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 <u>low</u> 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 = $(10 / 580) \times 100 = 1.7\%$ C1
% uncertainty in volume = $3 \times (0.1 / 6) \times 100 = 5.0\%$ C1
uncertainty in density = 0.18 g cm^{-3}
density = 2.7 ± 0.2 g cm^{-3} .... A1 [5]
(*answer 2.69 $\pm$ 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 (cd)
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   M1
        which makes all readings either higher or lower than true value   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 C1
             = $[7.5 \times \pi \times (0.38 \times 10^{-3})^2 / 4] / 1.75$ M1
             = $4.86 \times 10^{-7} \, \Omega$ m   A0   [2]

       (ii) (uncertainty in R =) $[0.2 / 7.5] \times 100 = 2.7\%$
             and (uncertainty in L =) $[3 / 1750] \times 100 = 0.17\%$ C1
             (uncertainty in A =) $2 \times (0.01 / 0.38) \times 100 = 5.3\%$ C1
             total = 8.13%   C1

             uncertainty = 0.395×10^{-7} $(\Omega$ m)   A1   [4]
             (missing 2 factor in uncertainty in A, then allow max 3/4)

   (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: $\mathrm{kg\,m\,s^{-2}}$ B1
             radius: m   velocity: $\mathrm{m\,s^{-1}}$ B1

             base units of D: $[F / (R \times v)]$ $\mathrm{kg\,m\,s^{-2}} / (\mathrm{m} \times \mathrm{m\,s^{-1}})$ M1
             = $\mathrm{kg\,m^{-1}\,s^{-1}}$ A0   [3]

       (ii) 1. $F = 6\pi \times D \times R \times v = [6\pi \times 6.6 \times 10^{-4} \times 1.5 \times 10^{-3} \times 3.7]$
                 = 6.9×10^{-5} N   A1   [1]

             2. $mg - F = ma$ hence $a = g - [F / m]$
                 $m = \rho \times V = \rho \times 4/3 \, \pi \, R^3 = (1.4 \times 10^{-5})$ C1
                 $a = 9.81 - [6.9 \times 10^{-5}] / \rho \times 4/3 \, \pi \times (1.5 \times 10^{-3})^3$ (9.81 – 4.88)   M1
                 $a = 4.9(3) \, \mathrm{m\,s^{-2}}$ A1   [3]

Q16.

4

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 $P = \rho gh$*)   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) $\dfrac{V}{t} - \dfrac{\pi P r^4}{8 C l}$

      $C = [\pi \times 2.5 \times 10^3 \times (0.75 \times 10^{-3})^4] / (8 \times 1.2 \times 10^{-6} \times 0.25)$ 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 t: 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.

6

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 $= (\pm)\,0.004$ .... 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 > ±0.5N but ≤ ±1N, 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.

9

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 = $\dfrac{1.5 \times 10^{11}}{3 \times 10^8}$ 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 $\frac{s^2kg}{m^3}$)   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]