Section A.

1. C

2. E

3. Unbalanced force acting on horsebox = tension
   \[ F = ma \quad (= T) \]
   \[ = 700 \times 2 \]
   \[ = 1400 \text{N} \quad \text{C}. \]

4. Total momentum before = total momentum after.

\begin{align*}
\text{Before} & & \text{After} \\
\frac{2 \text{ms}^{-1}}{6 \text{kg}} & & \frac{1 \text{ms}^{-1}}{2 \text{kg}} \\
\rho &= m_1v_1 + m_2v_2 \\
\rho &= (6 \times 2) + (2 \times (-1)) \\
\rho &= 12 - 2 \\
\rho &= \frac{10}{\text{kgms}^{-1}}
\end{align*}

\begin{align*}
\text{Before} & & \text{After} \\
\frac{1 \text{ms}^{-1}}{6 \text{kg}} & & \frac{\sqrt{v}}{2 \text{kg}} \\
\rho &= m_1v_3 + m_2v_4 \\
\rho &= (6 \times 1) + (2 \times \sqrt{v}) \\
\rho &= 6 + 2\sqrt{v}
\end{align*}

\[ \text{Kinetic energy} = \frac{1}{2}m_1v_3^2 + \frac{1}{2}m_2v_4^2 \]
\[ = (\frac{1}{2} \times 6 \times 1^2) + (\frac{1}{2} \times 2 \times 2^2) \]
\[ = 3 + 4 \]
\[ = 7 \text{J} \]

A.
5. \[ P = \frac{F}{A} \quad \rightarrow \quad F = PA \]

\[ \text{External} \rightarrow \quad \text{F}_{\text{cabin}} \]

\[ \text{F}_{\text{cabin}} - \text{F}_{\text{external}} = (P_{\text{cabin}} \times A) - (P_{\text{external}} \times A) \]
\[ = (1 \times 10^5 \times 2) - (0.4 \times 10^5 \times 2) \]
\[ = 2 \times 10^5 - 0.8 \times 10^5 \]
\[ \approx 1.2 \times 10^5 \text{ N} \]

6. \[ P = \rho gh \]
\[ P = (1 \times 10^3) \times 9.8 \times 1.5 \]
\[ P = 14700 \text{ Nm}^{-2} \quad \text{D.} \]

7. \[ P \propto T \]
   Pressure doubles \( \rightarrow \) \( T \) (in Kelvin) must double
   \[ \text{A.} \]

8. \[ E = Q \nu \quad (\nu = QV) \]
\[ V = \frac{E}{Q} \quad \text{in Joules} \quad \text{Coulombs} \quad \text{E.} \]
9. \[ \frac{R_1}{R_2} = \frac{R_3}{R_4} \]
\[ \frac{1}{5} = \frac{(3+R)}{15} \]
\[ 15 \times \frac{1}{5} = 3 + R \]
\[ 3 + R = 3 + R \]
\[ R = 21 - 3 \]
\[ R = 18 \text{ Ohms} \]

10. \[ \Delta V (\text{mV}) \]

When \( R \) is changed by small step away from balance, the \( \Delta R \) \( (\text{Ohms}) \) change in voltage is proportional \( \Delta V \) change in resistance.

11. \[ f = \frac{1}{T} \]
\[ SD = \frac{1}{T} \]
\[ T = \frac{1}{50} \]
\[ T = 0.02 \text{s} \]
\[ (-20 \text{ ms}) \]

2 divisions = 20 ms

\[ \text{2 divisions} = 20 \text{ ms} \]

1 division = 10 ms
12. \( V_p = \sqrt{2} V_{\text{rms}} \)
   \[ V_p = \sqrt{2} \times 6 \]
   \[ V_p = 6\sqrt{2} \text{ V} \]
   \[ A \]

\[ V_p = I_p R \]
\[ I_p = \frac{V_p}{R} \]
\[ I_p = \frac{6\sqrt{2}}{3} \]
\[ I_p = 2\sqrt{2} \text{ A} \]

13. \[ \phi = CV \]
\[ C = \frac{\phi}{V} \]
\[ C = \frac{500 \times 10^{-6}}{10} \]
\[ C = 50 \times 10^{-6} \text{ F} \]
\[ (50 \mu\text{F}) \]

\[ \frac{0.1}{10} \times 100 = \pm 1\% \text{ (voltage)} \]
\[ \frac{25}{500} \times 100 = \pm 5\% \text{ (charge)} \]

14. E.

15. destructive interference
\[ \rightarrow \text{path difference} = (n+\frac{1}{2})\lambda \]
\[ n=0 \rightarrow \text{p.d.} = (0+\frac{1}{2})\lambda = \frac{1}{2} \times 40 = 20 \text{ mm} \]
\[ n=1 \rightarrow \text{p.d.} = (1+\frac{1}{2})\lambda = 1.5 \times 40 = 60 \text{ mm} \]

\[ 500 - 20 = 480 \text{ mm} \]

D.
16. \[ I_1 d_1^2 = I_2 d_2^2 \]
   \[ 20 \times 5^2 = I_2 \times 25^2 \]
   \[ I_2 = \frac{20 \times 5^2}{25^2} \]
   \[ I_2 = 0.8 \text{ Wm}^{-2} \]

17. D.

18. A.

19. B.

20. A.
21. (a) (i) \( v^2 = u^2 + 2as \)
\[ 0 = 7^2 + (2 \times (-9.8) \times s) \]
\[ 0 = 49 - 19.6s \]
\[ 19.6s = 49 \]
\[ s = \frac{49}{19.6} = 2.5 \text{ m} \]

(ii) \( v = u + at \)
\[ 0 = 7 + (-9.8) \times t \]
\[ +9.8t = 7 \]
\[ t = \frac{7}{9.8} \]
\[ t = 0.71 \text{ s} \]

(b) (i) At \( t = 0.71 \text{ s} \), vertical velocity = 0
horizontal velocity is constant
\[ \therefore \text{velocity} = 1.5 \text{ m/s} \text{ to the right} \]

(ii) Statement 2.
Horizontal velocity of ball is constant and equal to velocity of the trolley.
(a) (i) Impulse = area under force-time graph

\[ \frac{1}{2} \times 0.25 \times 6.4 \]

\[ = 0.8 \text{ kgms}^{-1} \]

(ii) change in momentum = impulse

\[ = 0.8 \text{ kgms}^{-1} \text{ to the left.} \]

(iii) \[ F \text{at} = M \Delta v \]

\[ -0.8 = M(v - u) \]

\[ -0.8 = M(-0.45 - 0.48) \]

\[ -0.8 = M \times (-0.93) \]

\[ M = \frac{-0.8}{-0.93} \]

\[ M = 0.86 \text{ kg}. \]

(b) Graph of force vs. time revealing new magnets and old magnets.
23.

(a) (i) Mass of air = 111.49 - 111.26
= 0.23g
= 2.3 \times 10^{-4} \text{ kg}

\rho = \frac{m}{V} = \frac{2.3 \times 10^{-4}}{2 \times 10^{-4}}

\rho = 1.15 \text{ kg m}^{-3}

(ii) Not all of the air has been removed from the bell jar.

(b)

(i) \quad P_1V_1 = P_2V_2

1.01 \times 10^5 \times 200 = P_2 \times 250

P_2 = \frac{1.01 \times 10^5 \times 200}{250}

P_2 = 8.1 \times 10^4 \text{ Pa}

P_1 = 1.01 \times 10^5 \text{ Pa}

V_1 = 200 \text{ ml}

V_2 = 250 \text{ ml}

P_2 = ?

(ii) Air molecules collide with the walls of the bell jar. When air is removed, these collisions become less frequent. This reduces the average force on the bell jar walls. Pressure on the walls decreases.
24. (a) (i) 10J of energy are given to each coulomb of charge passing through the supply.

(ii) \[ E = V + Ir \]

\[ 10 = 7.5 + (1.25 \times r) \]

\[ 10 - 7.5 = 1.25r \]

\[ 1.25r = 2.5 \]

\[ r = \frac{2.5}{1.25} \]

\[ r = 2 \Omega \]

(b) (i) Total resistance in the circuit has decreased.

Current has increased due to lower resistance.

Lost volts \((= Ir)\) has increased, causing a decrease in TD0.
24. (b) (ii) \[ R_p = \frac{V}{I} = \frac{6}{2} = 3 \Omega \]

\[ \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \]

\[ \frac{1}{3} = \frac{1}{6} + \frac{1}{R_2} \]

\[ \frac{1}{R_2} = \frac{1}{3} - \frac{1}{6} = \frac{2}{6} - \frac{1}{6} = \frac{1}{6} \]

\[ R_2 = 6 \Omega \]

25. (a) When 220 \mu C of charge is stored on the capacitor plates, a potential difference of 11 V exists across the plates.

(b) (i) \[ I = \frac{V}{R} \]

\[ = \frac{12}{1400} \]

\[ I = 8.6 \text{ mA} \]
\[ (b) \ (ii) \ \text{initial energy stored.} \]
\[ E = \frac{1}{2} CV^2 \]
\[ = \frac{1}{2} \times (200 \times 10^{-6}) \times 12^2 \]
\[ = 0.0144J \]

**final energy stored**
\[ E = \frac{1}{2} CV^2 \]
\[ = \frac{1}{2} \times (200 \times 10^{-6}) \times 4^2 \]
\[ = 0.0016J \]

**decrease in stored energy**
\[ = 0.0144 - 0.0016 \]
\[ = 0.0128J \]

\[ (c) (ii) \ 0.3s \]

\[ (ii) \quad S = ut + \frac{1}{2} at^2 \]
\[ 0.8 = (1.5 \times 0.3) \]
\[ + \left( \frac{1}{2} \times a \times 0.3^2 \right) \]
\[ 0.8 = 0.45 + 0.045a \]
\[ 0.045a = 0.8 - 0.45 \]
\[ a = \frac{0.35}{0.045} \]
\[ a = \frac{0.35}{0.045} \approx 7.78 m/s^2 \]
25 (c) (iii)

The percentage uncertainty in the time measurement will decrease and the percentage uncertainty in the distance measurement will decrease.

* Note that scale reading uncertainty has not changed, so no marks for saying scale reading or absolute uncertainty is smaller. Must be percentage (or fractional) to get this mark.

26. (a) (i) Inverting mode

(ii) 
\[ V_0 = -\frac{\epsilon F}{R_i} \times V_i \]
\[ 6 = -\frac{4\epsilon}{10} \times V_i \]
\[ 6 = -4V_i \]
\[ V_i = \frac{6}{4} \]
\[ V_i = 1.5V \]

Choose any pair of values for \( V_0 + \epsilon F \) from graph (below saturation)
26 (a) (iii) The op amp has reached saturation.

(b) \[ V_o = \frac{20}{10} (V_2 - V_1) \]

For t = 0 → 1s:
\[ V_o = \frac{20}{10} (2 - 1) = +2V \]

For t = 1 → 2s:
\[ V_o = \frac{20}{10} (1 - 2) = -2V \]

For t = 2 → 3s:
\[ V_o = \frac{20}{10} (-1 + 2) = +2V \]
27. (a) (i) \[ n = \frac{\sin \theta_1}{\sin \theta_2} \]
\[ = 1.66 \times \frac{\sin 40}{\sin \theta} \]
\[ \sin \theta = \sin 40 \]
\[ = 1.66 \]
\[ \theta = \sin^{-1} \left( \frac{\sin 40}{1.66} \right) \]
\[ \theta = 22.8^\circ \]

(ii) (A) \[ \sin \theta_c = \frac{1}{n} \]
\[ \sin \theta_c = \frac{1}{1.66} \]
\[ \theta_c = \sin^{-1} \left( \frac{1}{1.66} \right) \]
\[ \theta_c = 37^\circ \]

(B) (\text{normal})

\[ \hat{I} + \hat{r} = X \]
\[ \hat{i} = 37^\circ , \quad \hat{r} = \hat{r} \]
so \[ X = 37 + 37 \]
\[ X = 74^\circ \]
27. (b) No.

Refractive index depends on frequency of light, so $\theta_{\text{blue}} < \theta_{\text{red}}$.

The angle of incidence is now greater than the critical angle for blue light, so total internal reflection will occur.

28. (a) Light is a wave.

\[ n' \lambda = d \sin \theta \]

\[ 2 \times \lambda = 5 \times 10^{-6} \times \sin 11^\circ \]

\[ \lambda = \frac{(5 \times 10^{-6}) \times \sin 11^\circ}{2} \]

\[ \lambda = 480 \text{nm} \]

(ii) The maxima will spread further apart. As R.I decreases, $\lambda$ will increase.

\[ \sin \theta = \frac{n' \lambda}{d} \]

so $\theta$ will increase when $\lambda$ increases.

*Note that $n'$ in this equation is order of maxima, not refractive index!!
29. (a) (i) \[ V = f \lambda \]
\[ f = \frac{V}{\lambda} = \frac{3 \times 10^8}{525 \times 10^9} = 5.71 \times 10^{-14} \text{ Hz} \]

\[ E = hf \]
\[ = (6.63 \times 10^{-34}) \times (5.71 \times 10^{14}) \]
\[ E = 3.79 \times 10^{-19} \text{ J} \]

(ii) Max \( E_k = E - W \)
\[ = hf - W \]
\[ = (3.79 \times 10^{-19}) - (2.24 \times 10^{-19}) \]
\[ \text{Max } E_k = 1.55 \times 10^{-19} \text{ J} \]

(b) (i) Photons with frequency less than \( f_0 \) have insufficient energy to free electrons from the metal.

(ii) \[ W = hf_0 \]
\[ 2.24 \times 10^{-19} = (6.63 \times 10^{-34}) \times f_0 \]
\[ f_0 = \frac{2.24 \times 10^{-19}}{6.63 \times 10^{-34}} \]
\[ f_0 = 3.38 \times 10^{14} \text{ Hz} \]
30. (a) i) nuclear fusion

(ii) total mass before

\[ = 5.005 \times 10^{-27} + 3.342 \times 10^{-27} \]

\[ = 8.347 \times 10^{-27} \text{ kg} \]

total mass after

\[ = 6.642 \times 10^{-27} + 1.675 \times 10^{-27} \]

\[ = 8.317 \times 10^{-27} \text{ kg} \]

mass lost = \((8.347 - 8.317) \times 10^{-27}\)

\[ = 0.03 \times 10^{-27} \text{ kg} \]

\[ E = Mc^2 \]

\[ E = (0.03 \times 10^{-27}) \times (3 \times 10^8)^2 \]

\[ = (0.03 \times 10^{-27}) \times (9 \times 10^{16}) \]

\[ = 2.7 \times 10^{-12} \text{ J} \]
(b) energy absorbed

\[ E = (-1.360 \times 10^{-19}) - (-5.424 \times 10^{-19}) \]

\[ E = 4.064 \times 10^{-19} \text{ J} \]

\[ E = hf \]

\[ 4.064 \times 10^{-19} = (6.63 \times 10^{-34}) \times f \]

\[ f = \frac{4.064 \times 10^{-19}}{6.63 \times 10^{-34}} \]

\[ f = 6.13 \times 10^{14} \text{ Hz} \]

\[ v = f \lambda \]

\[ 3 \times 10^8 = (6.13 \times 10^{14}) \times \lambda \]

\[ \lambda = \frac{3 \times 10^8}{6.13 \times 10^{14}} \]

\[ \lambda = 489 \text{ nm} \]

(ii) \[ \lambda = 489 \text{ nm so blue} \]