Tampines Meridian Junior College

2023 JC2 H2 Physics Preliminary Examination Paper 3

Suggested Solution

1 **(a)** **(i)** Elastic collision (as the total kinetic energy of the system (car and wall) is conserved before and after collision) [B1]

(ii) Considering the toy car and the wall as one system, [B1]

The total momentum is conserved as there is no external resultant force acting on this system. [B1]

There is a corresponding change of momentum to the fixed wall.

Or

Considering the toy car as the system only, [B1]

The momentum is not conserved as there is an external resultant force acting on the toy car by the wall. [B1]

(b) **(i)** $\Delta p =$ area under F - t graph

$$= \frac{1}{2}(0.18)(-15)$$

$$= -1.35 \text{ kg m s}^{-1}$$ [C1]

$$\Delta p = p_f - p_i$$

$$= m(v_f - v_i)$$

$$= m(-v - v)$$

$$-1.35 = -2mv$$

$$p_i = mv$$

$$= \frac{1.35}{2}$$

$$= 0.675 \text{ kg m s}^{-1}$$ [A1]

(ii) $$F_{average} = \frac{1}{2}F_{\max} = \frac{1}{2}(-15) = -7.5 \text{ N}$$

or

$$\Delta p = F_{average}t$$

$$-1.35 = F_{average}(0.18)$$

$$F_{average} = -7.5 \text{ N}$$ [C1]

$$F_{average} = ma_{average}$$

$$-7.5 = 0.65a_{average}$$

$$a_{average} = -11.5 \text{ m s}^{-2}$$ [A1]

Or

$$p_i = mv_i$$

$$v_i = \frac{0.675}{0.65}$$

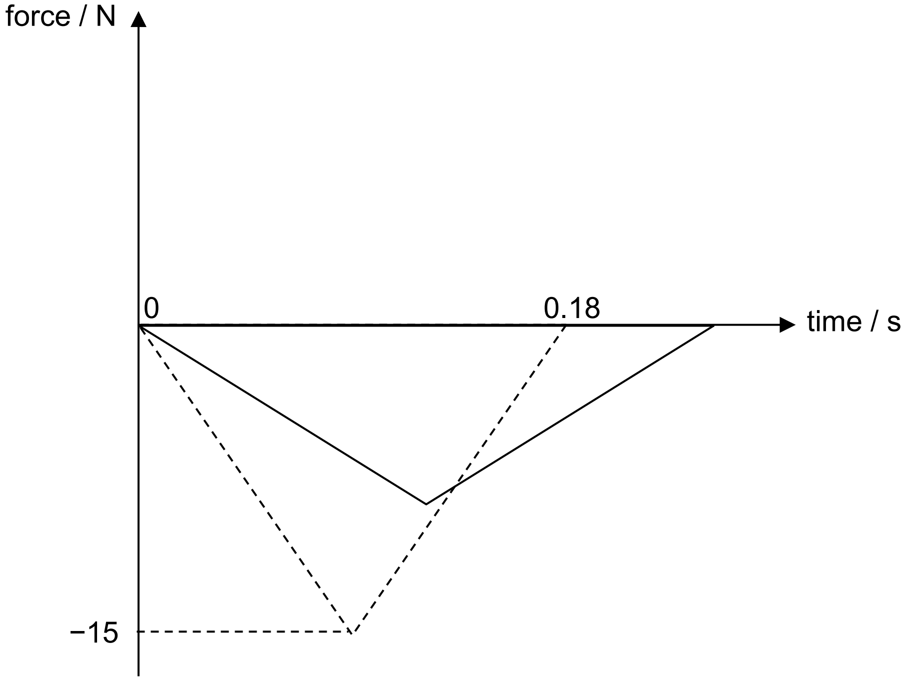
$$= 1.04 \text{ m s}^{-1}$$

$$a = \frac{v_f - v_i}{t}$$ [C1]

$$= \frac{-1.04 - 1.04}{0.18}$$

$$= -11.6 \text{ m s}^{-2}$$ [A1]

(iii)



[B1] shape with the time increased and magnitude of max force decreased.

2 **(a)** A field of force is a region of space in which a body experiences a force without physical contact with another body. [The field is produced by the presence of another body (or bodies)]. [B1]

(b) State one similarity and one difference between gravitational field and electric field.

Similarity [B1]:

- The field strength due to a point charge/mass follows an inverse square law with distance from the charge/mass.
- The potential due to a point charge/mass varies inversely with distance from the charge/mass.
- (Both G-fields and E-fields can be represented by field lines) In notes, we accept for students who memorised.

Difference [B1]:

- Gravitational fields are always attractive, whereas electric fields can be attractive or repulsive.
- Gravitational potential is always negative, whereas electric potential can be positive or negative.
- Source of gravitational field is a mass while source of electric field is a charge.

(c) **(i)** At point P, it is a gravitational neutral point where net gravitational field strength g is zero. [B1]

It is closer to the moon since the mass of the moon is smaller than the mass of the Earth. [B1]

(ii) At point P, *gravitational neutral point*.

$$g_M = g_E$$

$$G\frac{M_M}{r^2} = G\frac{M_E}{\left(3.80\times10^8 - r\right)^2} \quad \text{[M1- apply } g = G\frac{M}{r^2}\text{]}$$

$$\frac{\left(3.80\times10^8 - r\right)^2}{r^2} = \frac{5.98\times10^{24}}{7.35\times10^{22}} \quad \text{[B1]}$$

$$r = 3.79\times10^7 \text{ m} \quad \text{[A0]}$$

OR using potential method to solve,
Sum of potentials at point P (give method mark if approach is shown)

(iii) By conservation of energy

loss in KE = gain in GPE

$$\frac{1}{2}(m)(v)^2 - 0 = m(\phi_f - \phi_i)$$

$$\frac{1}{2}(v)^2 - 0 = (-1.3 - (-62.3)) \times 10^6 \quad [C1]$$

$$v = 11018$$
$$= 1.10 \times 10^4 \text{ m s}^{-1} \quad [A1]$$

The space probe needs to have sufficient energy from the Earth's surface to just reach the point P with maximum potential. Thereafter, the net gravitational force on the space probe (pointing towards Moon) will enable it to reach the Moon. [B1]

(d) **(i)** P is negative.
Near P, the electron has a positive potential energy. [M1]

Being very close to P, potential energy due to P on the electron is more significant than potential energy due to Q on the electron. (i.e. **approximately** $E_P \approx \frac{Q_P e}{4\pi\varepsilon_0 r}$)
For potential energy to be positive, P and electron must be of the same sign.
Hence P is negative. [A1]

OR

P is negative.
Potential energy increases towards P.[M1]

Since positive work must be done on electron to move it towards P.
Therefore, P and electron must be repelling each other.
Hence P is negative. [A1]

OR

P is negative.
Gradient of the graph is negative. [M1]

Since force points in the direction of decreasing potential energy ($F = -\frac{dU}{dr}$) electrostatic force on electron must be in the direction of positive r (right). Hence P and electron must be repelling each other
Hence P is negative. [A1]

(ii) Magnitude of force = gradient of potential energy graph [C1]

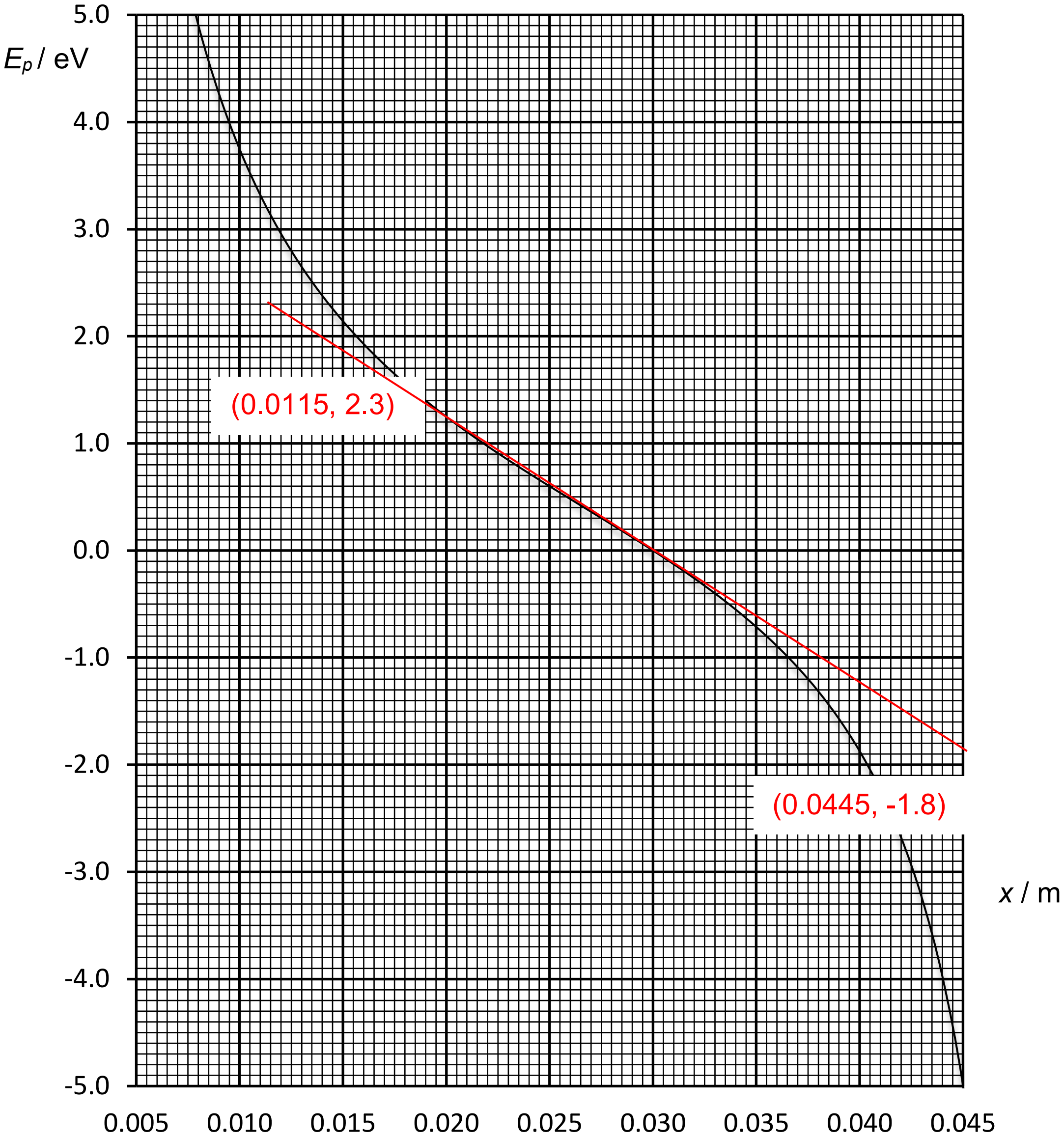
Gradient of graph (at x = 3.0 cm)

$$= \frac{2.3-(-1.8)}{(0.0115-0.0445)} = 124 \text{ eV m}^{-1}$$ [C1: gradient within range]

Accept gradient between 110 to 135 eV m^{-1}

Convert the unit to SI unit, force = 124 x 1.6 x 10^{-19} = 1.98 x 10^{-17} N
[A1:conversion to SI]

Accept a range of force due to gradient.
1.76 x 10^{-17} N
2.16 x 10^{-17} N



(iii) Curve with value of Ep near P to be lower & steeper gradient nearer to Q.

3 **(a)** **(i)** $v_{max} = 1.4 \text{ m s}^{-1}$

$$E_K = \frac{1}{2} m v_{max}^2$$

$$= \frac{1}{2}(0.50)(1.4)^2 \qquad [C1]$$

$$= 0.49 \text{ J} \qquad [A1]$$

(ii) $v_{max} = \omega x_0$

$$x_0 = \frac{1.4}{\left(\frac{2\pi}{0.50}\right)} \qquad [C1]$$

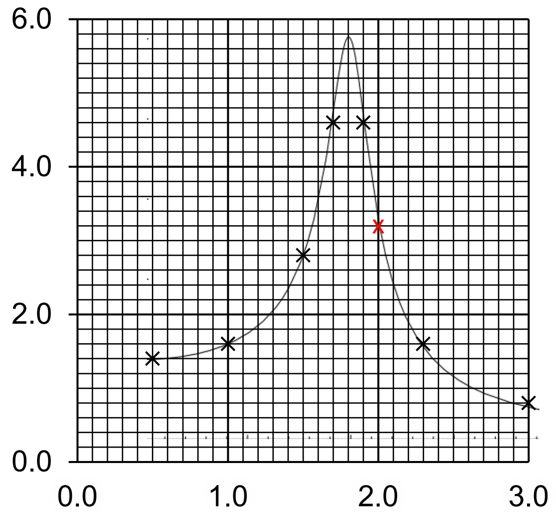
$$= 0.11 \text{ m} \qquad [A1]$$

(b) Damped oscillation. [B1]

Air resistance [B1] on the wooden board.

(c) **(i)**

(ii)



Correct plot (2.0, 3.2) [B1]

Correct curve of best fit [B1]

(iii) 1.8 Hz (accept 1.75, 1.8, 1.85) [B1]

4 **(a)** **(i)**

$$\sin\theta = \frac{\lambda}{b}$$

$$\sin(0.16°) = \frac{\lambda}{0.24\times10^{-3}}$$

$\lambda = 6.70\times10^{-7}$ m [B1]

(ii) Distance from centre to first minimum, *y*:

$$\tan\theta = \frac{y}{D}$$

$y = (1.8)\tan(0.16°) = 5.0\times10^{-3}$ m

$= 5.0$ mm [M1]

Width of central maximum = 2*y* = 10.0 mm [A1]

(iii)

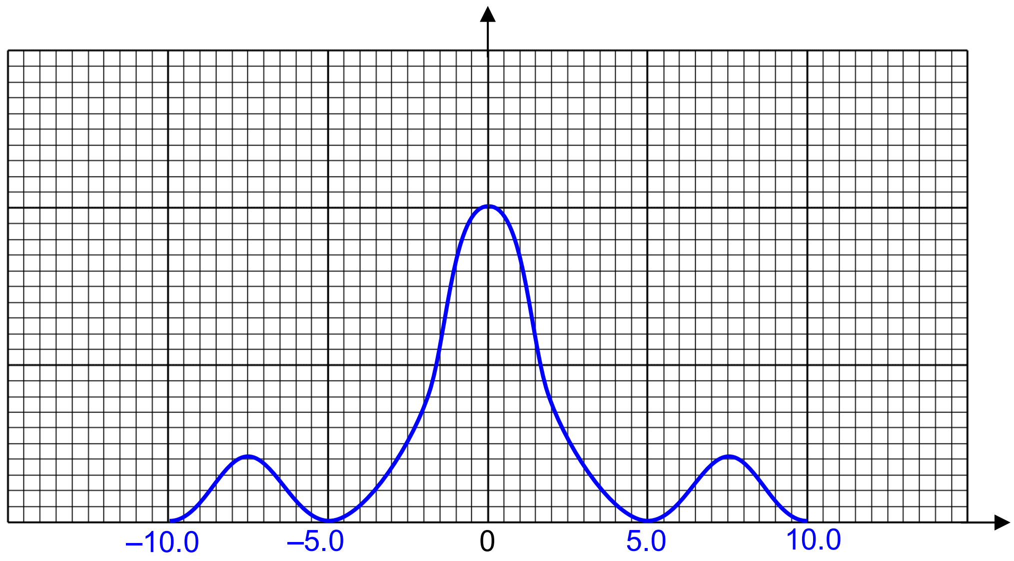


Fig. 4.2

[B1] correct shape

[B1] correct labels on horizontal axis + distance between minima = distance from centre to 1st minimum

(iv) The minimum will be further away from the centre / The central maximum will spread out more. [B1]
The intensity will be reduced. [B1]

(b) **(i)** Light waves from the sources have a <u>constant phase difference</u> (and same frequency) [B1]

(ii) Fringe separation, *x*:

$$x = \frac{\lambda D}{a} = \frac{(638\times10^{-9})(1.8)}{0.82\times10^{-3}} \quad \text{[M1]}$$

$= 1.40\times10^{-3}$ m $= 1.40$ mm [M1]

distance to 2nd dark fringe = 1.5*x* = 2.10 mm [A1]

(iii) Resultant amplitude at bright fringe = A + A = 2A [C1]

$I \propto A^2$

$$\frac{I_{fringe}}{I} = \frac{A_{fringe}{}^2}{A^2} = \frac{(2A)^2}{A^2}$$ [M1 - awarded for concept of proportionality]

$I_{fringe} = 4I$ [A0]

(iv) Although intensity of bright fringe is $4I$, intensity at dark fringes are zero. [B1]
Hence average intensity of the interference pattern is $2I$. [B1]
Principle of conservation of energy is not violated.

5 **(a)** **(i)** $2\pi f = 377$ [M1]
$f = 60$ Hz [A1]

(ii) $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{240}{\sqrt{2}}$ [M1]
$= 170$ V [A1]

(iii) Alternating magnetic field is created in the coil.
Hence there is an alternating magnetic flux linkage through the ring [B1]

By Faraday's law, an e.m.f. will be induced in the ring [B1 – link to emf to flux linkage]

Since the ring is a closed loop, current is induced in the ring. [B1]

By Lenz's law, the current will flow in a direction to oppose the changes in the magnetic flux linkage, hence creating a (average opposing) force which balances the weight. [B1]

(iv) Since the ring is not a closed loop, current is not induced in the ring. [M1]

Hence no opposing force is created, ring does not float. [A1]

(b)

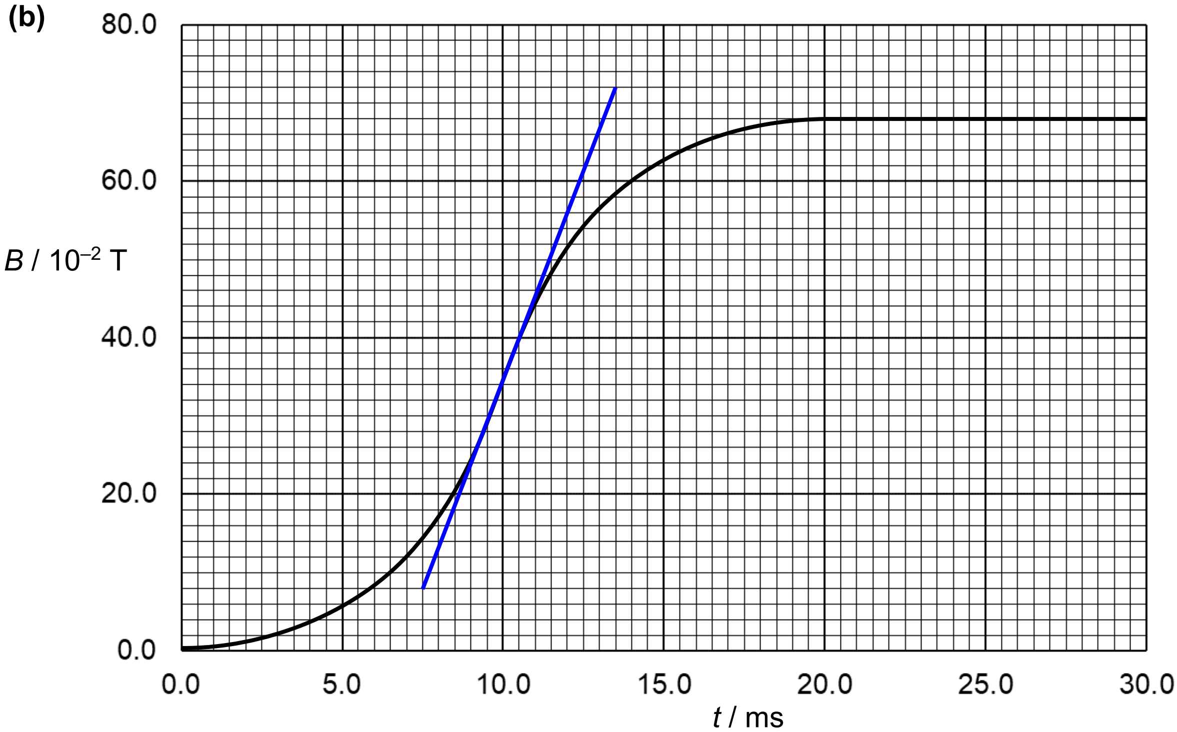


Fig. 5.4

Maximum e.m.f. will be induced when the gradient is steepest, i.e. at 10 ms.

$$Gradient = \frac{dB}{dt} = \frac{(72.0 - 8.0)\times 10^{-2}}{(13.5 - 7.5)\times 10^{-3}} = 106.67 \quad \text{[M1]}$$

$$|\varepsilon_{max}| = \frac{d(N\phi)}{dt} = NA\frac{dB}{dt} = (80)(4.2\times 10^{-5})(106.67) = 0.3584 = 0.36 \text{ V} \quad \text{[A1]}$$

Allow variation in value of gradient from 100 to 112 (which relates to a final answer for maximum e.m.f to be from 0.336 to 0.376 V)
–1 mark if gradient triangle is less than one big square (vertically)

6 (a) (i) When the liquid boils, the molecules in the liquid are totally separated with a large increase in the inter-molecular distance. This results in a significant increase in the potential energy of the molecules. [B1]

The kinetic energy of the molecules does not change as the temperature remains constant during boiling. [B1]

The internal energy of a system is the sum of a random distribution of kinetic and potential energies associated with the molecules of a system. Hence, the internal energy of the liquid increases due to the increase in the potential energy of the molecules in the liquid. [B1]

(ii)

$$\text{Heat loss} = Q_{\text{steam convert to water at } 100^\circ\text{C}} + Q_{\text{water cooled to } 50^\circ\text{C}}$$
$$= m_s L_v + m_s c_w \Delta T_{100\to 50^\circ\text{C}}$$
$$= m_s (2.3\times10^6) + m_s (4.2\times10^3)(100-50) \text{ [C1]}$$

$$\text{Heat gain} = Q_{\text{glass heated to } 50^\circ\text{C}} + Q_{\text{water heated to } 50^\circ\text{C}}$$
$$= m_g c_g \Delta T_{20\to 50^\circ\text{C}} + m_w c_w \Delta T_{20\to 50^\circ\text{C}}$$
$$= (0.100)(8.4\times10^2)(50-20) + (0.200)(4.2\times10^3)(50-20) \text{ [C1]}$$

$$\text{Heat loss} = \text{Heat gain}$$
$$m_s = 0.0110 \text{ kg} \quad \text{[A1]}$$

(iii) The specific latent heat of vaporisation of steam is 2.3 × 10^6 J kg^{-1}. This means that 1 kg of 100 °C steam will release 2.3 × 10^6 J of thermal energy as it condenses to 100 °C water. And after it releases this much of energy onto the skin, it is now identical to 100 °C water and will continue to burn the skin.

Hence 100 °C steam will cause a more serious burn [A1]
as it releases more / extra amount of thermal energy as compared to 100 °C water. [M1]

or
When there is conversion of phase (gaseous to liquid), extra energy will be release.

or
For 1 kg of steam, 10^6 J of energy will be released.
For 1 kg of 100 degree water, at most 10^5 J of energy will be released.
[no need to give values]

(b) (i) An ideal gas is one which obeys the ideal gas equation ($pV = nRT$) at [B1]
all temperatures, volumes and pressures. [B1]

(ii) When the gas is being compressed, the piston moves to the right and it collides with the gas molecules, the molecules will rebound with a higher speed and thus average kinetic energy increases. [B1]

Since average kinetic energy is proportional to temperature, temperature increases. [B1]

(iii) **1.** $pV = nRT$

$$n = \frac{pV}{RT}$$

$$= \frac{1.1\times10^{5}(6.2\times10^{-4})}{8.31(28+273)}$$ [C1]

$$= 0.0273 \text{ mol}$$ [A1]

2. Q = 0 J (as process happens quickly, no time for heat exchange) [M1]

$$\Delta U = Q + W_{on}$$
$$\Delta U = 0 + 15$$
$$= 15 \text{ J}$$ [A1]

3. $N = nN_A$

$$= 0.0273(6.02\times10^{23})$$
$$= 1.64\times10^{22} \text{ molecules}$$ [M1]

$$U = KE \quad \text{(for ideal gas, } PE = 0\text{)}$$
$$\Delta KE_{\text{total}} = \Delta U_{\text{total}}$$
$$\Delta KE_{\text{one molecule}} = \frac{\Delta U_{\text{total}}}{N}$$
$$= \frac{15}{1.64\times10^{22}}$$
$$= 9.15\times10^{-22} \text{ J}$$ [A1]

(c) **(iv)** When the gas is compressed slowly, the temperature T remains constant.
For the process that is compressed quickly, the temperature increases.
The final temperature of the gas that compressed slowly is lower than the final temperature of the gas that compressed quickly (in (b)). [M1]

Using the ideal gas equation, $pV = nRT$, with the same final volume (n & R remaining constant), the final pressure of the gas that is compressed slowly is lower than the gas that is compressed slowly. [A1]
(or the final pressure of the gas is greater for the gas that is compressed quickly).

7 **(a)** **(i)** – 5.17 + 3.50 eV = –1.67 eV => Highest energy level is n = 3

number of spectral line = $^{3}C_{2}$ = 3 [A1]

(ii) $hf = E_2 - E_1$

$(6.63\times10^{-34})f = (-3.07-(-5.17))(1.60\times10^{-19})$ [C1]

$f = 5.07\times10^{14}$ Hz [A1]

(iii) 1. from ground state to n = 2: cannot occur [B1]

2. from ground state to n = 3: can occur [B1]

The energy of the photon must be exactly equal to the energy difference between two energy levels before it can be absorbed. [B1]

(iv) There are discrete energy levels within the nucleus. [B1]

The energy transitions are of large energies, since the radiation is in the gamma range. [B1]

(b) **(i)** When high speed electrons emitted from the decay of Yttrium **collides** with the **lead** nucleus/ are deflected by **lead** nucleus [B1],

it undergoes **large** deceleration/slows down abruptly. This produces X-ray photons [B1].

The X-ray photons produced are of a range of energies as the electrons decelerates to **different** extent. [B1]

(ii) $E = \dfrac{hc}{\lambda}$

$(100\times10^{3})(1.60\times10^{-19}) = \dfrac{(6.63\times10^{-34})(3.00\times10^{8})}{\lambda}$ [C1]

$\lambda = 1.243\times10^{-11}$ m

$p = \dfrac{h}{\lambda}$

$= \dfrac{(6.63\times10^{-34})}{(1.243\times10^{-11})}$ [C1]

$= 5.3\times10^{-23}$ kg m s^{-1} [A1]

(iii) $\text{Force} = \dfrac{(1.6\times10^{5})(5.3\times10^{-23}-0)}{1}$ [C1]

$= 8.5\times10^{-18}$ N [A1]

(c) Photoelectric experiment. [B1]

Discussion of the evidence:

1) The existence of a threshold frequency below which no photoelectrons are emitted proves that electromagnetic radiation (EM) consists of discrete quanta of energy given by *hf*. [B1]

2) The instantaneous emission of photoelectrons when all the photon energy is transferred immediately to the electron in a single collision gives evidence to particulate nature of EM. [B1]

3) The maximum kinetic energy of the photoelectrons being dependent only on frequency of radiation *f*, which relates to the discrete energy of photon, and independent on the intensity of radiation also give evidence for the particulate nature of EM. [B1]