metre Students should be able to describe the energy transfer involved when work is done. Students should be able to convert between newton-metres and joules. Work done against the frictional forces acting on an object causes a rise in the temperature of the object.	

5. Forces and elasticity	4 – Use diagrams to show the forces involved in stretching , bending or compressing an object 5 – Make a spring and use an equation to calculate its spring constant 6 – Calculate how much work a spring does and its elastic potential energy	Students should be able to: • give examples of the forces involved in stretching, bending or compressing an object • explain why, to change the shape of an object (by stretching, bending or compressing), more than one force has to be applied – this is limited to stationary objects only • describe the difference between elastic deformation and inelastic deformation caused by stretching forces. The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.	wire to make homemade newtonmeter – the wire must be thin enough to make a spring that will be stretched by 10g and thick enough to not get deformed by at least 50g 10 x 10g masses

		force = *spring constant* × *extension* $[F = k\,e]$ force, F, in newtons, N spring constant, k, in newtons per metre, N/m extension, e, in metres, m This relationship also applies to the compression of an elastic object, where 'e' would be the compression of the object. A force that stretches (or compresses) a spring does work and elastic potential energy is stored in the spring. Provided the spring is not inelastically deformed, the work done on the spring and the elastic potential energy stored are equal. Students should be able to: • describe the difference between a linear and non-linear relationship between force and extension • calculate a spring constant in linear cases • interpret data from an investigation of the relationship between force and extension • calculate work done in stretching (or compressing) a spring (up to the limit of proportionality) using the equation: *elastic potential energy* = 0.5 × *spring constant* × $(extension)^2$ $[E_e = \frac{1}{2}k\,e^2]$ Students should be able to calculate relevant values of stored energy and energy transfers.	

6. RP 18 force and spring extension	4 – Describe the relationship between force applied and extension of a spring 6 – Accurately measure spring extension and plot on a line graph. Draw a straight line of best fit.		RP 18 equipment
7. Speed and velocity	4 – Recall typical values of speed for walking, running, cycling, sound and transportation systems 5 – Categorise displacement, distance, velocity and speed as vector or scaler quantities 6 – Calculate speed and distance using an equation	Distance is how far an object moves. Distance does not involve direction. Distance is a scalar quantity. Displacement includes both the distance an object moves, measured in a straight line from the start point to the finish point and the direction of that straight line. Displacement is a vector quantity. Students should be able to express a displacement in terms of both the magnitude and direction. $distance\ travelled = speed \times time$ $[\ s = v\ t\ ]$ distance, s, in metres, m speed, v, in metres per second, m/s time, t, in seconds, s Students should be able to calculate average speed for non-uniform motion. The velocity of an object is its speed in a given direction. Velocity is a vector quantity. Students should be able to explain the vector–scalar distinction as it applies to displacement, distance, velocity and speed. (HT only) Students should be able to explain qualitatively, with examples, that motion in a circle involves constant speed but changing velocity. Speed does not involve direction. Speed is a scalar quantity. The speed of a moving object is rarely constant. When people walk, run or travel in a car their speed is constantly changing. The speed at which a person can walk, run or cycle depends on many factors including: age, terrain, fitness and distance travelled. Typical values may be taken as: walking - 1.5 m/s running - 3 m/s cycling - 6 m/s. Students should be able to recall typical values of speed for a person walking, running and cycling as well as the typical values of speed for different types of transportation systems. It is not only moving objects that have varying speed. The speed of sound and the speed of the wind also vary. A typical value for the speed of sound in air is 330 m/s. Students should be able to make measurements of distance and time and then calculate speeds of objects. For an object moving at constant speed the distance travelled in a specific time can be calculated using the equation:	Ticker timer investigation: ticker timer + tape Trolley investigation: trolley stopwatch board

8. Distance - time graphs	4 – Draw a distance-time graph 5 – Calculate an object's speed from a distance-time graph 6 – Calculate an accelerating object's speed at a particular point by drawing a tangent (higher)	If an object moves along a straight line, the distance travelled can be represented by a distance–time graph. The speed of an object can be calculated from the gradient of its distance–time graph. (HT only) If an object is accelerating, its speed at any particular time can be determined by drawing a tangent and measuring the gradient of the distance–time graph at that time. Students should be able to draw distance–time graphs from measurements and extract and interpret lines and slopes of distance–time graphs, translating information between graphical and numerical form. Students should be able to determine speed from a distance–time graph.	
9. Acceleration	4 – Draw velocity-time graphs 5 – Use two equations and a graph to calculate acceleration 6 – Use the area under the graph to calculate distance or displacement (Higher)	The average acceleration of an object can be calculated using the equation: $acceleration = \frac{change\ in\ velocity}{time\ taken}$ $\left[a = \frac{\Delta v}{t} \right]$ acceleration, a, in metres per second squared, m/s^2 change in velocity, Δv, in metres per second, m/s time, t, in seconds, s An object that slows down is decelerating. Students should be able to estimate the magnitude of everyday accelerations. The following equation applies to uniform acceleration: $(final\ velocity)^2 - (initial\ velocity)^2 = 2 \times acceleration \times distance$ $\left[v^2 - u^2 = 2\,a\,s \right]$ final velocity, v, in metres per second, m/s initial velocity, u, in metres per second, m/s acceleration, a, in metres per second squared, m/s^2 distance, s, in metres, m Near the Earth's surface any object falling freely under gravity has an acceleration of about 9.8 m/s^2. The acceleration of an object can be calculated from the gradient of a velocity–time graph. (HT only) The distance travelled by an object (or displacement of an object) can be calculated from the area under a velocity–time graph. Students should be able to: • draw velocity–time graphs from measurements and interpret lines and slopes to determine acceleration • (HT only) interpret enclosed areas in velocity–time graphs to determine distance travelled (or displacement) • (HT only) measure, when appropriate, the area under a velocity–time graph by counting squares.	

10. Newton's first and third laws	4 – Calculate resultant forces 5 – Apply Newton's first law to say whether an object is stationary, moving at a steady speed, accelerating or decelerating 5 – Apply Newton's third law to equilibrium situations	Whenever two objects interact, the forces they exert on each other are equal and opposite. Students should be able to apply Newton's Third Law to examples of equilibrium situations. Newton's First Law: If the resultant force acting on an object is zero and: • the object is stationary, the object remains stationary • the object is moving, the object continues to move at the same speed and in the same direction. So the object continues to move at the same velocity. So, when a vehicle travels at a steady speed the resistive forces balance the driving force. So, the velocity (speed and/or direction) of an object will only change if a resultant force is acting on the object. Students should be able to apply Newton's First Law to explain the motion of objects moving with a uniform velocity and objects where the speed and/or direction changes. (HT only) The tendency of objects to continue in their state of rest or of uniform motion is called inertia.	cup or beaker, index card, penny

11. Newton's second law	4 – Describe what acceleration is. (A01) 5 – Recall and use Newton's Second Law to explain scenarios. (A02) 6 – Use the formula relating force, mass and acceleration. (A02) 7 – HIGHER - Explain what inertial mass is. (A01)	Newton's Second Law: The acceleration of an object is proportional to the resultant force acting on the object, and inversely proportional to the mass of the object. As an equation: *resultant force = mass × acceleration* $F = m\,a$ force, *F*, in newtons, N mass, *m*, in kilograms, kg acceleration, *a*, in metres per second squared, m/s^2 (HT only) Students should be able to explain that: • inertial mass is a measure of how difficult it is to change the velocity of an object • inertial mass is defined as the ratio of force over acceleration. Students should be able to estimate the speed, accelerations and forces involved in large accelerations for everyday road transport. Students should recognise and be able to use the symbol that indicates an approximate value or approximate answer, -	
12.RP 19 Newton's 2nd law		**Required practical activity 19:** investigate the effect of varying the force on the acceleration of an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by a constant force.	see RP19 sheet

13. Braking Distances	4 – How are human reaction times measured? (A01) 5 – What are typical reaction times? (A01) 6 - What are the factors that effect the stopping time of a vehicle?	Specification The stopping distance of a vehicle is the sum of the distance the vehicle travels during the driver's reaction time (thinking distance) and the distance it travels under the braking force (braking distance). For a given braking force the greater the speed of the vehicle, the greater the stopping distance. The braking distance of a vehicle can be affected by adverse road and weather conditions and poor condition of the vehicle. Adverse road conditions include wet or icy conditions. Poor condition of the vehicle is limited to the vehicle's brakes or tyres. Students should be able to: • explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies, and the implications for safety • estimate how the distance required for road vehicles to stop in an emergency varies over a range of typical speeds. Reaction times vary from person to person. Typical values range from 0.2 s to 0.9 s. A driver's reaction time can be affected by tiredness, drugs and alcohol. Distractions may also affect a driver's ability to react. Students should be able to: • explain methods used to measure human reaction times and recall typical results • interpret and evaluate measurements from simple methods to measure the different reaction times of students • evaluate the effect of various factors on thinking distance based on given data. When a force is applied to the brakes of a vehicle, work done by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases. The greater the speed of a vehicle the greater the braking force needed to stop the vehicle in a certain distance. The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control. Students should be able to: • explain the dangers caused by large decelerations • (HT only) estimate the forces involved in the deceleration of road vehicles in typical situations on a public road.	
14. Momentum – HIGHER ONLY	6 – How is momentum calculated? (A02) 7 – How is momentum related to force and acceleration? (A01/2) 7 – What happens to momentum in collisions? (A01/2)	Momentum is defined by the equation: $momentum = mass \times velocity$ $p = m\,v$ momentum, p, in kilograms metre per second, kg m/s mass, m, in kilograms, kg velocity, v, in metres per second, m/s In a closed system, the total momentum before an event is equal to the total momentum after the event. This is called conservation of momentum. Students should be able to use the concept of momentum as a model to describe and explain examples of momentum in an event, such as a collision.	ramp, balance, masses, light gates with timers, trolleys that join on collision