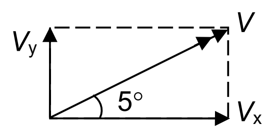
2017 Year 6 H2 Physics Prelim Paper 2 Mark Scheme

1 **(a)** Acceleration is defined as the rate of change of velocity with respect to time. [B1]

(b) **(i)**
$$v = u + (-g\sin\theta)t$$
$$= 9.0 + (-9.81\times\sin 26°)(0.70)$$ [M1]
$$= 5.99 = 6.0 \text{ m s}^{-1} \text{ (2 s.f.)}$$ [A0]

(ii) By the principle of conservation of energy,
gain in GPE = loss in KE
$$mgh = \frac{1}{2}m(u^2 - v^2)$$
$$h = \frac{u^2 - v^2}{2g}$$
$$= \frac{(9.0)^2 - (6.0)^2}{2(9.81)}$$ [M1]
$$= 2.29 = 2.3 \text{ m (2.s.f)}$$ [A1]

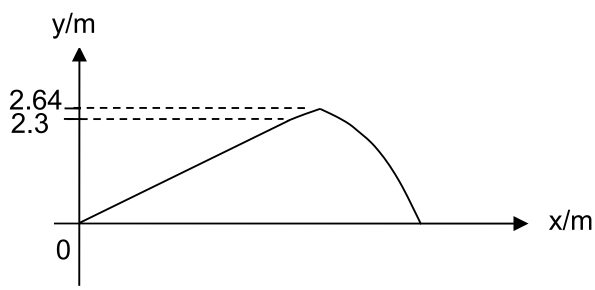
(c) **(i)**
$$\tan 5.0° = \frac{v_y}{v_x}$$
$$= \frac{v_y}{6.0\times\cos 26°}$$ [M1]
$$v_y = (\tan 5.0°)(6.0\cos 26°)$$
$$= 0.472 = 0.47 \text{ m s}^{-1}$$ [A0]



(ii)
$$v_y{}^2 = u_y{}^2 + 2as_y$$
$$s_y = \frac{v_y{}^2 - u_y{}^2}{2a}$$
$$= \frac{(0.47)^2 - (6.0\times\sin 26°)^2}{2(-9.81)}$$ [M1]
$$= 0.341 = 0.34 \text{ m}$$ [A1]

(ii) The momentum of the sphere is <u>not conserved</u> during the collision because there is <u>a net force acting on it due to the contact force by the ceiling</u> and <u>the gravitational force on it by the Earth.</u> [B1]

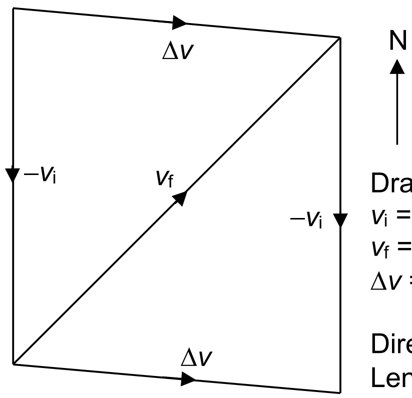
(d)



Linear displacement up the slope (must use ruler). [B1]
Shape of 2 disjointed parabolas (peak must be obvious). [B1]

2 (a) Vector quantities have magnitude and direction, whereas scalar quantities only have magnitude. [B1]

(b) (i)



Drawn to scale, where
v_i = initial velocity
v_f = final velocity
Δv = the change in velocity = $v_f - v_i$

Directions and labels of all vectors are correct. [B1]
Length of Δv is correct (accept 4.5 – 4.8 cm) [B1]

(ii) Using cosine rule,

$$\Delta v = \sqrt{v_i^2 + v_f^2 - 2v_i v_f \cos\theta}$$
$$= \sqrt{50.0^2 + 65.0^2 - 2\times 50.0\times 65.0\cos 45^\circ}$$
$$= 46.1\text{ km h}^{-1}$$
$$= 12.8\text{ m s}^{-1}$$

Using scale drawing,

$$\Delta v = 4.6\text{ cm}$$
$$= 46\text{ km h}^{-1}$$
$$= 12.8\text{ m s}^{-1}$$

[M1]

$$a_{ave} = \frac{\Delta v}{\Delta t} = \frac{12.8}{30} = 0.427\text{ m s}^{-2}$$ [A1]

(c) (i)

$$s_1 + s_2 = v_i t_1 + v_f t_2$$
$$= 50.0\times\frac{25.0}{60} + 65.0\times\frac{30.0}{60}$$
$$= 53.33 = 53.3\text{ km (3 s.f.)}$$ [A1]

(ii)

$$\frac{\Delta s_1}{s_1} = \frac{\Delta v_i}{v_i} + \frac{\Delta t_1}{t_1}, \text{where } s_1 = v_i t_1$$

$$\Delta s_1 = \left(\frac{\Delta v_i}{v_i} + \frac{\Delta t_1}{t_1}\right) v_i t_1 = (\Delta v_i)t_1 + v_i(\Delta t_1) = 0.5\times\frac{25.0}{60} + 50.0\times\frac{0.5}{60}$$ [M1]
$$= 0.208 + 0.416 = 0.625\text{ km}$$

$$\Delta s_2 = \Delta(v_f t_2) = (\Delta v_f)t_2 + v_f(\Delta t_2) = 0.5\times\frac{30.0}{60} + 65.0\times\frac{0.5}{60}$$ [M1]
$$= 0.250 + 0.542 = 0.792\text{ km}$$

$$\Delta s_1 + \Delta s_2 = \Delta(v_i t_1) + \Delta(v_f t_2)$$
$$= 0.625 + 0.792 = 1.417 = 1\text{ km (1 s.f.)}$$ [A1]

OR OR

$$s_{max} = 50.5 \times \frac{25.5}{60} + 65.5 \times \frac{30.5}{60} = 54.758 \text{ km}$$ [M1]

$$s_{min} = 49.5 \times \frac{24.5}{60} + 64.5 \times \frac{29.5}{60} = 51.925 \text{ km}$$ [M1]

$$\Delta s = \frac{s_{max} - s_{min}}{2} = \frac{54.758 - 51.925}{2} = 1.417 = 1 \text{ km}$$ [A1]

(iii) Total distance $= 53 \pm 1$ km (both values have the same precision) [B1]

3 (a) The principle of conservation of momentum states that the total momentum of a system remains constant, provided no net external force acts on it. [B1] [B1]

(b) (i) Taking the velocity to the right as positive. (Statement must be written.)

By the principle of conservation of momentum,

$$m_X u_X + m_Y u_Y = (m_X + m_Y)v$$

$$(2.2)(6.0) + (1.0)(-2.0) = (2.2 + 1.0)v$$ [M1]

$$v = 3.5 \text{ m s}^{-1}$$

Since we have taken velocity to the right as positive, the blocks move right. [B1]

Note: Accept – 3.5 m s^{-1}, if taken velocity to the left as positive.

(ii)

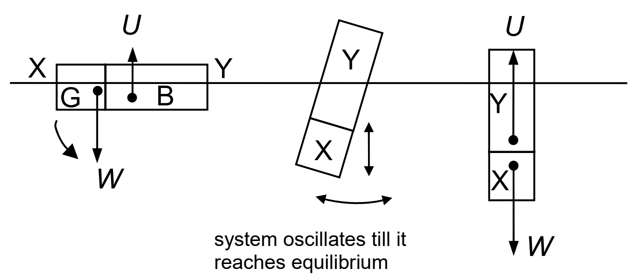
$$F_{ave} = \frac{\Delta p}{\Delta t}$$

$$= \frac{m(v_Y - u_Y)}{\Delta t}$$

$$= \frac{(1.0)(3.5 - (-2.0))}{0.35}$$ [M1]

$$= 15.7 = 16 \text{ N (2 s.f.)}$$ [A1]

(iii) 1.



Weight W and upthrust U creates a net moment on the system which causes the system of blocks to rotate anticlockwise and oscillate. [B1]

The blocks eventually reach equilibrium when there is no net force on the system where upthrust and weight are equal. [B1]

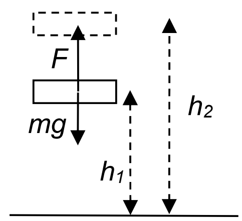
2. By N2L,

$$\text{upthrust} = \text{weight of blocks}$$
$$V_w \rho_w g = (m_x + m_y)g$$
$$(0.10 \times 0.10 \times h)(1000) = (2.2 + 1.0) \quad \text{[M1]}$$
$$h = 0.32 \text{ m} \quad \text{[A1]}$$

4 **(a)** The work done by a force is defined as the product of the force and the displacement in the direction of the force. [B1]

(b) Consider an object of mass *m* being raised upwards from height h_1 to height h_2 by an external force near the Earth's surface.

The external force required to lift the object at a constant speed is equal to its weight *mg*. [B1]



Increase in gravitational potential energy ΔE_p = work done by external force [M1]
= force × displacement in the direction of force
= $mg\,(h_2 - h_1)$
= $mg\,\Delta h$ [A0]

(Although it is not necessary for the speed to be constant, it is important that the speeds at the starting and ending point are the same so that there is no change in kinetic energy.)

(c) **(i)** By the principle of conservation of energy, the decrease in the gravitational potential energy of the blocks goes into the increase in kinetic energy of the blocks and the work done against friction. [B1]

Note: All energy gains and losses must be described to be awarded the mark.

(ii) By the principle of conservation of energy,
loss in GPE of system
$= \text{loss in GPE of block Q} - \text{gain in GPE of block P}$
$= m_Q g h - m_P g (h \sin 30^\circ)$
$= (3.0)(9.81)(0.45) - (1.0)(9.81)(0.45 \times \sin 30^\circ)$ [M1]
$= 11.04 = 11$ J (2 s.f.) [A0]

(iii) By the principle of conservation of energy,
loss in GPE = gain in KE + work done against friction
gain in KE = loss in GPE − work done against friction
$= 11.04 - (6.3)(0.45)$ [M1]
$= 8.20 = 8.2$ J (2 s.f.) [A1]

(iv) By the principle of conservation of energy,
loss in KE + loss in GPE = gain in EPE + work done against friction

$$8.20+(3.0)(9.81)e-(1.0)(9.81)(e\sin 30^\circ)=\frac{1}{2}(800)e^2+(6.3)e$$ [M1]

$$400e^2-18.225e-8.20=0$$

$$e=0.168\text{ m (reject }-0.122\text{ m)}$$ [A1]

OR
Alternatively, considering the whole motion:
loss in GPE = gain in EPE + work done against friction
gain in EPE = loss in GPE – work done against friction

$$\frac{1}{2}ke^2=\frac{5}{2}g(h+e)-f(h+e)$$

$$\frac{1}{2}(800)e^2=\frac{5}{2}(9.81)(0.45+e)-(6.3)(0.45+e)$$ [M1]

$$0=400e^2-18.225e-8.20125$$

$$e=0.168\text{ m (reject }-0.122\text{ m)}$$ [A1]

Allow e.c.f. of KE from part (iii).

(iv) A larger incline results in a smaller loss in the gravitational potential energy of the system. Hence, the maximum compression of the spring decreases. [B1]

5 **(a)** Internal energy is determined by the state of the system and it can be expresses as the sum of a random distribution of kinetic and potential energies associated with the molecules of the system. [B1]

(b) $pV = NKT$
$(1.05 \times 10^5) \times (2.9 \times 10^{-4}) = N \times (1.38 \times 10^{-23}) \times (303)$ [M1]
$N = 7.282 \times 10^{21} = 7.28 \times 10^{21}$ [A1]

(c)

$$E_K=\frac{3}{2}kT$$

$$=\frac{3}{2}\times\left(1.38\times10^{-23}\right)\times\left(303\right)$$

$$=6.272\times10^{-21}=6.27\times10^{-21}\text{ J}$$ [A1]

(d) **(i)**

$$\Delta U=\frac{3}{2}Nk\Delta T$$

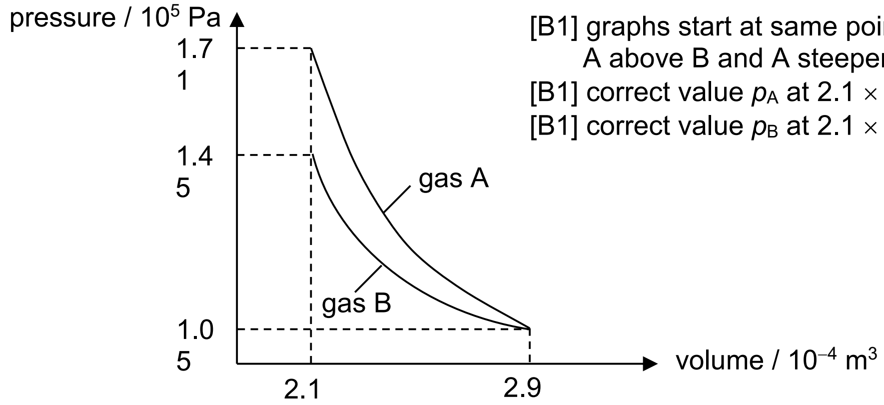
$$=\frac{3}{2}\left(7.282\times10^{21}\right)\left(1.38\times10^{-23}\right)\times\left(357-303\right)$$ [M1]

$$=8.14\text{ J}$$ [A1]

Allow e.c.f. from part (b).

(ii) Since gas A undergoes an adiabatic compression, $Q = 0$.
From the 1st law of thermodynamics,
$\Delta U = Q + W$
8.14 = 0 + W
W = 8.14 J [A1]

(iii)



[B1] graphs start at same point, with A above B and A steeper than B
[B1] correct value p_A at 2.1×10^{-4} m^3
[B1] correct value p_B at 2.1×10^{-4} m^3

For gas A, $\dfrac{PV}{T} = \text{ constant}$.

$$\frac{1.05\times10^5\times2.9\times10^{-4}}{303} = \frac{p_A\times2.1\times10^{-4}}{357} \Rightarrow p_A = 1.71\times10^5 \text{ Pa}$$

For gas B, PV = constant.
$(1.05 \times 10^5) \times (2.9 \times 10^{-4}) = p_B \times (2.1 \times 10^{-4}) \Rightarrow p_B = 1.45 \times 10^5$ Pa

6 (a) (i) Equation of graph is $V = E - Ir$, where gradient = $-r$ and vertical-intercept = E.

$$\text{Gradient} = \frac{0.000 - 1.050}{2.000 - 0.500} = -0.700\ \Omega$$ [M1]

$r = 0.700\ \Omega$ [A1]

$E = 1.050 + 0.700\times0.500 = 1.400$ V or read from graph (both 3 d.p.) [A1]

Note: Deduct [1] for wrong d.p. in this part, not the cover page.

(ii) The <u>maximum resistance of R is 2.10 Ω or is not infinite</u>, and hence the current cannot be reduced below 0.500 A. [B1]

(b) (i) $R = r$ [B1]

(ii) Since $R = r$, $V = E/2 = 1.400/2 = 0.700$ V [M1]

Hence, $I = V/R = 0.700/0.700 = 1.00$ A (3 s.f.) [A1]

OR OR

Applying the potential divider rule, the p.d. across the load resistance is equal to the p.d. across the internal resistance (since $R = r$).

Hence, p.d. across load is half of the e.m.f., which is $\dfrac{1.400}{2} = 0.700$ V. [M1]

From graph, the corresponding current is $I = 1.000$ A (3 d.p.). [A1]

(iii) Efficiency $\eta = \frac{P_{out}}{P_{in}} = \frac{I^2 R}{I^2(R+r)} = \frac{R}{R+r} = 50.0\%$ [A1]

Working or proof must be shown for mark to be awarded. Not allowed to quote.

(c) From above, $\eta = \frac{P_{out}}{P_{in}} = \frac{R}{R+r} = \frac{1}{1+r/R}$

Hence, maximum efficiency occurs when R is maximum.

From the graph, maximum $R = \frac{1.050}{0.500} = 2.10\ \Omega$ [M1]

Thus, maximum efficiency $= \frac{1}{1+0.700/2.10} \times 100\% = 75.0\%$ [A1]

OR OR

Maximum efficiency $= \frac{P_{out,max}}{P_{in}} = \frac{IV_{max}}{IE}$

$= \frac{1.050}{1.400}$ [M1]

$= 75.00\%$ [A1]

7 (a) (i) The magnetic force provides the centripetal force for the circular motion. [B1]

$Bqv = \frac{mv^2}{r}$ [M1]

$mv = Bqr$

$p = Bqr$

(ii) The particle which produces the track <u>loses energy</u> by ionizing the hydrogen atoms; hence, it slows down and the <u>radius of the track decreases</u>. [M1]

From the diagram, for the circular track to get smaller, the charged particle is moving in an <u>anti-clockwise direction</u>. [A1]

Note: DO NOT award anti-clockwise [A1], unless explanation [M1] is correct.

(iii) Since the charged particle is moving in an anti-clockwise direction and the magnetic field is acting into the page, by applying Fleming's left-hand rule, the particle is <u>positively charged</u>. [B1]

(b) (i) 1. l = 7.0 cm (accept 6.9 cm and 7.1 cm) [B1]
s = 1.5 cm (accept 1.4 cm and 1.6 cm) [B1]

2. $r = \frac{l^2}{8s} + \frac{1}{2}s = \frac{(7.0)^2}{8 \times 1.5} + \frac{1}{2} \times 1.5 = 4.833 \text{ cm} \simeq 4.8 \text{ cm}$ [A1]

(ii) **1.**

$$\frac{1.0\,\text{MeV}}{c} = \frac{\left(1.0\times10^{6}\right)\times\left(1.60\times10^{-19}\right)}{3.00\times10^{8}}$$ [M1]

$$= 5.3\times10^{-22}\ \text{kg m s}^{-1}$$ [A0]

2. $p = Bqr$

$$= \left(0.50\right)\times\left(1.60\times10^{-19}\right)\times(4.833\times10^{-2})$$ [M1]

$$= 3.8664\times10^{-21}\ \text{kg m s}^{-1}$$

$$= \frac{3.8664\times10^{-21}}{5.3\times10^{-22}}$$

$$= 7.3\ \ \text{MeV}\ c^{-1}$$ [A1]

(iii)

$$m_0 = \frac{p}{v}\sqrt{1-\left(\frac{v}{c}\right)^2}$$

$$= \frac{5.3\times10^{-22}}{0.89\times\left(3.00\times10^{8}\right)}\sqrt{1-\left(\frac{0.89c}{c}\right)^2}$$

$$= 9.1\times10^{-31}\ \text{kg}$$ [M1]

Since the particle's mass is similar to that of an electron and its charge is positive, it is a positron. [A1]
Allow e.c.f. from (a)(iii) and accept electron.

(c) **(i)** Correct LBF drawn. [B1]

(ii) The gradient is *n* and the vertical-intercept is *lg k.*

$$\text{Gradient} = \frac{2.04-0.00}{1.100-0.600}$$ [M1]

$$= 4.08$$

$$n = 4$$ [A1]

Substituting (1.100,2.04) and *n* = 4.08 into $\lg d = n\lg p + \lg k$,

$$2.04 = 4.08\left(1.100\right) + \lg k$$

$$\lg k = -2.448$$

$$k = 3.56\times10^{-3}\ \text{cm}\ (\text{MeV}\ c^{-1})^{-4}$$ [A2]

For *k*, award [1] for correct numerical value and [1] for correct units.
[1] mark deducted for wrong d.p. in this part, not on the cover page.
Allow e.c.f.

(iii)

$$p = \left(\frac{d}{k}\right)^{\frac{1}{4}} = \left(\frac{d}{3.56\times10^{-3}}\right)^{\frac{1}{4}}$$

$$= 4.09\,d^{\frac{1}{4}}\ \text{or}\ 4.1d^{\frac{1}{4}}$$ [A1]

(iv) It is not possible to determine the radius from a photograph when the track length is very short or when the circle is very small because both l and s cannot be measured accurately. [B1]