Section A

1. **A**	11. **E**
2. **E**	12. **C**
3. **C**	13. **B**
4. **B**	14. **B**
5. **E**	15. **A**
6. **B**	16. **A**
7. **C**	17. **D**
8. **D**	18. **D**
9. **E**	19. **B**
10. **C**	20. **D**

Section B

21.a.i. (A) Mean = sum/N
Mean = (0.015 + 0.013 + 0.014 + 0.019 + 0.017 + 0.018)/6
Mean = 0.096/6
Mean = 0.016s

(B) RND Uncertainty = (Max - Min)/N
RND Uncertainty = (0.019 - 0.013)/6
RND Uncertainty = 0.006/6
RND Uncertainty = 0.001s

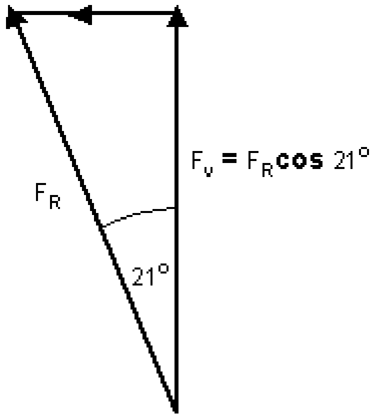
a.ii. u = 0m/s
v = 1.25m/s [v = card width/t = 0.020/0.016 = 1.25m/s]
s = 0.60m

Use: $v^2 = u^2 + 2as$
$a = (v^2 - u^2)/2s$
$a = (1.25^2 - 0)/2x0.6$
$a = 1.5625/1.2$
$a = 1.30m/s^2$

b.i. Photoconducting mode.

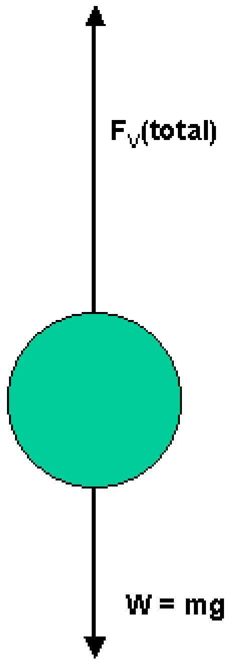
ii. When the beam is broken the photodiode is in darkness and does not conduct. This increases the voltage at point Y. When this voltage reaches 2.0V or higher the MOSFET conducts and starts the timer.

22.a.i.



$F_V(\text{total}) = 2F_R\cos 21^\circ$
$F_V(\text{total}) = 2 \times 4.5\times10^3\cos 21^\circ$
$\mathbf{F_V(total) = 8402.22N}$

a.ii.



$F_{un} = F_V(\text{total}) - mg$
$F_{un} = 8402.22 - (236 \times 9.8)$
$F_{un} = 6089.42\text{N}$

$a = F_{un}/m$
$a = 6089.42/236$
$\mathbf{a = 25.8m/s^2}$

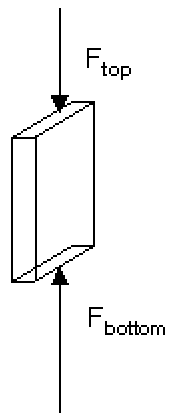
b. The tension in the cords decrease as the capsule rises. This means the total upward force and therefore the unbalanced force decreases, reducing the acceleration.

c. When there is no upward tension force the seat and occupants will both be projectiles in free fall. Both will be accelerating downwards at a rate of $9.8m/s^2$.

23.a. $m = 12g = 12x10^{-3}kg$
$v = (0.5x0.3x0.1)m^3 = 0.015m^3$

$\rho = m/v$
$\rho = 12x10^{-3}kg/0.015m^3$
$\boldsymbol{\rho = 0.8kg/m^3}$

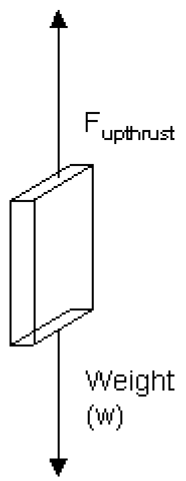
b. Pressure is directly proportional to the depth. This means that the lower surface has a greater pressure acting on it than the upper surface. The resulting forces (F = PA) are shown in the diagram.



F_{bottom} is greater than F_{top}.

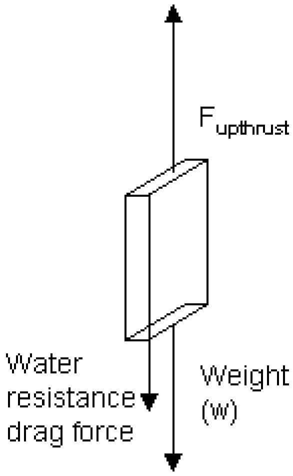
$\mathbf{F_{upthrust} = F_{bottom} - F_{top}}$

c. The initial accelerating force is given by:
$F_{un} = F_{upthrust}$ - weight(w)



However, as the float accelerates upwards and its speed increases the water resistance force also increases. This means the **acceleration of the float**

decreases.



$F_{un} = F_{upthrust}$ - (weight(w) + water resistance)

d. As the density is greater the mass and weight of the float is greater. The upward unbalanced force:

$F_{un} = F_{upthrust}$ - weight(w) ...is less.

The acceleration :

a = F_{un}/m ...is also less.

24.a.i.

Temperature/°C	25	50	75	100
Temperature/k	298	323	348	373
Volume/ml	20.6	22.6	24.0	25.4
(Volume/Temperature)/(ml/k)	0.0691	0.0700	0.0690	0.0681

Volume/Temperature(k) = constant
Volume = constant x Temperature(k)
Volume varies directly with the kelvin temperature.

a.ii. T(k) = (65 +273)k = 338k
Constant = 0.69ml/k

Volume = constant x Temperature(k)
Volume = 0.069 x 338
Volume = 23.3ml

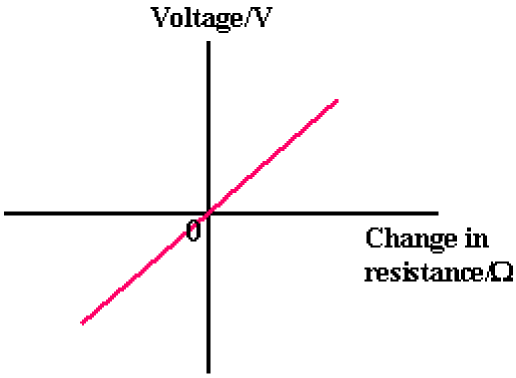
a.iii. As the temperature of the gas increases the kinetic energy and speed of the gas particles increase. This means that the average force, per collision, of the gas particles with the container walls increases. This produces an upward force on the syringe causing it to move upward until the pressure inside is the same as the air pressure outside.

b.i. This is a wheatstone bridge circuit and is balanced when the voltmeter reads 0V.

General equation: $R_1/R_2 = R_3/R_4$

$R_{variable}/500 = 2000/1000$
$R_{variable} = 500 \times 2$
$\mathbf{R_{variable} = 1000\Omega}$

b.ii.



25.a. e.m.f
The open circuit voltage.
OR
The energy supplied by the battery to each coulomb of charge.

b.i. (A) The e.m.f. is found at the y-intercept.
e.m.f. = 6.0V.

(B) The internal resistance(r) is equal to the negative gradient (-m)

$m = (y_2 - y_1)/(x_2 - x_1)$
$m = (6.0 - 1.0)/(0 - 1.0)$
$m = -5$

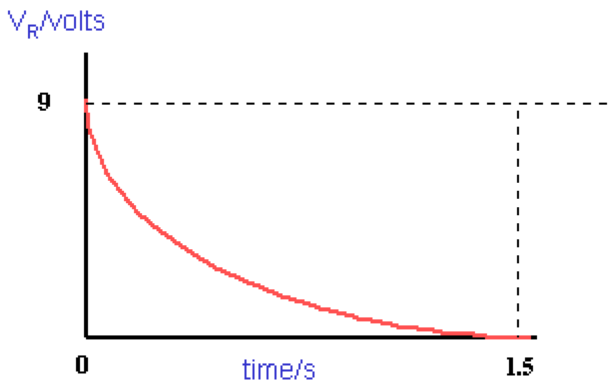
$\mathbf{r = -m = -(-5) = 5\Omega}$

b.ii. $E = I(R + r)$
$R = (E/I) - r$
$R = (6/0.3) - 5$
$\mathbf{R = 20 - 5 = 15\Omega}$ ...as required.

c. $1/R_p = 1/R_1 + 1/R_2$
$1/R_p = 1/15 + 1/30$
$1/R_p = 3/30$
$R_p = 10\Omega$

$I = E/(R_p + r)$
$I = 6.0/(10 + 5)$
$I = 6.0/15$
$\mathbf{I = 0.4A}$

26.a.i.



a.ii. The charging time is longer because less charge is transferred per second with a higher value resistor.

a.iii. $Q = CV_C$

$V_{supply} = V_C + V_R$
$V_C = V_{supply} - V_R$
$V_C = 9 - 4$
$V_C = 5V$

$Q = 2200\text{x}10^{-6} \text{ x } 5$
$Q = 11000\text{x}10^{-6}C$ (11mC)

b.i. Maximum energy is stored when: $V_C = V_{supply} = 9V$

$E_{max} = 1/2(CV_C^2)$
$E_{max} = 1/2(2200\text{x}10^{-6} \text{ x } 9^2)$
$E_{max} = 1100\text{x}10^{-6} \text{ x } 81$
$E_{max} = 89100\text{x}10^{-6}J$ (89.1mJ)

b.ii. The maximum discharge current occurs when the maximum voltage across the capacitor is applied across the resistor.

$I_{max} = V(R)_{max}/R$
$I_{max} = 9/100\text{x}10^3$
$I_{max} = 0.00009A$ (90μA)

27.a. x = source
y = gate
z = drain

b.i. $V_{out} = R_f/R_1(V_2 - V_1)$
$2 = 1\text{x}10^6/500\text{x}10^3(V_2 - V_1)$
$(V_2 - V_1) = 2/2$
$(V_2 - V_1) = 1V$

b.ii. $V_1 = V_Q$
$V_2 = V_P$

$V_2 = V_1 + 1$
$V_P = V_Q + 1$

The voltage at Q can be solved by proportion.

$V_Q = [R_{20k\Omega}/(R_{20k\Omega} + R_{100k\Omega})]V_{supply}$
$V_Q = [20k\Omega/(20k\Omega + 100k\Omega)]V_{supply}$
$V_Q = [20k\Omega/120k\Omega]V_{supply}$
$V_Q = [(1/6)]12$
$V_Q = 2V$

$V_P = V_Q + 1$
$V_P = 2 + 1$
$V_P = 3V$ (voltage across thermistor)

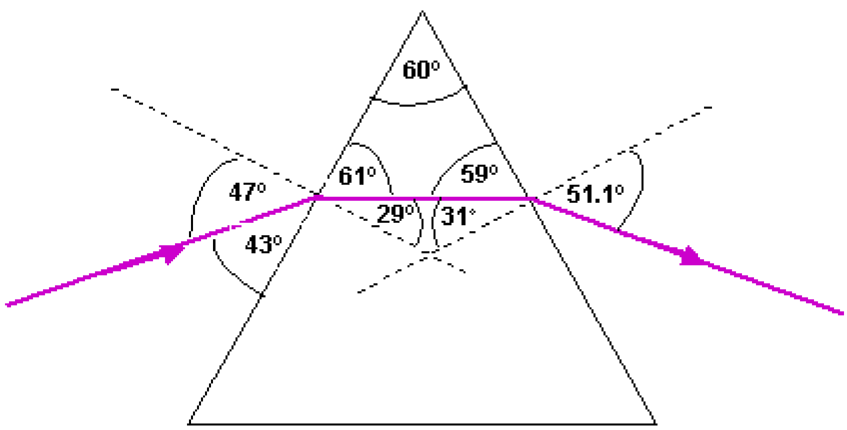
$V_P/V_{75k\Omega} = R_{thermistor}/R_{75k\Omega}$
$3/V_{75k\Omega} = R_{thermistor}/75k\Omega$

$V_{75k\Omega} = 9V$ [as $V_{supply} = V_P + V_{75k\Omega}$]
$3/9 = R_{thermistor}/75k\Omega$

$R_{thermistor} = 1/3(75k\Omega)$
$\mathbf{R_{thermistor} = 25k\Omega}$

28.a.i. $n = \sin_{glass} = \sin\theta_{air}/\sin\theta_{glass}$
$n_{glass} = \sin 47^\circ/\sin 29^\circ$
$n_{glass} = 1.51$

a.ii. $\sin\theta_{air} = n_{glass}\sin_{glass}$
$\sin\theta_{air} = 1.51 x \sin 31^\circ$
$\sin\theta_{air} = 0.778$
$\theta_{air} = 51.1^\circ$



b.i. When the path difference between adjacent slits to a point on the screen is zero or a whole number of wavelengths a bright spot is produced because of constructive interference.

b.ii. $d\sin\theta = n\lambda$

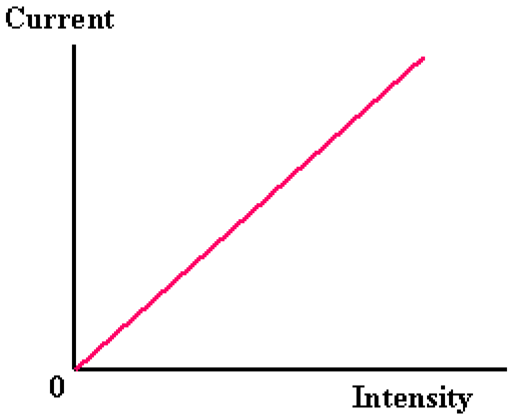
300 lines/mm => 300000 lines/m

$d = 1/300000 = 3.3333\times10^{-6}$m
$n = 2$ (second order)

$\sin\theta = n\lambda/d$
$\sin\theta = 2 \times 650\times10^{-9}/3.3333\times10^{-6}$
$\sin\theta = 0.390$
$\theta = 22.95^\circ$

b.iii. The blue fringes are closer together because shorter wavelength blue light is diffracted less than the longer wavelength red light.

29.a. Above the threshold frequency the photoelectric current is directly proportional to the intensity of radiation.



b.i. $E_k(\text{max}) = E_{photon} - E_{work\ function}$

$f_{photon} = v/\lambda$
$f_{photon} = 3\times10^{8}/400\times10^{-9}$
$f_{photon} = 7.5\times10^{14}$Hz

$E_{photon} = hf$
$E_{photon} = 6.63\times10^{-34} \times 7.5\times10^{14}$
$E_{photon} = 4.9725^{-19}$J

$E_k(\text{max}) = 4.9725\times10^{-19} - 3.11\times10^{-19}$
$\mathbf{E_k(max) = 1.8625\times10^{-19}J}$

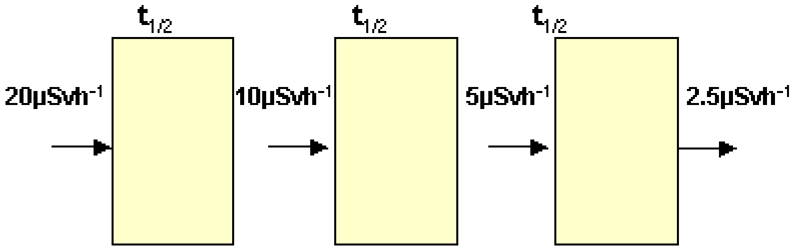
b.ii. The photons may have a kinetic energy greater than the work the electric field does trying to stop them.

$E_k(\text{max}) > eV$ [V = potential difference applied by battery
e = electronic charge]

30.a.i. At 200cpm material thickness = 1mm
At 100cpm material thickness = 6mm

5mm of material is required to half the count.
This is the half value thickness.

a.ii.



Three half value thicknesses are required.
Thickness = 3 x 5 = **15mm**

b. $H_{total}/h = H_{\gamma}/h + H_{thermal\ neutrons}/h + H_{fast\ neutrons}/h$

$H_{\gamma}/h = Q_{\gamma}D_{\gamma}/h$
$H_{\gamma}/h = 1 \times 2.0mGy/h$
$H_{\gamma}/h = 2.0mSv/h$

$H_{thermal\ neutrons}/h = Q_{thermal\ neutrons}D_{thermal\ neutrons}/h$
$H_{thermal\ neutrons}/h = 3 \times 400\mu Gy/h$
$H_{thermal\ neutrons}/h = 1200\mu Sv/h = 1.2mSv/h$

$H_{fast\ neutrons}/h = Q_{fast\ neutrons}D_{fast\ neutrons}/h$
$H_{fast\ neutrons}/h = 10 \times 80\mu Gy/h$
$H_{fast\ neutrons}/h = 800\mu Sv/h = 0.8mSv/h$

$H_{total}/h = (2.0 + 1.2 + 0.8)mSv/h$
$H_{total}/h = 4.0mSv/h$

$t_{hours} = 500/4$
$\mathbf{t_{hours} = 125hours}$