Section A

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

Section B

21.a.i. Initial displacement(s_1) from sensor = 0.2m

a.ii. Final displacement(s_2) from sensor = 1.8m

$\Delta s = s_2 - s_1$
$\Delta s = 1.8 - 0.2$
$\boldsymbol{\Delta s = 1.6m}$

a.iii. $s = 1.6$
$u = 0m/s$
$t = 0.6s$
$a = ?$

$s = ut + (at^2)/2$
$s = (at^2)/2$
$a = 2s/t^2$
$a = 2x1.6/0.6^2$
$a = 3.2/0.36$
$\boldsymbol{a = 8.9m/s^2}$ (as required)

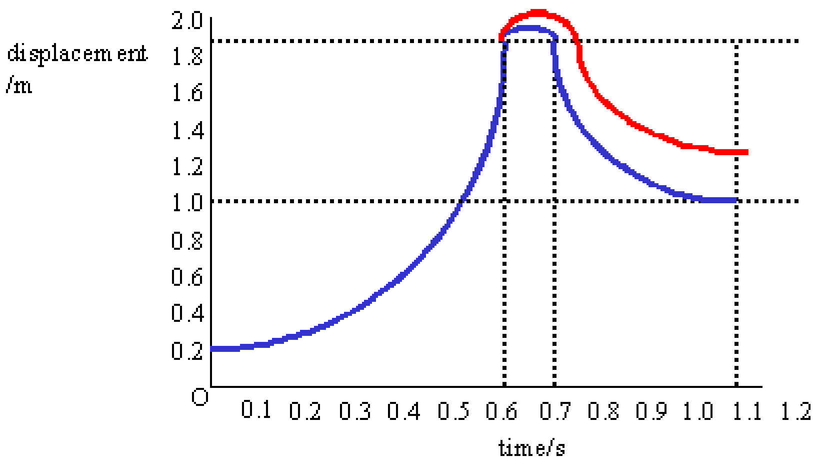
b. Mean = total/N
Mean(a) = (8.9+9.1+8.4+8.5+9.0)/5
Mean(a) = (43.9)/5
Mean(a) = 8.78m/s²

Random error = (max-min)/N
Random error(a) = (9.1-8.4)/5
Random error(a) = (9.1-8.4)/5
Random error(a) = (0.7)/5
Random error(a) = 0.14m/s²

a = (8.8+-0.1)m/s²

NB: It is only useful to quote the final mean and error to the same number of decimal places as the least accurate individual measurement.

d.



i. The contact time is greater with the softer surface.

ii. The rebound height will be less because the sponge will absorb more of the balls kinetic energy. The reduced rebound height can also be explained as a result of the average upward force exerted by the sponge on the ball being less.

iii. As the ball will sink more into the sponge the maximum displacement from the sensor will be greater.

22.a. P_1 = 109kPa
T_1 = (15+273)K = 288K

P_2 = ?
T_2 = (45+273)K = 318K

$P_1/T_1 = P_2/T_2$
$P_2 = P_1T_2/T_1$
P_2 = 109x318/288
P_2 = 120.35kPa

b. As the temperature increases the nitrogen gas molecules gain kinetic energy. With increased kinetic energy the atoms are moving faster and collide with the container walls more frequently and forcefully. The pressure(force/area) therefore increases.

c.i. $P = 1.75\text{x}10^5$Pa
$A = 4.0\text{x}10^{-6}\text{m}^2$

F = PA
$F = 1.75\text{x}10^5\text{x}4.0\text{x}10^{-6}$
F = 0.7N

c.ii. Read from the graph the length of the spring when the force is 0.7N.

Length = 35mm

d. The assumption in the original set up is that the temperature of the water is the same as the temperature of the gas inside the flask. Placing the thermometer inside the flask will give a more direct and accurate reading of the gas temperature.

23.a. Use the law of conservation of momentum to solve this problem.

$\mathbf{P_{before} = P_{after}}$

Before collision

$P_{before} = m_{vehicle}u_{vehicle} + m_{probe}u_{probe}$

$P_{before} = 2500 \times 0.5 + 1500 \times u_{probe}$

$P_{before} = (1250+1500u_{probe})$ kgm/s

After collision

$P_{after} = (m_{vehicle}+m_{probe})v$

$P_{after} = (2500 + 1500)0.2$

$P_{after} = 800$kgm/s

$(1250+1500u_{probe}) = 800$ (by conservation of momentum)

$1500u = 800-1250$

$1500u = -450$

$u = -450/1500$

u = -0.3m/s The negative indicates the probe is initially moving in the opposite direction to the vehicle.

b.i. The direction of thrust from the engine must be opposite to the direction of motion. This means it must be the **probe rocket engine** that was switched on. ($F_{avg} = -500$N)

NB: The average force has a negative value because it is acting towards the left.

b.ii. $F_{avg}t = \Delta P$

$F_{avg}t = (mv-mu)$

$F_{avg}t = m(v-u)$

$t = m(v-u)/F_{avg}$

$t = [4000(0-0.2)]/-500$

t = 1.6s

c. The initial acceleration to the RHS must be produced by the space vehicle rocket engine. To then decelerate the combined mass of the probe and vehicle the space probe rocket engine must fire. In the maneuver the space probe rocket must fire for twice the time of the vehicle rocket because it only produces half the thrust.

Mathematically:

$F_{probe}t_{probe} = F_{vehicle}t_{vehicle}$

$500t_{probe}=1000t_{vehicle}$

$t_{probe} = 2t_{vehicle}$

24.a. An emf of 6V means the battery will supply 6J of energy to each coulomb of charge passing through it.

b.i. emf = $V_r + V_{R1} + V_{R2}$
emf = $Ir + IR_1 + IR_2$

$I = 200mA = 0.2A$

$R_2 = (emf - Ir - IR_1)/I$
$R_2 = (6.0 - 0.2x2.0 - 0.2x20)/0.2$
$R_2 = (1.6)/0.2$
$R_2 = (1.6)/0.2$
$\mathbf{R_2 = 8\Omega}$

b.ii. V_{tpd} = emf - V_r
V_{tpd} = emf - Ir
$V_{tpd} = 6.0 - 0.2x2$
$\mathbf{V_{tpd} = 5.6V}$

c. When the switch is closed a larger current is drawn from the battery. This increases the voltage drop across the 2.0Ω resistor. This voltage drop, called the "lost volts", therefore increases. Consequently, the voltmeter reading, equal to: emf - "lost volts", decreases.

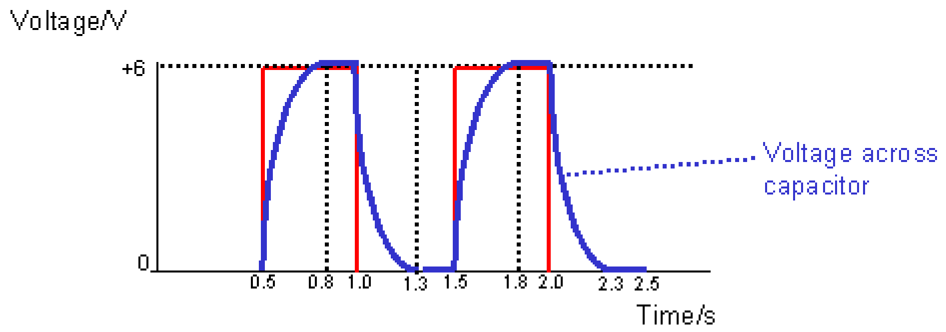
25.a.i. Initially all the supply voltage is across the resistor.
$V_R = V_{supply} = 6V$

When the capacitor is fully charged: $V_{supply} = V_{capacitor}$
$\mathbf{V_{capacitor} = 6V}$

a.ii. $E = CV^2/2$
$E = (2000x10^{-6}x6^2)/2$
$E = 0.072/2$
$\mathbf{E = 0.036J}$

a.iii. $I_{max} = V_{supply}/R$
$R = V_{supply}/I_{max}$
$R = 6/7.5x10^{-3}$
$\mathbf{R = 800\Omega}$

b.



26.a. Period(T) = 4cm x 2ms/cm
T = 8ms

f = 1/T
$f = 1/8x10^{-3}$

$f = 125Hz$

b.i. Inverting mode.

b.ii. The output voltage from the amplifier is calculated using:

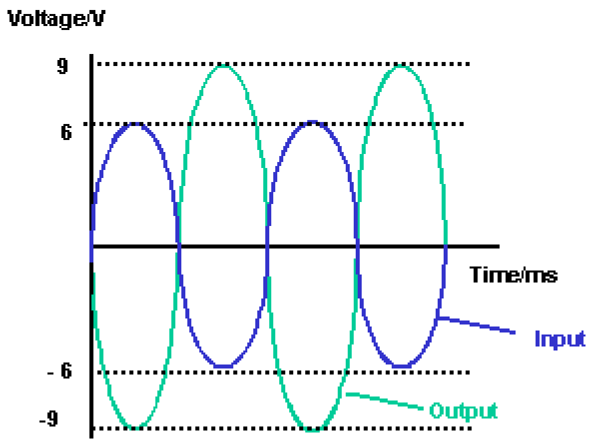
$V_{output}/V_{input} = -R_{feedback}/R_{input}$

=> $V_{output} = -V_{input} x (R_{feedback}/R_{input})$

$V_{output}(peak) = -6x(3.0x10^3/2.0x10^3)$

$\mathbf{V_{output}(peak) = -9V}$

(A)



(B) $V_{RMS} = V_{peak}/SQRT2$

$V_{RMS} = 9/1.414$

$\mathbf{V_{RMS} = 6.36V}$

b.iii. As $R_{feedback}$ is increased the amplifier saturates. This means the peak output voltage increases to a maximum of about +/- 13V.

27.a. $n_{glass} = \sin\theta_{air}/\sin\theta_{glass}$

$n_{glass} = \sin 20^\circ/\sin 13^\circ$

$n_{glass} = 1.52$

b. The critical angle is the angle, measured between the ray and the normal, at which light striking the glass air boundary will be totally internally reflected.

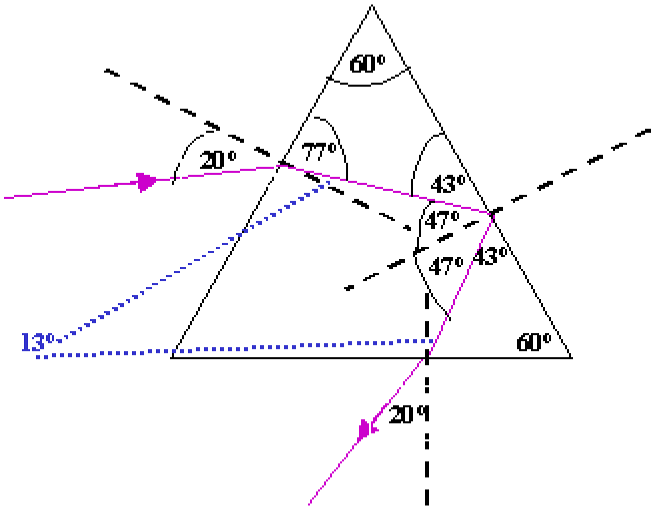
c. $\theta_{critical} = \sin^{-1}(1/n)$

$\theta_{critical} = \sin^{-1}(1/1.52)$

$\theta_{critical} = \sin^{-1}(0.658)$

$\mathbf{\theta_{critical} = 41.1^\circ}$

c.iii.



28.a. Threshold frequency.

28.b.i. $f_0 = 3.33 \times 10^{14}$Hz
work function(ϕ) = hf_0
$\phi = 6.63 \times 10^{-34} \times 3.33 \times 10^{14}$
$\boldsymbol{\phi = 2.21 \times 10^{-19}}$**J**

b.ii. $E_{photon} = hf$
$E_{photon} = 6.63 \times 10^{-34} \times 5.66 \times 10^{14}$
$E_{photon} = 3.75 \times 10^{-19}$J

E_k(electron) = $E_{photon} - \phi$
E_k(electron) = $3.75 \times 10^{-19} - 2.21 \times 10^{-19}$
E_k(electron) = 1.54×10^{-19}J

b.iii. E_k(gain) = $q\Delta V$
$q = e = 1.6 \times 10^{-19}$C
$\Delta V = 2.00 \times 10^4$V

E_k(gain) = $1.6 \times 10^{-19} \times 2.00 \times 10^4$
E_k(gain) = 3.2×10^{-15}J

29.a. Adding the impurity will **decrease** the resistance.

b.i. When the electrons in the n-type material combine with holes in the p-type material, as they cross the junction, they lose energy. This energy is emitted as quanta of visible radiation.

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

$d = 5.0 \times 10^{-6}$m
$\theta = 11°$
$n = 2$
$\lambda = ?$

$\lambda = d\sin\theta/n$
$\lambda = 5.0 \times 10^{-6}\sin 11°/2$

$\lambda = 4.77 \times 10^{-7}$m
λ = 477nm

30.a. Start by calculating the mass of pure torbernite($m_{torbernite}$) in the 0.6kg of material.

$m_{torbernite} = (40/100) \times 0.6$
$m_{torbernite} = 0.24$kg

The problem can now be solved by proportion.

MASS : ACTIVITY
1.0kg : 5.9×10^6decays per second = 5.9×10^6Bq = 5.9Mbq
0.24kg: 0.24x5.9Mbq

0.24kg has an activity of 1.416Mbq

b. Alpha

$H = QD$
$H = (20 \times 150)\mu Sv$
$H = 3000\mu Sv$

$H/t = 3000/6$
$H/t = 500\mu Sv/h$.............1

Other
$H = (Q \times 400)\mu Sv$
$H/t = (Q \times 400/8)\mu Sv/h$
$H/t = (Q \times 50)\mu Sv/h$..........2

Equate 1 & 2

$500\mu Sv/h = (Q \times 50)\mu Sv/h$
$Q = 500/50$
$Q = 10$

This radiation must be **fast neutrons**.