H1P2
Section A

1. (a) The gradient of the momentum-time graph represents the resultant force that acts on the object. [1]

(b) According to Newton's third law, the resultant force that acts on them are in opposite directions, therefore the gradients have opposite signs. [1]

(c)

$$Force,\ F_B = gradient = \frac{(28-22)\times 10^3}{1.5} = 4.0\ kN \quad [1]$$

$$By\ N3L,\ F_A = F_B = 4.0\ kN \quad [1]$$

(d)

According to Newton's second law, $Force,\ F_A = \frac{dp}{dt} = \frac{m_A v_A - m_A u_A}{dt}$ [1]

Similarly, $Force,\ F_B = \frac{dp}{dt} = \frac{m_B v_B - m_B u_B}{dt}$

According to Newton's third law, $F_A = -F_B$ [1]

$$\Rightarrow \frac{m_A v_A - m_A u_A}{dt} = -\frac{(m_B v_B - m_B u_B)}{dt} \Rightarrow m_A u_A + m_B u_B = m_A v_A + m_B v_B$$

Therefore, momentum is conserved since total *initial* momentum = total *final* momentum. [1]

2(a) Resistance is the ratio of the potential difference across an electrical component to the current flowing through it. [1]

Resistivity ρ is given by *RA*/*L*, where *R* is the resistance of the component, *A* is its cross-sectional area, and *L* is its length. [1]
(Do not accept *A* = area)

Resistivity is a property of the material that the component is made of, [1]
whereas the resistance is a property of the component (depending on ρ, *L* and *A*).[1]

(b)(i) Resistance, $R = \frac{\rho L}{A} = \frac{(0.13)(0.20)}{1.0\times 10^{-4}} = 260\ \Omega$ [1]

(ii) Current, *I* = *V*/*R* = 3.0/260 = $\mathbf{1.15 \times 10^{-2}\ A}$ [1]

(iii) Resistance of the object, $r = \frac{\rho L}{A} = \frac{\left(\frac{0.13}{2}\right)(0.10)}{1.0\times 10^{-4}} = 65\ \Omega$ [1]

The object and half of the original water-tube are connected in series.

Total resistance of the combined tube = $R/2 + r$ = 130 + 65
= 195 Ω [1]

New current, I_2 = 3.0/195 = **1.54 × 10^{-2} A** [1]

3(a) Magnetic flux density is defined as the force per unit current per unit length of conductor, with the conductor placed perpendicular to magnetic field. [2]

(b) (i) The current I in wire Q will produce magnetic fields around wire Q. At position P, the magnetic field due to wire Q is outwards of the plane of the paper. [1]
By Fleming's left hand rule, P will experience a force to the right towards Q. [1]

(ii)

[1] – drawing the force F

(iii) $F = BIL\sin\theta$

$B = \dfrac{F}{IL\sin\theta}$ [1]

$= \dfrac{2.4\times10^{-5}}{2.0\times1\times\sin 90^o}$

$= 1.2\times10^{-5}$ T [1]

(iv) $B = \dfrac{\mu_o I}{2\pi d}$

$1.2\times10^{-5} = \dfrac{4\pi\times10^{-7} I}{2\pi\times0.050}$

$I = 3.0$ A (Shown) [1]

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(a) When intensity of the incoming light is increased, more photons are incident upon the surface of the metal. [1] Hence, the number of photoelectrons that are produced are increased proportionally [1]

(b) When the potential difference is made negative, photoelectrons lose kinetic energy and gain electric potential energy as they approach the gauze. [1] When the potential difference is sufficiently large, even the fastest photoelectron will have zero kinetic energy before it reaches the gauze, causing no current be observed. [1]

(c) According to Einstein's photoelectric equation, the maximum kinetic energy of the photoelectrons depends only on the frequency of incident light used and the work function of the metal. [1] Hence, even if the intensity is increased, the maximum kinetic energy of each photoelectron remains the same and the stopping potential remains constant. [1]

(d) Using the modified Einstein's photoelectric equation:

$$\frac{hc}{\lambda} = \phi + eV \qquad [1]$$

$$\frac{6.63\times10^{-34}\times3\times10^{8}}{1\times10^{-8}} = 4.3\times1.6\times10^{-19} + 1.6\times10^{-19}\times V$$

$$V = 120\ \text{V} \qquad [1]$$

5a. Take 2 points on the curve for which x > r, e.g. (1.2r, 6.8) and (3.9r, 0.6). Check to see if gx^2 is constant.

For (1.2r, 6.8), $gx^2 = 6.8 \times (1.2r)^2$
$= 9.79\ r^2$

For (3.9r, 0.6), $gx^2 = 0.6 \times (3.9r)^2$
$= 9.12\ r^2$

Although they are not equal, they are within 10% of each other. So can be equal.

Since g = $\frac{\text{constant}}{x^2}$, g is inversely proportional to x^2

[1 m each for accurate reading of coordinates (max 2 m), 1 m for correct working]

b. At x = r, g = 9.8 m s^{-2}

$$\frac{g_{Moon}}{g_{Earth}} = \left(\frac{x_{Earth}}{x_{Moon}}\right)^2 \qquad [1m]$$

$$g_{Moon} = 9.8\left(\frac{1}{60}\right)^2$$

$= 2.7$ m s^{-2} [1m]

c. For g = 8.81 m s^{-2}, x = 1.1 r (x must be > r) [1m]
∴ h = 0.1 r
= 637 km [1m]

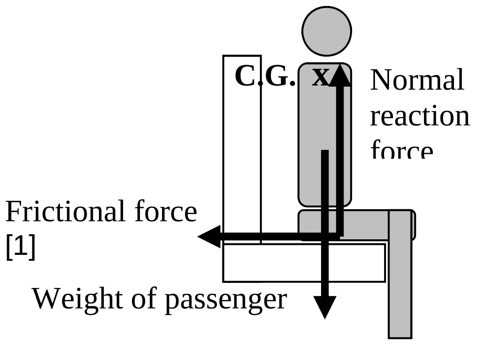
d. Gain in g.p.e. = area under the graph from x = r to x = 1.1r. [1m]

Section B

6)(a) 110 km h^{-1} = 30.6 m s^{-1}.
$v^2 = u^2 + 2as = (30.6)^2 + 2(0.85)(-9.81)(4.2)$ [1]
v = 29.4 m s^{-1}. [1]

(b)(i) Rate of change of momentum is proportional to the net force acting on the object, and this change in momentum takes place in the direction of the force. [1]

(ii)



(iii) From the diagram shown, the frictional force will provide a clockwise moment about the center of gravity, resulting in the driver rotating clockwise. [1]
Hence the driver will lean forward during this instant. [1]

(iv) Net force, F = ma = (65)(0.85)(9.81) = 542 N [1]

(c)(i) Since, they move off together as one body after the collision, it is a completely inelastic collision. [1]
Therefore, the total kinetic energy of the system before and after collision is not conserved. [1]

(ii) Assuming a head-on collision, [1]
by Conservation of Momentum,
(1500)(29.4) = (1500+2500)(v) [1]
v = 11.0 m s^{-1} [1]

(iii) The airbag helps to increase the time of impact[1] and by Newton 2^{nd} law, $F = \Delta p/t$, this will greatly reduce the force of impact on the passenger. [1]

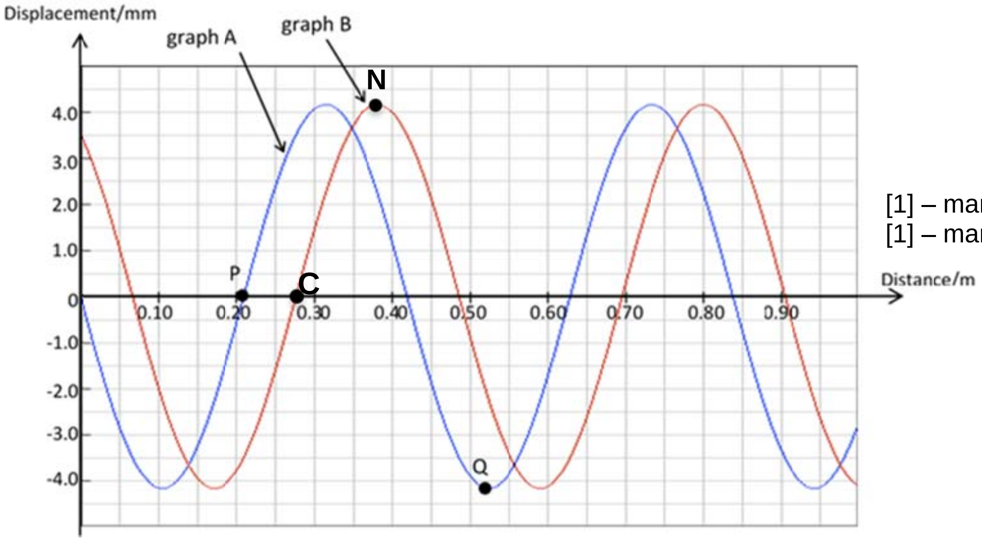
(d)(i) Rate of increase of GPE = mgv_y = (1500 + 2000)(9.81)(1.2 sin10^o) [1]
= 7.15 kJ[1]

(ii) By Conservation of Energy, [1]
Power delivered = Rate of increase of GPE + rate of work done against R
55 x 10^3 = 7.15 x 10^3 + R(1.2) [1]
R = 40 kN

(iii) By N2L, F - mgsinθ - R = 0 [1]
F = (3500)(9.81)(sin10^o)+ 40 x 10^3 = 46 kN [1]

7(a) (i) Longitudinal wave is a wave where the vibration of the particles is parallel to the direction of wave propagation. [1]
Progressive wave means that energy will be transmitted in the direction of wave propagation. [1]

(ii)



[1] – marking point C
[1] – marking point N

(iii)1. From the graph, wavelength λ = 0.42 m. [1]

2. From graph A to graph B, the wave has moved a distance of 0.070 m in 0.20 ms.

v = dist/time
= $0.070/(0.20 \times 10^{-3})$
= 350 m s^{-1} [2]

3. $v = f\lambda$
$f = v/\lambda$
= 350/0.42 = 830 Hz [1]

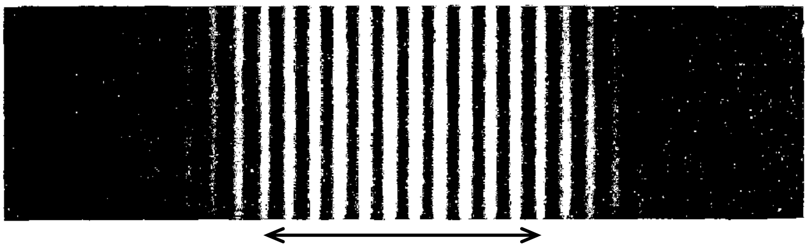
4. distance between P and Q, x = 0.31 m
phase diff, $\phi = (x/\lambda) \times 2\pi$ [1]
$= (0.31/0.42) \times 2\pi$
= 4.6 rad. [1]

Or: P and Q is ¾ of a wavelength apart, hence
$\phi = (x/\lambda) \times 2\pi$
$= (3/4) \times 2\pi = 3\pi/2$.

(b) (i) Principle of superposition states that when 2 or more waves meet at a point the resultant displacement is the vector sum of the individual displacements. [1]
When monochromatic light passes through the two closely spaced slits, the light waves from the two slits will superpose. Bright fringes are formed at points where the two waves meet in phase and interfere constructively. [1]

Dark fringes are formed at points where the two waves meet out of phase and interfere destructively. [1]

(ii)



Since photograph is full-scale, by measuring using a ruler as shown:
13 fringe spacings = 4.5 cm [1]
Hence fringe spacing Δx = 4.5/13 = 0.35 cm = 3.5 x 10^{-3} m [1]

(iii)

$$\Delta x = \frac{\lambda D}{d}$$

$$\lambda = \frac{\Delta x \times d}{D}$$

$$= \frac{3.5 \times 10^{-3} \times 0.30 \times 10^{-3}}{1.5}$$

$$= 7.0 \times 10^{-7}\ \text{m} = 700\ \text{nm}$$

(iv)

The fringes appear brighter at the centre compared to the edges is because of diffraction of light from each of the slit. [1]
When light passes through each of the small slit, the light waves will spread or diffract. [1] This causes the central fringes to be brighter than those at the edges.

(v) Any sketch of a bright patch of light without fringes. [1]

8 (a)(i) 10 lines can be produced. [1]

(ii) Electrons moving at a speed of 1.09×10^6 m s^{-1} are now introduced into a sample of cool sodium vapour at ground state.

1. Kinetic Energy of electrons,

$$K = \frac{1}{2}mv^2 = \frac{1}{2} \times 9.1 \times 10^{-31} \times (1.09 \times 10^6)^2 = 5.41 \times 10^{-19}\ \text{J} \quad [1]$$

Hence the possible frequencies of light visible are from

$$E_3 \rightarrow E_1 = \Delta E_{31} = 5.12 \times 10^{-19} \text{ J}$$

$$f_{31} = \frac{\Delta E_{31}}{h} = \frac{5.12 \times 10^{-19}}{6.63 \times 10^{-34}} = 7.72 \times 10^{14} \text{ Hz}$$

$$E_2 \rightarrow E_1 = \Delta E_{21} = 3.38 \times 10^{-19} \text{ J}$$

$$f_{21} = \frac{\Delta E_{21}}{h} = \frac{3.38 \times 10^{-19}}{6.63 \times 10^{-34}} = 5.10 \times 10^{14} \text{ Hz}$$

$$E_3 \rightarrow E_2 = \Delta E_{32} = (5.12 - 3.38) \times 10^{-19} = 1.74 \times 10^{-19} \text{ J}$$

$$f_{32} = \frac{\Delta E_{32}}{h} = \frac{1.74 \times 10^{-19}}{6.63 \times 10^{-34}} = 2.62 \times 10^{14} \text{ Hz}$$

[1] for correct equations, [1] for all 3 answers.

2. The lowest KE will be obtained when the electron has the highest energy transition (i.e. $E_1 \rightarrow E_3$)

$$KE_{lowest} = K - \Delta E_{31} \qquad [1]$$
$$= 5.41 \times 10^{-19} - 5.12 \times 10^{-19}$$
$$= 2.90 \times 10^{20} \text{ J} \qquad [1]$$

(iii) Since the photon energy does not exactly match an energy transition from ground state to an excited state, the photon cannot be absorbed [1] and will simply scatter.

(iv) The energy difference,

$$\Delta E = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_2} = (6.63 \times 10^{-34} \times 3 \times 10^8)(\frac{1}{589.0 \times 10^{-9}} - \frac{1}{589.6 \times 10^{-9}})$$
$$= 3.44 \times 10^{-22} \text{ J} \qquad [1]$$

The energy transition is to the ground state. [1]

(v) The ionization energy of sodium is 8.23 x 10^{-19} J.

1. It is the amount energy required to remove an electron from an atom in the <u>gaseous state</u> to <u>infinity</u> [1]

2. Minimum wavelength is associated with the highest energy radiation. Hence a free electron captured and de-excited to the ground state will have the minimum wavelength.

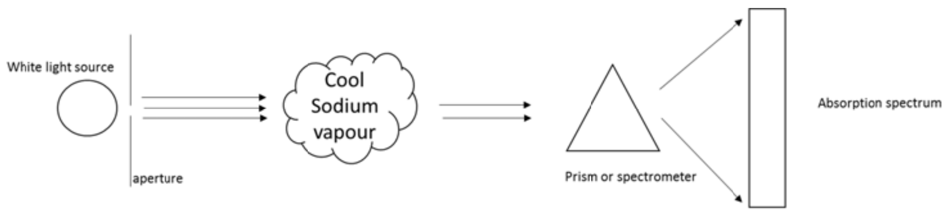
$$\frac{hc}{\lambda_{\min}} = \Delta E_{\infty \to 1} = 8.23\times10^{-19}\ \text{J}$$

$$\therefore \lambda_{\min} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{8.23\times10^{-19}} = 2.42\times10^{-7}\ \text{m} = 242\ \text{nm} \qquad [1]$$

The radiation is Ultra-violet. [1]

(b) **(i)** An absorption spectrum appears as a series of black lines on a background of continuous spectra. [1]
An emission spectrum appears as a series of isolated discrete colored lines. [1]

(ii)



[1] for diagram with white light source, gas vapour and prism.

- A beam of white light is obtained by placing an aperture between an incandescent lamp [no need to mark for this] and a sample of cool sodium vapour. [1]
- The resulting beam is then passed through a spectrometer or prism. [1]
- The resulting spectrum obtained will be an absorption spectrum. [1]

(iii) Compare the absorption spectrum obtained with the spectrometer to the emission spectrum of sodium.[1] If the dark lines contains the same wavelengths as the bright fringes of sodium given in part (a), then the sun contains sodium vapour. [1]