**1** **(a)** vernier callipers
zero error (do not accept parallax)

**(b)**
$$V = \pi\left(\frac{d^2}{4}\right)h$$
$$= 964.665\ \text{cm}^3$$
$$\frac{\Delta V}{V} = \frac{2\Delta d}{d} + \frac{\Delta h}{h}$$
$$\Delta V = \left(\frac{2\times 0.01}{8.50} + \frac{0.1}{17.0}\right)\times 964.665$$
$$= 8\ \text{cm}^3$$
$$V = (965 \pm 8)\ \text{cm}^3$$

**2(a)** Random errors are errors with different magnitudes and signs in repeated measurements, and can be reduced by taking the average of many readings.

Systematic errors are errors of measurements that occur according to some 'fixed rule or pattern' such that they yield a consistent over-estimation or under-estimation of the true value.

**(b)**
$$k = \frac{F}{e} = \frac{mg}{(x_2 - x_1)}$$
$$= \frac{0.020 \text{ x } 9.81}{(36.30 - 32.00)}$$
$$= 4.563\ \text{N m}^{-1}$$

$$\frac{\Delta k}{k} = \frac{\Delta m}{m} + \frac{\Delta e}{e}$$
$$= \frac{1}{20} + \frac{0.1}{4.3} = 0.073$$
$$\Delta k = 0.073 \text{ x } 4.563 = 0.3\ \text{N m}^{-1} \text{ (to 1 sf)}$$
Hence k = (4.6 ± 0.3) N m$^{-1}$

**(c)** Advantages of many sets of readings and drawing graph: (state any 3)
1. By drawing best fit line, random errors are reduced.
2. Systematic error can be spotted eg. if the F-e graph does not pass through origin.
3. Can spot erroneous points that are out of the trend.
4. Can check if the proportionality limit is exceeded eg. if the F-e graph turns into a curve instead of a straight line.

**3(a)(i)** $V = \frac{\pi}{6} \times d^3$, where $d$ = 22 cm (accept values from18 cm to 24 cm)

$\therefore V$ = 5.6 x $10^{-3}$ $m^3$ (accept values from 3.0 to 7.5 x $10^{-3}$ $m^3$ ); accept corresponding values if alternative units are used (e.g. $mm^3$ or $m^3$)

**3(a)(ii)** $KE = \frac{1}{2}mv^2$, where $v$ = 10 m $s^{-1}$ (accept values from 8 m $s^{-1}$ to 12 m $s^{-1}$) and mass = 60 kg (accept values from 40 kg to 100 kg)

$\therefore KE$ =3000 J (accept values from 1900 J to 7200 J); accept corresponding values if alternative units are used (e.g. kJ)

**(iii)** Density is between 800 to 1100 kg $m^{-3}$

**(b)(i)** **The values are close to each other but very far from the expected value** which should be less than density of water (1000 kg $m^3$).
Therefore, **set B** is precise but inaccurate.

**(b)(ii)**
- mass of beaker is included in the measurement of mass
- balance calibrated incorrectly
- negligence in zero-ing the weighing balance

(either one of the above)

**4 (a)** kg m $s^{-1}$ = [mass] × [velocity] = [momentum] or [impulse] [B1]

$$\text{electric field strength} = \frac{\text{electric force}}{\text{charge}}$$

$$\text{electric field strength} = \frac{\text{electric force}}{\text{charge}}$$

electric field strength = $[E] = \frac{[\text{mass}] \times [\text{acceleration}]}{[\text{current}] \times [\text{time}]}$

$$[E] = \frac{\text{kg m s}^{-2}}{\text{A s}}$$

$[E] = \text{kg m A}^{-1}\text{ s}^{-3}$ [B1]

**(b) (i)** Estimate the density of plastic to be 2 times that of water = 2 g $cm^{-3}$

Mass of protractor = (Volume) (Density)
Mass of protractor = ½ π $r^2$ x $\rho$
Mass of protractor = ½ π $(5.0)^2$ (0.1) (2)
Mass of protractor = 7.9 g

[M1] for logical reason. [A1] for acceptable range of 5 to 50 g

**(ii)** Micrometer Screw Gauge [B1]

**(iii)** Repeat the measurement of $x$ at different parts of the protractor and taking average. [B1]

**5a** Scalar: Magnitude and no direction (mass) B1

Vector: Magnitude and direction (weight) B1

**b**

$$\Delta V = B - A = B + (-A)$$

$$x: A_x + B_x = -10\sin 45° + 5\sin 35° = -4.2$$

$$y: A_y + B_y = -10\cos 45° - 5\cos 35° = -11.2$$ M1

$$\Delta V = \sqrt{4.2^2 + 11.2^2} = 11.9$$

$$a = \frac{11.9}{30} = 0.40$$

$$\theta = \tan^{-1}\frac{4.2}{11.2} = 20.6°$$ M1

Hence 0.40 m $s^{-2}$ at bearing of 201 A1

**6(a)** A systematic error is one that occurs consistently more or consistently less than the actual reading. [1]
A random error is one that gives a scatter of readings about a mean value. [1]

**(b)** Method 1:
Volume = $\pi(d/2)^2h = 40.46$ $cm^3$
$\Delta vol/vol = \Delta h/h + 2(\Delta d/d) = 0.0206$ [1]
$\Delta vol = (0.0206)(40.46) = 0.8$ $cm^3$ [1]

Method 2
$\Delta vol = 1$ cm3 (given by question)

Conclusion:
Method 1 has a $\Delta vol$ that has 1 more d.p. than Method 2 [1], hence Method 1 is more precise.

**7 (a)** Mass and temperature [1]

**(b) (i)** Base units of thermal energy = base units of energy [2]
= kg $ms^{-2}$ .m
= kg $m^2$ $s^{-2}$

**(ii)** Base units of the constant c (heat capacity) [2]
= base units of energy

(units of mass)(units of temperature)

$= \frac{\text{kg m}^2\ \text{s}^{-2}}{\text{kg.K}}$

$= \text{m}^2\ \text{s}^{-2}\ \text{K}^{-1}$

**8** **(a)** d/h = 394/450 = 0.876 ~ 0.90 [B1]
Since Chart No.49 has the correct $f_{cu}$, $f_y$ and $d/h$, Chart No.49 is appropriate to be used for this design. [B1]

**(i)** $M/bh^2 = 2.25$ [M1]
$N/bh = 27.3$ [M1
From Chart No.49,

$100A_{sc}/bh = 2.6$ [M2 - allow errors up to 0.05 i.e. $2.55 < x < 2.65$]
(If $100A_{sc}/bh = 2.7$ or 2.5, allocate only one mark)

**(ii)** Therefore, $A_{sc} = 2340\ \text{mm}^2$ [A1]
Provided four 32 mm reinforcement bars ~ 3220 $\text{mm}^2 > A_{sc}$, therefore the provided reinforcement steel is sufficient. [B1]

**(c)**

$N/bh > f_{cu}$ [B1]
Column would be crushed/break/crack. [B1]

**(d)**

At 12 metres, the column is too slender with respect to its dimension. Might twist and buckle under load. [B1, any of the underlined words]

**(e)**

From Chart No.39, corresponding $N/bh = 21.0$; allow $21.0 \pm 0.5$ [B1]
From Char No.49, corresponding $N/bh = 25.5$; allow $25.5 \pm 0.5$ [B1
Decrease in $N = 3.48bh$ kN
Percentage decrease of $N = 3.48/25.42 \times 100 = 13.7\%$ [M1 and A1; ecf allowed]

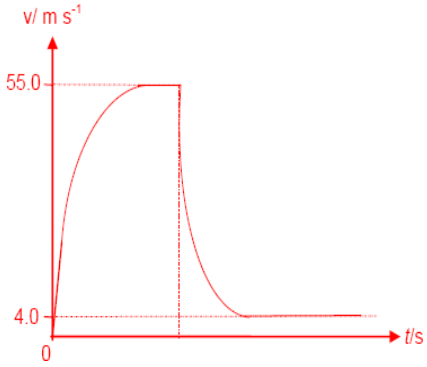
**9) (a) (i)**

$$[A] = \frac{(\text{kg m s}^{-\sim})\ \text{m}}{(\text{kg m s}^{-2}\ \text{m}^{-2})^2\ \text{m}\sqrt{(\text{kg m}^2\ \text{s}^{-2})}}\sqrt{\frac{\text{m}^{12}}{}} = m^8$$

**(ii)** percentage uncertainty introduces into the value of $Q$ = 4 x 0.02 / 2.05 x 100% = 3.90 %

**(b) (i)** *Peter's acceleration downwards decreases (or velocity increases at a decreasing rate), as the weight remains the same but the air resistance increases with increasing velocity, resulting in the net force downwards decreasing with time, till terminal velocity is reached when the weight is equal to the air resistance.*

**(ii)**




**(iii)** *The velocity is decreasing at a decreasing rate because the net force is upwards. However, as the net force upwards is decreasing with time, the deceleration is decreasing. Hence the gradient is getting less negative, until it is equal to 0 m s$^{-2}$ where terminal velocity is reached.*

**END**

1 **(a)** The acceleration of a body at any instant is defined as the time rate of change of velocity of the body at that instant.

**(b)**

$v_y^2 = u_y^2 + 2a\ s$

$0 = u_y^2 + 2(-9.81)(4.75 - 1.0 - 0.25)$ ↑ +ve

$u_y = 8.29\ m\ s^{-1}$

$\sin 75^o = \frac{8.29}{u} \quad \Rightarrow u = 8.58\ m\ s^{-1}$

(ii)

$s_y = u_y t + \frac{1}{2} a_y t^2$ ↑ +ve

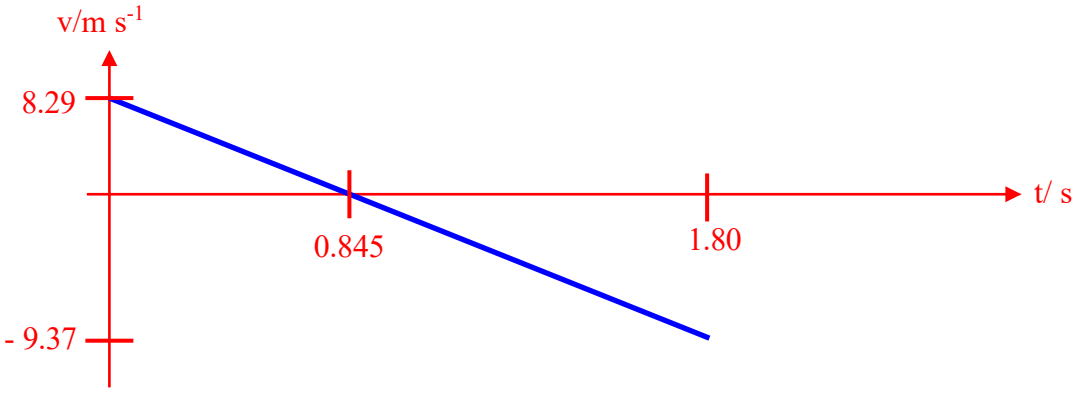
$-1.0 = (8.29)t + \frac{1}{2}(-9.81)t^2$

$t = 1.80\ s \text{ or } -0.113\ s\ (rej)$

$s_x = u_x t$

$= (8.58 \cos 75^o) \times 1.80 = 4.0\ m$

**(iii)**



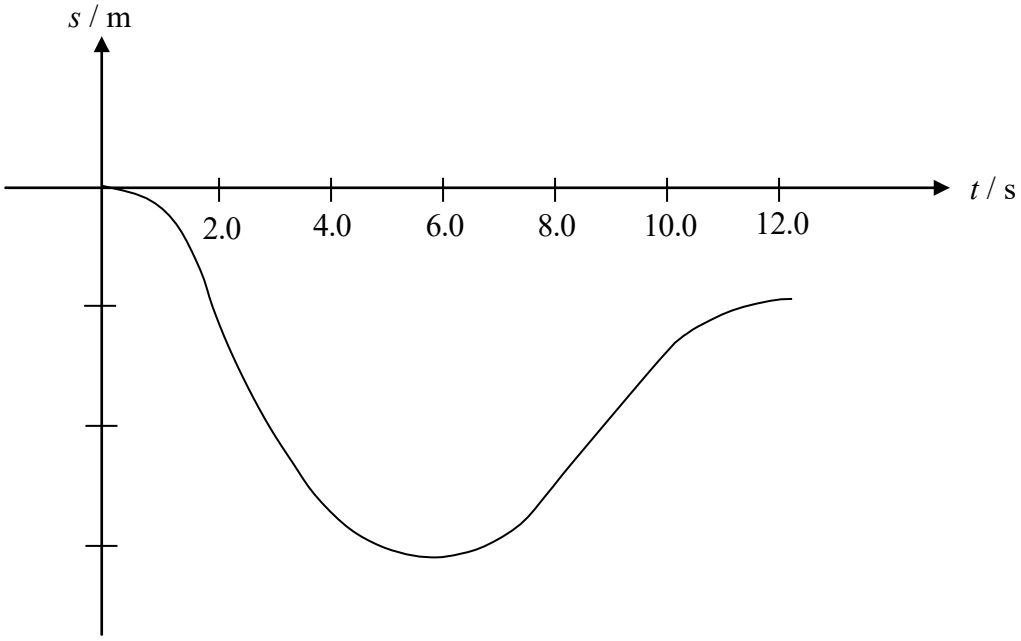

**(iv)** He should go closer to the durian. Directly below the durian so that he can exert his force in the vertical direction and initial vertical velocity is at its greatest.

**2(a)** Velocity is the rate of change of displacement.
Acceleration is the rate of change of velocity.

**(b)(i)** 6.0 s

**(b)(ii)** Displacement $= -\frac{1}{2}(6.0)(20) + \frac{1}{2}(6.0+2.0)(10)$
$= -20$ m

**(b)(iii)**




**3(a)** Length of S$2 = 12.7 cm (10 ~ 15 cm),
Human reaction time = 0.3 s (0.1 ~ 0.5 s)
u = 0, s = 0.127 m, a = 9.81 m $s^{-2}$
$s = ut + \frac{1}{2} at^2$ ➔ $0.127 = 0 + 4.905\ t^2$ ➔ $t = 0.17$ s
Since human reaction is around 0.3 s, more than 0.17 s, hence student B would not be able to catch the note.

**(b)** Distance travelled by lecturer in time $t = v_L\ t$
Distance travelled by student in time $t = v_s\ (t - t_o)$
$v_L\ t = v_s\ (t - t_o) + d$
$t = (d - v_s\ t_o) / (v_L - v_s)$

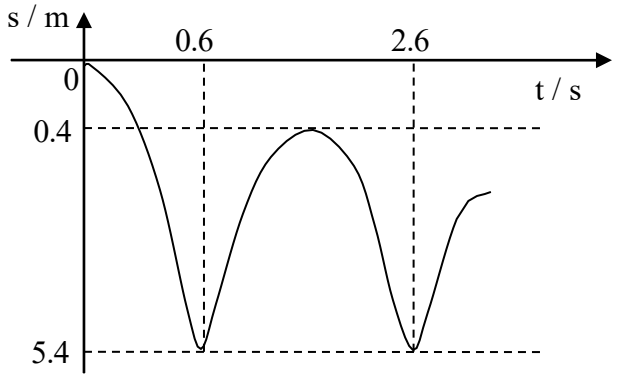
**4 (a)** Distance = Area under the graph = $\frac{1}{2}(6+12)0.6]$
$= 5.4$ m [1]

**(b)** Max height =Area under the graph = $\frac{1}{2} \times 1.0 \times 10 = 5.0$ m [1]

**(c)** $a$ = Gradient= $\frac{12-6}{0.6} = 10$ m $s^{-2}$ [1]

**(d)** From graph, time taken to reach max height on rebound = time taken to next reach ground = 1.0 s.
Thus, time taken to next reach ground = 1.0 + 1.6 = 2.6 s [1]

**(e)** [2]




1 m for correct shape,
1 m for correct values

**5**

**(a)** ↑+ $v_y^2 = u_y^2 + 2a_y s_y$

$0 = (u\sin 80.0°)^2 + 2\,(-9.81)\,(1.75)$ [M1]

$u = 5.95$ m s$^{-1}$ [C1]

**(b)** $v_y = u_u + a_y t$

$0 = 5.95 \sin 80.0^o - 9.81(T/2)$,

where $T$ is time of flight and is twice the time to reach maximum height,

$T = 1.1946$ s [C1]

Range $S_x = 5.95 \cos 80.0° (1.1946) = 1.23$ m. [A1]

**(c)**

1. Large angle gives a longer time of flight for a given projection speed and hence juggler has more time to manipulate balls. [B1]
2. Large angle keeps (horizontal) range small and of the order of the natural distance between the juggler's hands. [B1]

**(d)** The left hand has 1.19/2 = 0.597 seconds before ball 1 arrives. [A1]

**(e)** The minimum distance between the two hands must be at least greater than the diameter of the balls. [B1]

Otherwise, an upward moving ball will collide with a downward moving ball. [B1]

**6 (a) (i)** Taking into consideration, the vertical component of the motion

Vertical component of initial velocity

$u_y = u\sin\theta = (20)\sin 30^o = 10.0$ m s$^{-1}$

$v_y^2 = u_y^2 + 2gh$

$0 = (10.0)^2 + 2(-9.81)h$ [M1]

$h = 5.10$ m [A1]

**(ii)** The time taken to reach maximum height

$v_y = u_y + gt$

$0 = 10.0 + (-9.81)t$

$t = 1.02$ s [C1]

$v_x = u = u\cos\theta = (20)\cos 30^o = 17.3$ m s$^{-1}$

The horizontal distance (or the range)

$= (u_x)(time\ of\ flight)$

$= (17.3)(1.02 \times 2)$

$= 35.3$ m [A1]

**(b)**

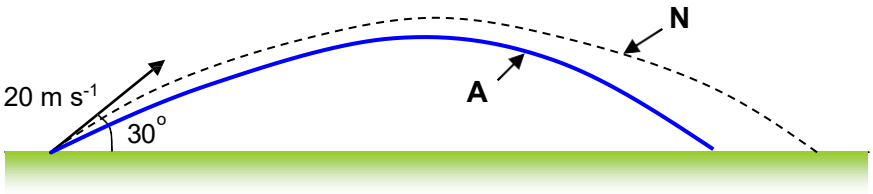



Fig. 2.1

**(i)** The maximum height and the horizontal distance will both be reduced. [B1]

*Note: The path should be shorter in height and in range slightly. No mark for excessive reduction in height and range as the effect of air resistance is slight. The path should be asymmetrical as the net force on the clay disc is varied.*

**(ii)** The maximum vertical height is smaller because the net force acting against the object moving up is larger (weight plus air resistance). The deceleration on the object is greater, thus the maximum vertical displacement is reduced. [B1]

The shorter time of flight due to the reduced maximum height causes the horizontal distance covered to be reduced. Or the additional horizontal force due to air resistance causes the object to be displaced less horizontally. [B1]

**7** **(a)** 90 km h$^{-1}$ = (90 x 1000) / 3600 = **25 m s$^{-1}$.** Conversion [1]
**OR** 35 m s$^{-1}$ = (35 x 3600) / 1000 = 126 km h$^{-1}$.
Since 35 m s$^{-1}$ > 25 m s$^{-1}$, the motorcycle has exceeded the speed limit.

**(b)** $v = u + at = 0 + 4.0 \times 13.0 = 52$ m s$^{-1}$ Working [1]

**(c)**

$s_{motorcycle} = ut = (35)(20 + 13.0) =$ **1155 m** value of $s_{motorcycle}$ [1]

$s_{car} = \frac{1}{2}at^2 = \frac{1}{2}(4)(13.0)^2 =$ **338 m** value of $s_{car}$ [1]

$\Delta s = s_{\text{motorcycle}} - s_{\text{car}} = 1155 - 338 = \mathbf{817\ m}$ value of $\Delta s$ [1]

$817 - 100 = \mathbf{717\ m}$ working [1]

**(d)**

$\Delta v = 52 - 35 = 17\ \text{m s}^{-1}$ Working [1]

$t = \frac{717}{17} = \mathbf{42.2\ s}$ answer [1]