

The displacement – velocity - time equation.

**s** = displacement travelled, in metres (m)

**v** = average velocity, in metres per second (m/s)

**t** = time taken for trip, in seconds (s)

Displacement is distance from beginning to end of journey in a ***straight line***. Since it is a vector, it also has direction eg right, north, or 53°.

This equation is only used when the velocity is ***constant***, or for an average velocity.

If the velocity is changing, use the area under a velocity – time graph to calculate displacement.

This equation governs the horizontal component of projectile motion, since **a** is constant (0 ms-2).

 

To calculate constant or average acceleration.

**a** = acceleration of object, in metres per second per second (m/s2)

**Δv** = change in velocity of object, in metres per second (m/s)

**t** = time for change in velocity to occur, in seconds (s)

Use this equation when the question gives you a change in velocity, rather than initial and final velocities.



The equation from National 5, rearranged.

Equation of motion without displacement **s**.

**v** = final velocity, in metres per second (m/s)

**u** = initial velocity, in metres per second (m/s)

**a** = average acceleration, in metres per second per second (m/s2)

**t** = time taken for trip, in seconds (s)

**v**, **u**, and **a** are ***vector*** quantities. **t** is a ***scalar*** quantity.

For projectiles, the link between horizontal and vertical motion is time, **t**.



Equation of motion without final velocity **v**.

**s** = displacement, in metres (m)

**u** = initial velocity, in metres per second (m/s)

**t** = time taken for trip, in seconds (s)

**a** = average acceleration, in metres per second per second (m/s2)

Remember: only the **t** is squared, not the **a**.



Equation of motion without time **t**.

**v** = final velocity, in metres per second (m/s)

**u** = initial velocity, in metres per second (m/s)

**a** = average acceleration, in metres per second per second (m/s2)

**s** = displacement, in metres (m)



Equation of motion without acceleration **a**.

**s** = displacement, in metres (m)

**u** = initial velocity, in metres per second (m/s)

**v** = final velocity, in metres per second (m/s)

**t** = time taken for trip, in seconds (s)

There is a fifth equation of motion, not in the data book, without initial velocity u:

 **s = vt - ½ at2**

To calculate the weight of an object.

**W** = weight of object, in Newton (N)

**m** = mass of object, in kilograms (kg)

**g** = gravitational field strength, in newton per kilogram (N/kg)

Weight is a ***force***. The weight of an object is the force on it due to gravitational pull. If an object weighs 100 N on Earth, it weighs 0 N in space (no gravity) and 16 N on the moon.

Gravitational field strength is the weight per unit mass of an object in the field. The value of g on Earth is 9.8 N/kg.

The mass of an object is the amount of matter in the object. The mass remains constant anywhere in the universe. An object with mass 10 kg on earth will have a mass of 10 kg in space and a mass of 10 kg on the moon.



The equation for Newton’s Second Law.

**F** = unbalanced force acting on body, in newton (N)

**m** = mass of body, in kilograms (kg)

**a** = acceleration of body, in metres per second per second (m/s2)

The unbalanced force is the resultant of all forces acting on a body.

Forces can change the shape, speed and direction of motion of an object.

When the force stays constant and the mass increases, the acceleration decreases.

When the mass stays constant and the force increases, the acceleration increases.



To calculate work done by a force.

**Ew** = work done, in joules (J) or newton metres (Nm)

**F** = force applied, in newton (N)

**d** = distance moved by force, in metres (m)

Work done is a measure of energy transferred.



To calculate change in gravitational potential energy.

**E**p = change in gravitational potential energy, in joules (J)

**m** = mass, in kilograms (kg)

**g** = gravitational field strength, in newton per kilogram (N/kg)

**h** = vertical height moved, in metres (m)

Gravitational potential energy is the energy required to move a mass upwards through a height.

It is also the energy transferred when an object drops though a height. In this case, the energy is usually converted to kinetic energy.

To calculate kinetic energy.

**E**k = kinetic energy of the body, in joules (J)

**m** = mass of the body, in kilograms (kg)

**v** = velocity of the body, in metres per second (m/s)

Kinetic energy is the energy possessed by moving objects.

Note: only the velocity is squared – not the mass!



To calculate the power of both mechanical and electrical systems.

**P** = power, in watts (W)

**E** = energy transferred, in joules (J)

**t** = time taken, in seconds (s)

Power is the energy transferred in one second.

Power can also be expressed in joules per second (J/s).

To calculate momentum.

p = momentum of object, in kilogram metre per second (kgm/s)

m = mass of object, in kilograms (kg)

v = velocity of object, in metres per second (m/s)

**The Law of Conservation of momentum**

When two bodies interact, in the absence of net external forces, the ***total*** momentum remains constant before and after the interaction.

 Total momentum before = total momentum after

m1u1 + m2u2 = m1v1 + m2v2

There are 2 types of collision: elastic & inelastic:

**elastic**: both momentum and kinetic energy are conserved

**inelastic**: momentum only is conserved. This usually occurs when the objects stick together after impact.



To calculate impulse.

F = unbalanced force acting on body, in newton (N)

t = time which unbalanced force acts for, in seconds (s)

m = mass of body, in kilograms (kg)

u = initial velocity of body, in metres per second (m/s)

v = final velocity of body, in metres per second (m/s)

The term Ft is the *impulse*. The term mv-mu is the effect of the impulse and is the change in momentum.

If re-arranged to F=(mv-mu)/t, the term (mv-mu)/t is the rate of change of momentum, and is another definition of force.

When the force is not constant, the size of the impulse can be found from the area under a Force – Time graph.



To calculate pressure.

P = pressure, in pascals (Pa) or (N/m2)

F = force normal to surface, in newton (N)

A = area over which force is exerted, in metres squared (m2)

One pascal is a force of one newton per square metre, when the force acts normal to the surface.



To calculate the pressure at a point in a fluid at rest.

P = pressure, in pascals (Pa) or (N/m2)

ρ = density of fluid, in kilogram per metre cubed (kg/m3)

g = gravitational field strength, in newton per kilogram (N/kg)

h = depth, in metres (m)

Pressure exerts a force equally in all directions.

The upthrust, or buoyancy force, of an object in a fluid is equal to the weight of fluid displaced. It is also related to the difference in pressure between the top and bottom of an object.

 Fu = ρgV

Fu = upthrust, or buoyancy force, in newton (N)

ρ = density of fluid, in kilogram per metre cubed (kg/m3)

g = gravitational field strength, in newton per kilogram (N/kg)

V = volume of object, in metres cubed (m3)

Explain why a buoyancy force acts on an object when it is submerged in a fluid.





The General Gas Law.

**P** = gas pressure, in pascals (Pa) or (N/m2)

**V** = volume of gas, in metres cubed (m3)

**T** = temperature of gas, in Kelvin (K)

The ***mass*** is kept constant.

K = °C + 273.15

At 0 K, or absolute zero, all particle motion stops. Particles have no energy, and this is the lowest possible temperature.

The kinetic theory of gas states that pressure is caused by very small particles bouncing elastically off surfaces. Their change in momentum **mv – mu** is transferred to the surface.

Use the kinetic model to explain the change in pressure as the temperature of a gas increases.

As temperature increases, the kinetic energy of the gas particles increases. {½}

The particles hit the wall of the container more often {½}

And with greater force. {½}

So the pressure increases. {½}

To calculate the amount of charge transferred in an electrical circuit.

**Q** = charge transferred, in coulombs (C)

**I** = current, in amperes (A)

**t** = time taken for charge to transfer, in seconds (s)

To calculate work done by a potential difference on a charge.

**W** = work done, in joules (J).

**Q** = charge, in coulombs (C)

**V** = potential difference, or voltage, in volts (V)

Field lines start at the positive point or plate, and finish on the negative point or plate. The direction of the lines indicates the force on a positive “test” charge placed in the field.

The pd between 2 points is a measure of the work done in moving one coulomb of charge between 2 points.

If 1 joule of work is done in moving 1 coulomb of charge between 2 points, then the pd between the points is 1 volt.

The equation for a non-ideal battery ie one with an internal resistance.

**E** = electromotive force of supply, or emf, in volts (V).

**V** = potential difference across supply, in volts (V).

**I** = current in circuit, in amperes (A).

**r** = internal resistance of supply, in ohms ( Ω).

The term **Ir** is known as the ***lost volts***, because it is the voltage lost inside the battery due to its internal resistance.

The emf of a source is the electrical potential energy supplied to each coulomb of charge which passes through the source. It is equal to the open circuit pd across its terminals.

V = IR stated as a conservation of energy equation.

 Σ E = sum of electromotive forces (emf), in volts (V)

Σ IR =sum of current, in amperes (A) x resistance, in ohms (Ω)

IR = is the pd across a component.

The sum off all the energies put into a closed circuit = the sum of all the energies taken out of the circuit.

To calculate the total resistance of resistances in series.

**RT** = total resistance of circuit, in ohms (Ω)

**R1** = resistance of first resistor, in ohms (Ω)

**R2** = resistance of second resistor, in ohms (Ω)

In a series circuit, the total resistance is the ***sum*** of the individual resistances.



R2

R1



To calculate the total resistance of resistors in parallel.

**RT** = total resistance of circuit, in ohms (Ω)

**R1** = resistance of first resistor, in ohms (Ω)

**R2** = resistance of second resistor, in ohms (Ω)



R2

R1

The equation for a balanced Wheatstone bridge.



**R1** = resistance of R1, in ohms (Ω)

**R2** = resistance of R2, in ohms (Ω)

**R3** = resistance of R3, in ohms (Ω)

**R4** = resistance of R4, in ohms (Ω)

The absolute values of the resistances are not important. Only their ratios count. A balanced bridge is when the pd across the terminals is 0 V. For small quantities, the out-of-balance pd is proportional to the change in resistance.



Also known as “Ohm’s Law” equation.

**V** = voltage across resistance, in volts (V)

**I** = current through resistance, in amperes (A)

**R** = resistance, in ohms (Ω)



To calculate electrical power.

**P** = power, in watts (W)

**V** = pd across resistance, in volts (V)

**I** = current through resistance, in amperes (A)

**R** = resistance, in ohms (Ω)

For alternating (sinusoidally varying) voltage:

**Vpeak** = amplitude of supply voltage, in volts (V)

**Vrms** = root mean square of peak voltage, in volts (V)

**Vrms** is also known as the ***effective voltage***.



Vrms, or
effective voltage

For alternating (sinusoidally varying) current:

**Ipeak** = amplitude of supply current, in amperes (A)

**Irms** = root mean square of peak current, in amperes (A)

**Irms** is also known as the ***effective current***. This would be the value of the direct current which would give the same effect.



The equation for capacitance.

**C** = capacitance of capacitor, in farads (F)

**Q** = charge “stored” in capacitor, in coulombs (C)

**V** = potential difference across capacitor, in volts (V)

One farad is a very large unit. Capacitance is usually measured in micro farads (μF) or even pico farads (pF).

Charge is not really stored in a capacitor: energy is. Charge is re-distributed from one plate to another. This creates a pd across the capacitor which opposed the supply pd.

The equation for energy stored in a capacitor:

**E** = energy stored in capacitor, in joules (J)

**Q** = charge “stored” in capacitor, in coulombs (C)

**V** = potential difference across capacitor, in volts (V)

**C** = capacitance of capacitor, in farads (F)

Work must be done to “charge” a capacitor because electrons are moved through a field against a pd. This energy stored is given by the area under the Q (charge) v V (pd) graph.

The Period equation.

**T** = period of wave, in seconds (s)

**f** = frequency of wave, in hertz (Hz)

**T** is the time taken for 1 complete wave to pass a point, in seconds (s).

Frequency = no of waves

 time taken

$ path difference=mλ$For **constructive** interference.

**path difference** = difference in length between 2 wave paths, in metres (m)

**m** = order of the maximum. This number has no units, and is an integer.

**λ** = wavelength, in metres (m).

The 2 waves will have the same wavelength, because they are **coherent**.



At the central, (zero order) maximum, n = 0, so the path difference = 0 m. (ie the 2 paths are the same length)

At the first order maximum, n = 1, so the path difference = λ

$$path difference$$

$=(m+\frac{1}{2} )λ$ For **destructive** interference.

**path difference** = difference in length between 2 wave paths, in metres (m)

**n** = order of the minimum. This number has no units, and is an integer.

**λ** = wavelength, in metres (m).

The order of the 2 central minima is n= 0.

So, at the first minimum (n = 0), the path difference = θ/2.

$d sinθ=mλ$ The Grating Equation.

**d** = separation of slits, in metres (m)

**θ** = angle from zero order to nth order maximum

**n** = order of the maximum. This number has no units, and is an integer.

**λ** = wavelength, in metres (m).

Angle **θ** is dependent on wavelength **λ**. So, the bigger the wavelength, the bigger the angle. Since red has a longer wavelength than blue, it deflects further.

Approximate wavelengths:

 Red: 700 nm

 Green: 540 nm

 Blue: 490 nm



To calculate the refractive index of a material.

**n** = refractive index of material (no units)

**θ1** = angle of incidence of ray in vacuum, in degrees (°)

**θ2** = angle of refraction of ray in material, in degrees (°)

The refractive index of a material will vary with the wavelength of the light passing through it. It is assumed that air is the same as a vacuum.

**n** is always larger than 1. So **θ1** is always the larger angle ie the angle in air.



The wave relationship between angle, wavelength, and velocity of a wave passing from one medium to another.

**θ1** = angle of incidence of ray in material 1, in degrees (°)

**θ2** = angle of refraction of ray in material 2, in degrees (°)

**θ1** = wavelength of ray in material 1, in metres (m)

**θ2** = wavelength of ray in material 2, in metres (m)

**v1** = velocity of ray in material 1, in metres per second (m/s)

**v2** = velocity of ray in material 2, in metres per second (m/s)

To calculate the critical angle for a material.

**θc** = critical angle of material, in degrees (°)

**n** = refractive index of material (no units)



The critical angle occurs when the angle of refraction = 90°.

When the angle of refraction θ1 = 90°, then **sinθ1** = 1, and **sinθ2** becomes the critical angle, θc.

**Θ1**

For Perspex, θc ~ 42°.

**Θc**



To calculate the irradiance of a ***point source*** on a surface.

**I** = irradiance of point source, in watts per square metre (W/m2)

**k** = constant

**d** = distance from point source, in metres (m)

Irradiance is the term used for the amount of light energy that falls on a surface.

When radiation is incident on a surface, irradiance is power per unit area.

The irradiance equation is more useful in the form on the left, when irradiance is compared at 2 distances.

The energy of a photon.

**E** = energy of photon, in joules (J)

**h** = Planck’s constant: 6.63 × 10-34 Js (found in data sheet at start of paper)

**f** = frequency of photon, in hertz (Hz)

Light with a higher frequency has a higher energy. So, blue light has more energy per photon than red light.

To calculate the irradiance of photons.

**I** = total irradiance of photons, in watts per square metre (W/m2)

**N** = number of photons, no units.

**h** = Planck’s constant: 6.63 × 10-34 Js (found in data sheet at start of paper)

**f** = frequency of photon, in hertz (Hz)

To calculate the kinetic energy of a photo-emitted electron.

**Ek** = kinetic energy of emitted electron, in joules (J)

**h** = Planck’s constant: 6.63 × 10-34 Js (found in data sheet at start of paper)

**f** = frequency of photon, in hertz (Hz)

**f0** = threshold frequency, in hertz (Hz)

**hf0** is the work function, in joules (J), and is the energy required by a photon to dislodge one electron from the surface of the material.

**f0** is the minimum frequency of EM radiation required in order to eject electrons from a particular material. It is dependent on the surface being irradiated.

Any amount of irradiation of a frequency less than **f0** will not dislodge any electrons. For frequencies > **f0**, the photoelectric current produced is directly proportional to irradiance at the surface

To calculate the frequency of photons absorbed or emitted by specific energy levels.

**W2** = energy of electron at higher energy level, in joules (J)

**W1** = energy of electron at lower energy level, in joules (J)

**h** = Planck’s constant: 6.63 × 10-34 Js (found in data sheet at start of paper)

**f** = frequency of photon, in hertz (Hz)

 

ground state

The equation for Einstein’s theory of special relativity.

**E** = energy released by reaction, in joules (J)

**m** = decrease in mass of substances, in kilograms (kg)

**c** = speed of light in vacuum (3x108 m/s)

This equation is used to calculate the energy created during a nuclear reaction.



The energy released is carried away as kinetic energy of the products.

Uncertainties.

The best estimate of a true value is calculated from the average of multiple readings. The ***random uncertainty*** is calculated using the equation on this card.

The ***scale reading uncertainty*** is calculated as follows:

analogue scale:

± half the least division of the scale.

digital scale:

± 1 in the least significant digit displayed.