Q1.

1		kg m^{-3}	B1	
		frequency or count rate or activity or decay constant	B1	
		NC^{-1} or $V\ m^{-1}$ or kg m s^{-2} C^{-1} etc.	B1	
		momentum or impulse.....	B1	[4]
		(Allow solidus notation and non SI units)		

Q2.

1	(a)	scalar: magnitude only	B1	
		vector: magnitude and direction *(allow scalar with direction)*	B1	[2]
		(allow 1 mark for scalar has no direction, vector has direction)		
	(b)	diagram has correct shape	M1	
		with arrows in correct directions	A1	
		resultant = 13.2 ± 0.2 N *(allow 2 sig. fig)*	A2	[4]
		(for 12.8 → 13.0 and 13.4 → 13.6, allow 1 mark)		
		(calculated answer with a correct sketch, allow max 4 marks)		
		(calculated answer with no sketch – no marks)		
		Total		[6]

Q3.

3	(a)	(i)	scatter of points (about the line)	B1	
		(ii)	intercept (on t^2 axis)	B1	[2]
			(note that answers must relate to the graph)		
	(b)	(i)	gradient = $\Delta y / \Delta x$ = (100 – 0)/(10.0 – 0.6)	C1	
			gradient = 10.6 (cm s^{-2}) *(allow ±0.2)*	A1	[2]
			(Read points to within $\pm\frac{1}{2}$ square. Allow 1 mark for 11 cm s^{-2}		
			i.e. 2 sig fig, -1. Answer of 10 scores 0/2 marks)		
		(ii)	$s = ut + \frac{1}{2}at^2$	B1	
			so acceleration = 2 x gradient	B1	
			acceleration = 0.212 m s^{-2}	B1	[3]
			Total		[7]

Q4.

1	(a)	allow 100 m s^{-1} → 900 m s^{-1}	B1	[1]
	(b)	allow 0.5 kg m^{-3} → 1.5 kg m^{-3}	B1	[1]
	(c)	allow 5 g → 50 g	B1	[1]
	(d)	allow 2×10^3 cm^3 → 9×10^3 cm^3	B1	[1]

Q5.

1 **(a)** kg m s^{-2} B1 **[1]**

(b) kg m^{-1} s^{-1} B1 **[1]**

(c) **(i)** $v^2 = 2gs$
$= 2 \times 9.8 \times 4.5$ C1
$v = 9.4$ m s^{-1} A1 **[2]**

(ii) *either*
F $(= 3.2 \times 10^{-4} \times 1.2 \times 10^{-2} \times 9.4) = 3.6 \times 10^{-5}$ N M1
weight of sphere $(= mg = 15 \times 10^{-3} \times 9.8) = 0.15$ N M1
$3.6 \times 10^{-5} << 0.15$, so justified A1 **[3]**
or
$mg = crv_T$ (M1)
terminal speed $= 3.8 \times 10^4$ m s^{-1} (M1)
$9.4 << 3.8 \times 10^4$, so justified (A1)

Q6.

1 **(a)** **(i)** all positions (accept 20, 40, 60, 80) marked to within ±5° B2
positions are 40°, 70°, 90° and 102°
(-1 for each error or omission)

(ii) allow 107° → 113° B1 [3]

(b) e.g. more sensitive at low volumes B1 [1]
(do not allow reference to 'accuracy')

Q7.

1 **(a)** allow anything in range 20 Hz → 20 kHz B1 [1]

(b) allow anything in range 10 nm → 400 nm B1 [1]

(c) allow anything in range 10 g → 100 g B1 [1]

(d) allow anything in range 0.1 kg m^{-3} → 10 kg m^{-3} B1 [1]

Q8.

1 **(a)** **(i)** micrometer (screw gauge) / travelling microscope ..... B1 [1]

(ii) *either* ohm-meter *or* voltmeter and ammeter
or multimeter/avo on ohm setting ..... B1 [1]

(iii) *either* (calibrated) c.r.o. *or* a.c. voltmeter and × √2 ..... B1 [1]

(b) density = mass / volume C1
= 580 / 6^3 = 2.685 g cm^{-3} …(*allow 2.68, 2.69, 2.7*) A1

% uncertainty in mass = (10 / 580) × 100 = 1.7% C1
% uncertainty in volume = 3 × (0.1 / 6) × 100 = 5.0% C1
uncertainty in density = 0.18 g cm^{-3}
density = 2.7 ± 0.2 g cm^{-3} ..... A1 [5]
(*answer 2.69 ± 0.09 g cm^{-3} scores 4 marks*)

Q9.

1 **(a)** e.g. time (s), current (A), temperature (K), amount of substance (mol),
luminous intensity (cdl)
1 each, max 3 ..... B3 [3]

(b) density = mass / volume C1
unit of density: kg m^{-3} C1
unit of acceleration: m s^{-2} C1
unit of pressure: kg m^{-3} m s^{-2} m B1
kg m^{-1} s^{-2} ..... B1 [5]
(*allow 4/5 for solution in terms of only dimensions*)

Q10.

1 10^{-9} B1
c B1
mega B1
tera ..... B1 [4]

Q11.

2 **(a)** scalar B1
scalar B1
vector ..... B1 [3]

Q12.

1 **(a)** micrometer/screw gauge/digital callipers ..... B1 [1]

(b) **(i)** look/check for zero error ..... B1 [1]

(ii) take several readings M1
around the circumference/along the wire ..... A1 [2]

Q13.

1	(a)	(i)	1% of ±2.05 is ±0.02	A1	[1]
		(ii)	max. value is 2.08 V	A1	[1]
	(b)		there may be a zero error/calibration error/systematic error which makes all readings either higher or lower than true value	M1 A1	[2]

Q14.

1	(a)	(i)	metre rule / tape (*not 'rule'*)	B1	[1]
		(ii)	micrometer (screw gauge) / digital caliper	B1	[1]
		(iii)	ammeter and voltmeter / ohmmeter / multimeter on 'ohm' setting	B1	[1]
	(b)	(i)	resistivity = RA / L = $[7.5 \times \pi \times (0.38 \times 10^{-3})^2 / 4] / 1.75$ = $4.86 \times 10^{-7}\ \Omega$ m	C1 M1 A0	[2]
		(ii)	(uncertainty in R =) [0.2 / 7.5] × 100 = 2.7% and (uncertainty in L =) [3 / 1750] × 100 = 0.17% (uncertainty in A =) 2 × (0.01 / 0.38) × 100 = 5.3 % total = 8.13% uncertainty = 0.395×10^{-7} (Ω m) (*missing 2 factor in uncertainty in A, then allow max 3/4*)	C1 C1 C1 A1	[4]
	(c)		resistivity = $(4.9 \times 10^{-7} \pm 0.4 \times 10^{-7})\ \Omega$ m	A1	[1]

Q15.

2	(a)	(i)	base units of D: force: kg m s^{-2} radius: m velocity: m s^{-1} base units of D: $[F / (R \times v)]$ kg m s^{-2} / (m × m s^{-1}) = kg m^{-1} s^{-1}		B1 B1 M1 A0	[3]
		(ii)	1. $F = 6\pi \times D \times R \times v = [6\pi \times 6.6 \times 10^{-4} \times 1.5 \times 10^{-3} \times 3.7]$ $= 6.9 \times 10^{-5}$ N		A1	[1]
			2. $mg - F = ma$ hence $a = g - [F / m]$ $m = \rho \times V = \rho \times 4/3\ \pi R^3 = (1.4 \times 10^{-5})$ $a = 9.81 - [6.9 \times 10^{-5}] / \rho \times 4/3\ \pi \times (1.5 \times 10^{-3})^3$ (9.81 – 4.88) $a = 4.9(3)$ m s^{-2}		C1 M1 A1	[3]

Q16.

1 **(a)** 2nd row random, 3rd row neither, 4th row systematic all correct B2
two correct scores 1 only [2]

(b) **(i)** **1.** systematic error: the average / peak is not the true value / the readings are not centred around the true value B1 [1]

2. random error: readings have positive and negative values around the peak value / values are scattered / wide range B1 [1]

(ii) **1.** accurate: peak / average value moves towards the true value B1 [1]

2. precise: lines are closer together / sharper peak B1 [1]

Q17.

1 **(a)** **(i)** V units: m^3 (*allow metres cubed or cubic metres*) A1 [1]

(ii) Pressure units: $kg\,m\,s^{-2} / m^2$ (*allow use of* $P = \rho g h$) M1
Units: $kg\,m^{-1}\,s^{-2}$ A0 [1]

(b) V / t units: $m^3\,s^{-1}$ B1
Clear substitution of units for P, r^4 and l M1

$$C - \frac{\pi P r^4}{8 V t^{-1} l} - \frac{kg\,m^{-1}\,s^{-2}\,m^4}{m^3\,s^{-1}\,m}$$

Units: $kg\,m^{-1}\,s^{-1}$ A1 [3]
(*8 or* π *in final answer –1. Use of dimensions max 2/3*)

Q18.

1 **(a)** $\frac{V}{t} - \frac{\pi P r^4}{8 C l}$

$C = [\pi \times 2.5 \times 10^3 \times (0.75 \times 10^{-3})^4] / (8 \times 1.2 \times 10^{-6} \times 0.25)$ C1
$= 1.04 \times 10^{-3}\ N\,s\,m^{-2}$ A1 [2]

(b) $4 \times \%r$ C1
$\%C = \%P + 4 \times \%r + \%V/t + \%l$
$= 2\% + 5.3\% + 0.83\% + 0.4\%\ (= 8.6\%)$ A1
$\Delta C = \pm 0.089 \times 10^{-3}\ N\,s\,m^{-2}$ A1 [3]

(c) $C = (1.04 \pm 0.09) \times 10^{-3}\ N\,s\,m^{-2}$ A1 [1]

Q19.

(b) energy: N m / kg m^2 s^{-2} and volume m^3 C1
energy / volume: kg m^2 s^{-2} / m^3 M1
energy / volume: kg m^{-1} s^{-2} A0 [2]

(c) ε has no units B1
E: kg m s^{-2} m^{-2} M1
units of RHS: kg m^{-1} s^{-2} = LHS units / satisfactory conclusion to show C has no units A1 [3]

Q20.

1 **(a)** power = energy / time C1
= (force × distance / time) = kg m^2 s^{-2} / s C1
= kg m^2 s^{-3} A1 [3]

(b) **(i)** units of L^2: m^2 and units of ρ: kg m^{-3} and units of v^3: m^3 s^{-3} C1
($C = P / L^2 \rho v^3$) hence units of C: kg m^2 s^{-3} m^{-2} kg^{-1} m^3 m^{-3} s^3
or any correct statement of component units M1
argument /discussion / cancelling leading to C having no units A1 [3]

(ii) power available from wind = $3.5 \times 10^5 \times 100 / 55$ ($= 6.36 \times 10^5$) C1
$v^3 = 3.5 \times 10^5 \times 100 / (55 \times 0.931 \times (25)^2 \times 1.3)$ C1
v = 9.4 m s^{-1} A1 [3]

(iii) not all kinetic energy of wind converted to kinetic energy of blades B1
generator / conversion to electrical energy not 100% efficient / heat produced in generator / bearings etc B1 [2]
(there must be cause of loss and where located)

Q21.

1 **(a)** force: kg m s^{-2} A1 [1]

(b) **(i)** I^2: A^2 l: m x: m C1
K: kg m s^{-2} A^{-2} A1 [2]

(ii) curve of the correct shape (for inverse proportionality) M1
clearly approaching each axis but never touching the axis A1 [2]

(iii) curving upwards and through origin A1 [1]

Q22.

1	(a)	(i)	mass / volume …(ratio must be clear).....	B1	
		(ii)	$kg\ m^{-3}$ OR kg / m^3	B1	[2]
	(b)		v has unit of $m\ s^{-1}$	B1	
			p / ρ has unit of $kg\ m^{-1} s^{-2}$ / $kg\ m^{-3}$ (no e.c.f. from (a))	M1	
			$\sqrt{(p / \rho)}$ has unit of $m\ s^{-1}$	A1	
			LHS = RHS so γ has no unit	A0	[3]

Q23.

2	(a)	1.6 ± 0.2 cm	B1	[1]
	(b)	1.6 / 50 = 0.032 …(ignore any uncertainties).....	B1	[1]
	(c)	idea of adding fractional uncertainties	C1	
		(0.2 / 1.6) + (0.1 / 50)		
		= 0.127 OR 12.7% …(-2 marks if uncertainties not added)	A1	
		actual uncertainty = (±) 0.004	A1	[3]
		(do not allow more than 2 sig. fig)		

Q24.

1	(a)	(i)	e.g. check for zero error (on micrometer)/zero the micrometer	**B1**	
		(ii)	take readings along the length of the wire/at different points	**B1**	
		(iii)	take readings spirally/around the wire	**B1**	**[3]**
	(b)	(i)	4%	**A1**	
		(ii)	8%	**A1**	**[2]**

Q25.

1	(a)	(i)	force per unit area (ratio idea essential)	B1	
		(ii)	$kg\ m^{-1} s^{-2}$	B1	**[2]**
	(b)		ρ has base unit $kg\ m^{-3}$	B1	
			g has base unit $m\ s^{-2}$	B1	
			$h\rho g$ has base unit $m \times kg\ m^{-3} \times m\ s^{-2}$	M1	
			same as pressure QED	A0	**[3]**

Q26.

1 **(a)** systematic: e.g. constant error (in all readings)
cannot be eliminated by averaging
error in measuring instrument B1

random: e.g. readings scattered (equally) about true value
error due to observer
can be eliminated by averaging
(*only if averaging not included for systematic*) B1 [2]

(b) $15 = \pi \times R^2 \times 20$
$R = 0.4886$ cm (accept any number of s.f.) C1
% uncertainty in $V = 3.3$ % (or 0.5/15) C1
% uncertainty in $L = 0.5$ % (or 0.1/20) C1
% uncertainty in $R = 1.9$ % (i.e. one half of the sum) C1
$R = 0.489 \pm 0.009$ cm A1 [5]

Q27.

1 **(a)** **(i)** $Q = It$ (*allow any subject for the equation*) B1 [1]

(ii) I B1
t B1 [2]
(*allow 1 mark only if all three quoted*)

(b) **(i)** base unit of I is A
base unit of n is m^{-3} (*not* $/m^{-3}$)
base unit of S is m^2
base unit of q is A s (*not C*)
base unit of v is $m\ s^{-1}$
(*–1 for each error or omission*) B3 [3]

(ii) $A = m^{-3}\ m^2\ A\ s\ (m\ s^{-1})^k$ M1
e.g. for m: $0 = -3 + 2 + k$
$k = 1$ A1 [2]

Q28.

1 **(a)** **(i)** car uses 210 / 14 = 15 litres of fuel C1
volume reading = 45 litres ..... A1 [2]

(ii) from 'full' to '3/4' mark ..... B1 [1]

(b) **(i)** line/graph does not pass through ('empty, 0) / there is an intercept ..... B1 [1]
(*do not allow 'non-linear'*)

(ii) (meter shows zero fuel when there is some left in the tank so)
acts as a 'reserve' ..... B1 [1]

[Total: 5]

Q29.

1 **(a)** **(i)** *either* 1.55% *or* 1.6% …(not 1.5 or 2) ..... A1 [1]

(ii) *either* 1.09% *or* 1.1% …(not 1.0 or 1) ..... A1 [1]

(b) answer of {**(ii)** + 2 × **(i)**} to any number of sig. fig.
either 4.2% *or* 4.3% ..... A1 [1]

(c) **(i)** *either* the value has more significant figures than the data
or uncertainty of ±0.4 renders more than 2 s.f. meaningless) ..... B1 [1]

(ii) uncertainty in g = ±0.41 / ±0.42 to any number of s.f. C1
g = (9.8 ± 0.4) m s^{-2} ..... A1 [2]

[Total: 6]

Q30.

1 **(a)** length, current, temperature, amount of substance, (luminous intensity)
any three, 1 each B3 [3]

(b) **(i)** F: kg m s^{-2} B1
ρ: kg m^{-3} B1
v: m s^{-1} B1 [3]

(ii) some working e.g. kg m s^{-2} = m^2 kg m^{-3} (m s^{-1})^k M1
hence k = 2 A1 [2]

Q31.

1 **(a)** **(i)** scalar quantity has magnitude (allow size) B1
vector quantity has magnitude and direction B1 [2]

(ii) **1.** temperature: scalar B1 [1]
2. acceleration: vector B1 [1]
3. resistance: scalar B1 [1]

(b) *either* triangle / parallelogram with correct shape C1
tension = 14 .3 N (*allow ± 0.5 N*) A2 [3]

(*if > ±0.5 N but ≤ ±1 N, allow 1 mark*)
or R = 25 cos 35° (C1)
T = R tan 35° (C1)
T = 14.3 N (A1)
or T = 25 sin 35° (C2)
T = 14.3 N (A1)
or R and T resolved vertically and horizontally (C2)
leading to T = 14.3 N (A1)

Q32.

1 **(a)** allow 0.05 mm → 0.15 mm B1 [1]

(b) allow 0.25 s → 0.5 s B1 [1]

(c) allow 8 N → 12 N B1 [1]

ignore number of significant figures

Q33.

1 **(a)** spacing = 380 or 3.8×10^2 pm B1 [1]

(b) time = 24 × 3600
time = 0.086 (0.0864) Ms B1 [1]

(c) time = distance / speed = $\frac{1.5 \times 10^{11}}{3 \times 10^8}$ C1

= 500 (s) = 8.3 min A1 [2]

(d) momentum and weight B1 [1]

(e) **(i)** arrow to the right of plane direction (about 4° to 24°) B1 [1]

(ii) scale diagram drawn
or use of cosine formula $v^2 = 250^2 + 36^2 - 2 \times 250 \times 36 \times \cos 45°$
or resolving $v = [(36 \cos 45°)^2 + (250 - 36 \sin 45°)^2]^{1/2}$ C1

resultant velocity = 226 (220 – 240 for scale diagram) m s^{-1}
allow one mark for values 210 to 219 or 241 to 250 m s^{-1}
or use of formula (v^2 = 51068) v = 230 (226) m s^{-1} A1 [2]

Q34.

1 **(a)** kelvin / K B1
ampere / amp / A B1 [2]
[allow mole / mol and candela / Cd]

(b) **(i)** energy OR work = force × distance [allow any energy expression] C1
units: kg m s^{-2} × m OR kg (m s^{-1})^2 for ½ mv^2 or mc^2 M1
(ignore any numerical factor)
= kg m^2 s^{-2} A0 [2]

(ii) units: ρ: kg m^{-3} g: m s^{-2} A: m^2 l_0: m C1
C: kg m^2 s^{-2} / kg^2 m^{-6} m^2 s^{-4} m^2 m^3 [any subject] C1
= kg^{-1} m s^2 (allow m s^2 / kg) A1 [3]

Q35.

2 **(a)** $d = v \times t$ C1

$t = 0.2 \times 4$ (allow $t = 0.2 \times 2$) C1

$d = 3 \times 10^8 \times 0.8 \times 10^{-6}$ OR $3 \times 10^8 \times 0.4 \times 10^{-6}$ C1

$d = 240$ m hence distance from source to reflector = 120 m A1 [4]

(b) speed of sound 300 cf speed of light 3×10^8 OR time = 240 / 300 (= 0.8)
OR time = 120 / 300 (= 0.4) C1

sound slower by factor of 10^6 OR time for one division 0.8 / 4
OR time for one division 0.4 / 2 C1

time base setting 0.2 s cm^{-1} [unit required] A1 [3]

Q36.

2 **(a)** SI units for T: s, R: m and M: kg (or seen clearly in formula) C1

$K = T^2 M / R^3$ units: s^2 kg m^{-3} (allow s^2 kg / m^3 or $\frac{s^2 kg}{m^3}$) A1 [2]

(b) % uncertainty in K: 1% (for T) + 3% (for R) + 2% (for M) OR = 6% C1

$K = [(86400)^2 \times 6 \times 10^{24}] / (4.23 \times 10^7)^3 = 5.918 \times 10^{11}$ C1

6% of $K = 0.355 \times 10^{11}$ C1

$K = (5.9 \pm 0.4) \times 10^{11}$ (SI units) correct power of ten required for both A1 [4]
[incorrect % value then max. 1]