Physical Quantities

Name _____ Date _____

By the end of this topic I can…

- recall the SI base quantities and units, and derive units of other quantities
- use metric prefixes and check equations for homogeneity
- distinguish scalars from vectors
- add vectors, and resolve a vector into perpendicular components

Units of measurement

Every physical quantity has a _____ and a _____. Scientists use the **SI** system (Système International).

SI base units

base quantity	base unit	symbol
mass	_____	_____
length	_____	_____
time	_____	_____
electric current	_____	_____
temperature	_____	_____
amount of substance	_____	_____

All other units are **derived units**, built from the base units.

Example 1.1 Give the SI base units of (a) speed, (b) acceleration, (c) force, (d) work done.

Metric prefixes

name	symbol	factor	name	symbol	factor
pico	_____	_____	kilo	_____	_____
nano	_____	_____	mega	_____	_____
micro	_____	_____	giga	_____	_____
milli	_____	_____	tera	_____	_____
centi	_____	_____	deci	_____	_____

Typical sizes: Earth's radius $\approx$ 6370 km; a human hair $\approx$ 60–90 μm; a water molecule $\approx$ 0.3 nm.

Homogeneity and dimensional analysis

An equation is **homogeneous** if the _____. A correct equation must be homogeneous (but a homogeneous equation is not necessarily correct: constants, signs and extra terms are not checked).

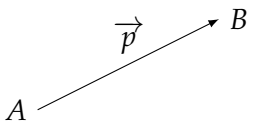
Pure numbers, π, the refractive index and the coefficient of friction are _____ (they have no units).

Example 1.2 A ball falls in vacuum, all its gravitational potential energy converts into kinetic energy. This is expressed by the equation: $mgh = \frac{1}{2}mv^2$. Show that this equation is homogeneous.

Example 1.3 The speed of a wave travelling along an elastic string is determined by three things: the tension T in the string, the length L of the string, and the mass m of the string. Let's assume $v = T^a L^b m^c$, where a, b, c are some numerical constants. Find the values of a, b and c.

Scalars and vectors

A **scalar** has _____; a **vector** has _____.



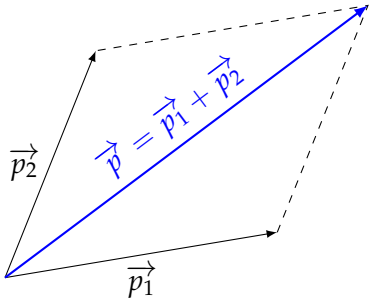
A vector drawn as an arrow from A to B.

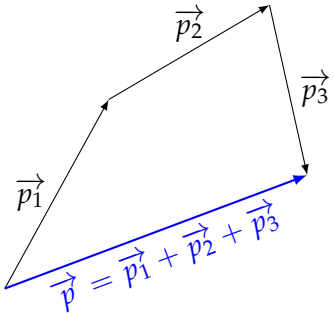
- scalars: time, distance, speed, mass, temperature, energy, density, volume
- vectors: _____, velocity, acceleration, force, field strength
- the arrow's _____ shows the magnitude and its _____ shows the direction

Adding vectors

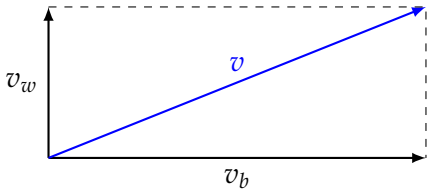
Scalars add like ordinary numbers; vectors need their directions taken into account. The sum is the **resultant**.

- **parallelogram rule**: the resultant lies along the _____ of the parallelogram formed by the two vectors
- **head-to-tail**: join the vectors one after another; the resultant joins the _____ to the _____

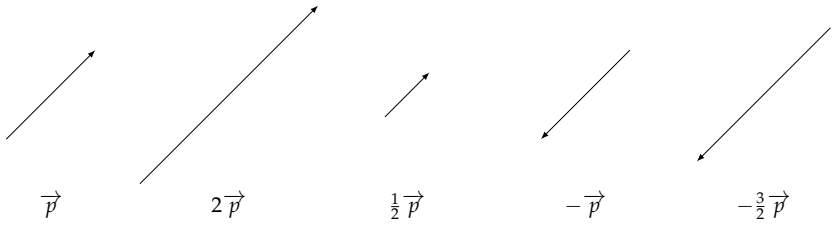




Example 1.4 A river flows from south to north at 2.0 m s^{-1}. A boat has a speed of 5.0 m s^{-1} relative to the water. (a) The boat heads due east from the west bank. What is its resultant velocity? (b) In what direction must it head to reach the point directly opposite?



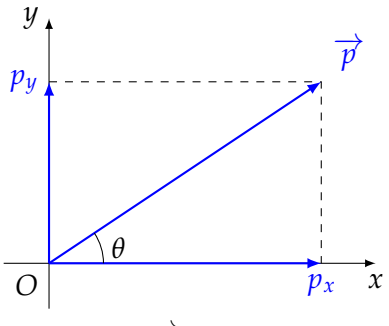
Multiplying a vector by a scalar



Multiplying by a positive number changes the _____ but not the direction. Multiplying by a negative number _____ the direction.

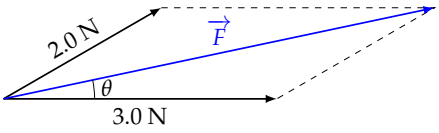
Resolving vectors

A vector can be split into two perpendicular components. For a vector p at angle θ to the x-axis:

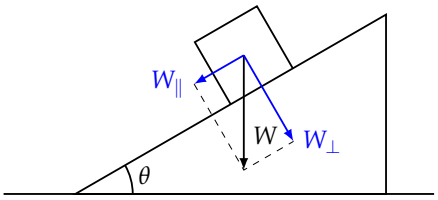


Resolving $\vec{p}$ into components.

and the magnitude and direction are recovered from



Example 1.5 A force of 3.0 N due east and a force of 2.0 N at 30° north of east act on an object. Find the magnitude and direction of the resultant force.



Example 1.6 A box of weight $W = 20.0$ N is resting on an inclined slope at 30° to the horizontal. Find the components of weight parallel to the slope and normal to the slope.

Practice questions

Question 1.1 What are the SI base units of (a) density, (b) pressure, (c) energy, (d) electric charge?

Question 1.2 For a substance of mass m, the heat energy Q needed to change its temperature by ΔT is given by: $Q = cm\Delta T$. Find the SI base units of the constant c.

Question 1.3 The resistive force F on a metal ball falling at low speeds in water is given by the equation $F = krv$, where r is the radius of the metal ball, v is its speed and k is a constant. Find the base units of k in the SI system.

Question 1.4 The speed of sound in air can be given by $c = \sqrt{\frac{\gamma p}{\rho}}$, where p is the pressure of the air and ρ is the air density. Show that γ is unit free.

Question 1.5 The effective power output from a wind turbine is given by the equation $P = \frac{1}{2}\eta\rho A v^n$, where ρ is the air density, A is the area of the turbine blades, and v is the wind speed. Given that η is a constant with no units, what is the value of n?

Question 1.6 Three forces of 5.0 N, 12 N and 13 N act at one point on an object. The angles at which the forces act can vary. What is the maximum and the minimum resultant force?