VICTORIA JUNIOR COLLEGE

SUGGESTED SOLUTIONS TO 2023 PHYSICS H1 PRELIM EXAM PAPER 2

Section A

Q1(a) The extension of a spring or wire is proportional to the external force applied provided the proportional limit is not exceeded. [1]

Q1(b) $F = k(x_2 - x_1)$ where x is the length of the spring. [1]

= 20(0.200-0.100) = 2.0 N [1]

$\Delta F = k(\Delta x_2 + \Delta x_1) = 20(0.001 + 0.001) = 0.04$ N [1]

Hence, $F = (2.00 \pm 0.04\ )$ **N** [1]

Q1(c) Let $x = x_2 - x_1$. So $U = \frac{1}{2}kx^2$. [1]

$$\frac{\Delta U}{U} = 2\frac{\Delta x_2 + \Delta x_1}{x_2 - x_1}$$ [1]

$$= 2\frac{0.1 + 0.1}{20.0 - 10.0} = 0.040$$ [1]

Q2(a) For the lower spring, the force acting on it is the weight of the lower mass. By Hooke's Law,

$Mg = ke_2$ or $e_2 = \frac{0.200(9.81)}{24.0} = 8.18\text{ cm}$ [1]

For the upper spring, $e_1 = \frac{2Mg}{k}$ [1]

$= 16.4\text{ cm}$ [1]

Q2(a)(ii)

The total elastic PE stored in the system is $E_{tot} = \frac{1}{2}ke_1^2 + \frac{1}{2}ke_2^2$ [1]

$$E_{tot} = \frac{1}{2}(24.0)(0.0818^2 + 0.164^2) = 0.403\text{ J}$$ [1]

Q2(a)(iii)

When the system is cut at P, the tension in the upper spring is 2*Mg* while the weight of the upper mass is *Mg*. [1]

By N2L, 2*Mg* – *Mg* = *Ma* [1]

Hence the upward acceleration of the upper mass is 9.81 m s^{-2} upwards. [1]

Q2(a)(iv)
The student's use of $v = u + at$ is wrong. [1]

This is because the acceleration of the mass is not constant. [1]

Q3(a) Tangential speed of acrobat B is $v = r\omega$ [1]
$= (2.0 + 1.1) \times 1.29 = 3.999 =$ **4.00 m s^{-1}** [1]

Q3(b)
The net vertical forces on A towards the centre of the circle provide the centripetal force for circular motion of acrobat A.

$$mg - N = \frac{mv^2}{r}$$

When acrobat A just loses contact with the cage, contact force $N = 0$

$$mg - 0 = \frac{mv^2}{r}$$ [1]

$$g = \frac{v^2}{r}$$

$$9.81 = \frac{v^2}{2.9}$$ (c.g. of A is 2.9 m from the centre) [1]

$v = 5.333 =$ **5.33 m s^{-1}** [1]

Q3(c) The net vertical forces on A provide the centripetal force for its circular motion.

$$mg + N = \frac{mv^2}{r}$$

When acrobat A is just in contact with the top of cage, contact force $N = 0$

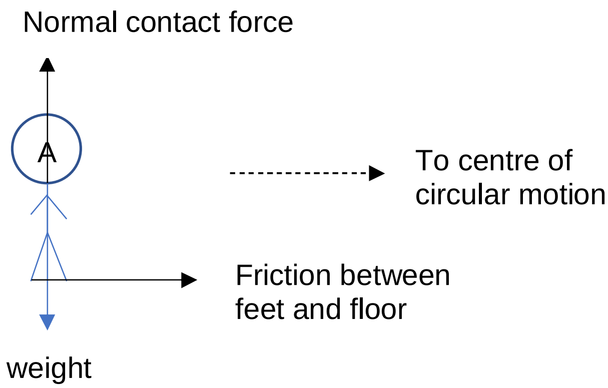
$$mg + 0 = \frac{mv^2}{r}$$ [1]

$$g = \frac{v^2}{r}$$

$$9.81 = \frac{v^2}{3.1}$$ (c.g. of A is 3.1 m from the centre)

$v = 5.5146 = 5.51$ m s^{-1}
Minimum velocity is **5.51 m s^{-1}** [1]

Q3(d)



[2]

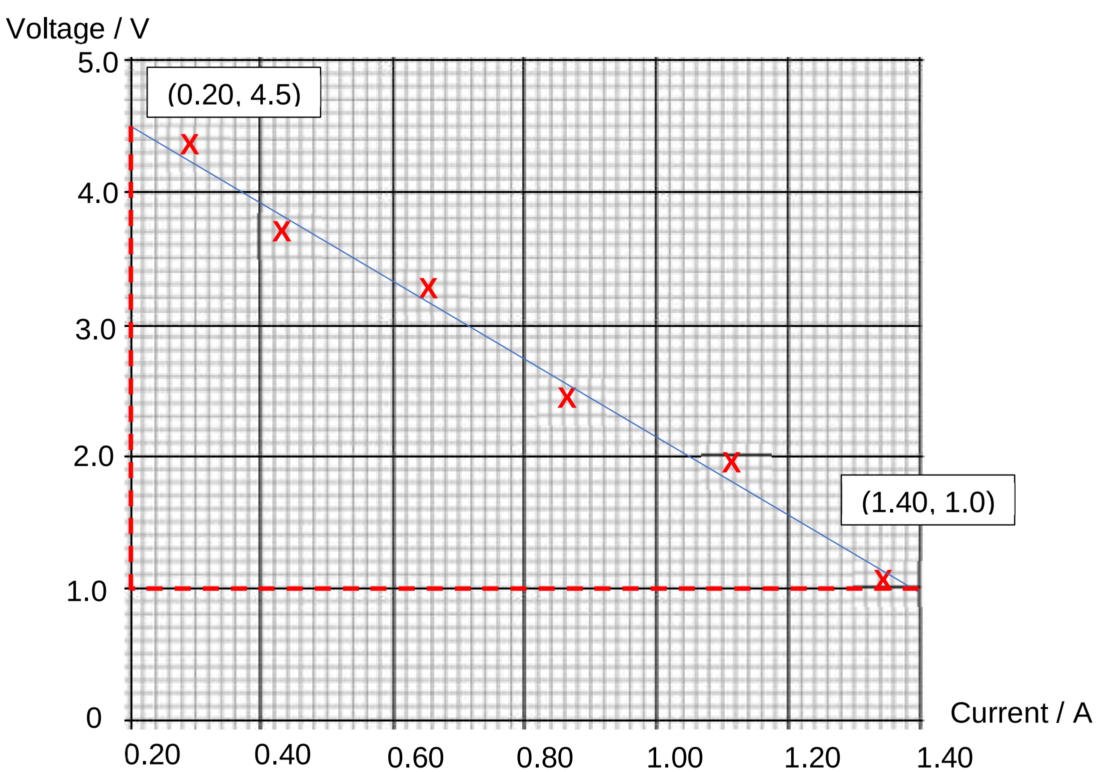
[1 mark for correct forces; 1 mark for identification of forces]

Q4(a)

$\varepsilon = 2V + Ir$

Rearranging, $2V = \varepsilon - Ir$ or $V = \frac{\varepsilon}{2} - \frac{r}{2}I$ [1]

Q4(b)



$V = \left(-\frac{r}{2}\right)I + \left(\frac{\varepsilon}{2}\right)$

[Apply knowledge of *y* = *mx* + *c*]

Thus, we can see that the gradient of this graph is equal to $\left(-\frac{r}{2}\right)$. [1]

Take gradient points (0.20, 4.5) and (1.40, 1.0),
(1m for gradient points correctly and clearly indicated and line clearly drawn)

$\left(-\frac{r}{2}\right) = \frac{y_2 - y_1}{x_2 - x_1}$

$\left(-\frac{r}{2}\right) = \frac{4.5 - 1.0}{0.20 - 1.40} = -2.917$ [1]

$r = 5.8333 = 5$ **83 Ω** [1]

Q4(c) Using point (1.40, 1.0) and $r = 5.8333\ \Omega$ substitute into $V = \left(-\frac{r}{2}\right)I + \left(\frac{\varepsilon}{2}\right)$

$1.0 = \left(-\frac{5.8333}{2}\right)(1.40) + \left(\frac{\varepsilon}{2}\right)$

$\varepsilon = 10.166$ = **10.2 V** [1]

Q4(d) When kept at $5.0\,\Omega$, the equation now becomes
$\varepsilon = V + I(5.0) + Ir$

Rearranging,
$V = \varepsilon - I(5.0 + r)$

$V = -(5.0 + r)I + \varepsilon$. Comparing to the original equation of line, $V = \left(-\frac{r}{2}\right)I + \left(\frac{\varepsilon}{2}\right)$

We see that the gradient will be steeper, more negative. [1]

The y-intercept will be doubled [1]

[*Note: No marks if student guesses without suitable explanation. Do not accept y-intercept is increased, as opposed to doubled. Not specific enough]*

Q4(e) By potential divider principle. $V = \frac{R_R}{R_{total}} \times \varepsilon$

To increase the reading of *V*, the total resistance of the circuit must fall. [1]

To reduce the resistance of LDR, it should be brighter. [1]

To reduce the resistance of thermistor, temperature should be higher. [1]

Q5(a) Half-life refers to the time taken for the number of a radioactive substance to decrease to half its initial value. [1]

Q5(b) Number of protons of $^{239}_{94}\mathrm{Pu}$ is **94.** [1]

Number of neutrons = 239-94 = **145** [1]

Q5(c) The power of the source is $P = AE$ where E is the energy of the emitted alpha-particle and A is the activity. [1]

Hence $A = \dfrac{2.5}{8.2x10^{-13}}$ = **3.05 x 10^{12} Bq** [1]

Assumptions: (1) the energy released is only via the alpha particles.

(2) the activity is effectively constant because of the long half-life. [1]

[choose one assumption for one mark]

Q5(d) When 40% of $^{239}_{94}\mathrm{Pu}$ nuclei have decayed, only 0.60 of the original nuclei are left. Hence using $\dfrac{N}{N_0} = \left(\dfrac{1}{2}\right)^n$ where $n = \dfrac{t}{t_{\frac{1}{2}}} = \text{number of half-lives}$, we have $0.60 = \left(\dfrac{1}{2}\right)^n$ or $n = 0.737$

[1]

Hence $0.737 = \dfrac{t}{2.4x10^4}$ or ***t*** =**1.77 x 10^4 yr** [1]

Q6(a)(i) $p_{water} = 190 \times 1000 \times 9.81$ = **1.86 x 10^6 Pa** [1]

Q6(a)(ii) Using Bernoulli's equation, $p_A + (1/2)\,\rho\, v_A^2 + h_A\,\rho\, g = p_B + (1/2)\,\rho\, v_B^2 + h_B\,\rho\, g$

$(p_{atm} + p_{water}) + (1/2)\,\rho\,(0)^2 + h_A\,\rho\, g = p_{atm} + (1/2)\,\rho\, v_B^2 + h_B\,\rho\, g$ [1]

$(p_{water}) + h_A\,\rho\, g = (1/2)\,\rho\, v_B^2 + h_B\,\rho\, g$

$(p_{water}) + (h_A - h_B)\,\rho\, g = (1/2)\,\rho\, v_B^2$

$1.86 \times 10^6 + 1100 \times 1000 \times 9.81 = (1/2) \times 1000\, v_B^2$

$v_B = 159.1\ \mathrm{m\ s^{-1}}$ [1]

$= 159\ \mathrm{m\ s^{-1}}$

Q6(a)(iii) The cylindrical volume of water that exits each pipe per second = $V/t = (\pi r^2)\, v$ [1]

Hence, mass of water that exits each pipe per second = $(\pi r^2)\, v\rho$

Hence, mass of water that exits 6 pipes per second = $6(\pi r^2)\, v\rho$

$= 6 \times \pi \times 0.081^2 \times 159 \times 1000$ [1]

= **1.97 × 10^4 kg s^{-1}**. [1]

Q6(a)(iv) Efficiency = electrical power output / work done by water per second [1]

0.92 = 183 MW / work done by water per second

Work done by water per second = **199 MW** [1]

Q6(a)(v) = $R\ \omega$ [1]

$v = 1.7 \times 500 \times 2\pi / 60 =$ **89.0 m s^{-1}** [1]

Q6(a)(vi) $P = F\,v$ [1]

$199 \times 10^6 = F \times 89.0$

$\boldsymbol{F = 2.24 \times 10^6}$ **N** [1]

Q6(b)(i) The shape of the bucket causes the direction of flow of the water to be reversed. [1]

This maximises the change in momentum of the water and so increases the force exerted by the water on the bucket. [1]

Q6(b)(ii) Possible answers:

- The buckets are not able to capture the kinetic energy of the impacting water entirely.
- Energy is wasted in overcoming any frictional or resistive forces present between the moving parts of the turbine or electric generator. [1]

Section B

Q7(a) Method 1: Using equations of motion and taking downwards to be positive:

$v^2 = u^2 + 2as = (1.5)^2 + 2(9.81)(0.65)$ [1]

Final speed = **3.9 m s^{-1}** [1]

<u>OR</u>

Method 2: Using conservation of energy

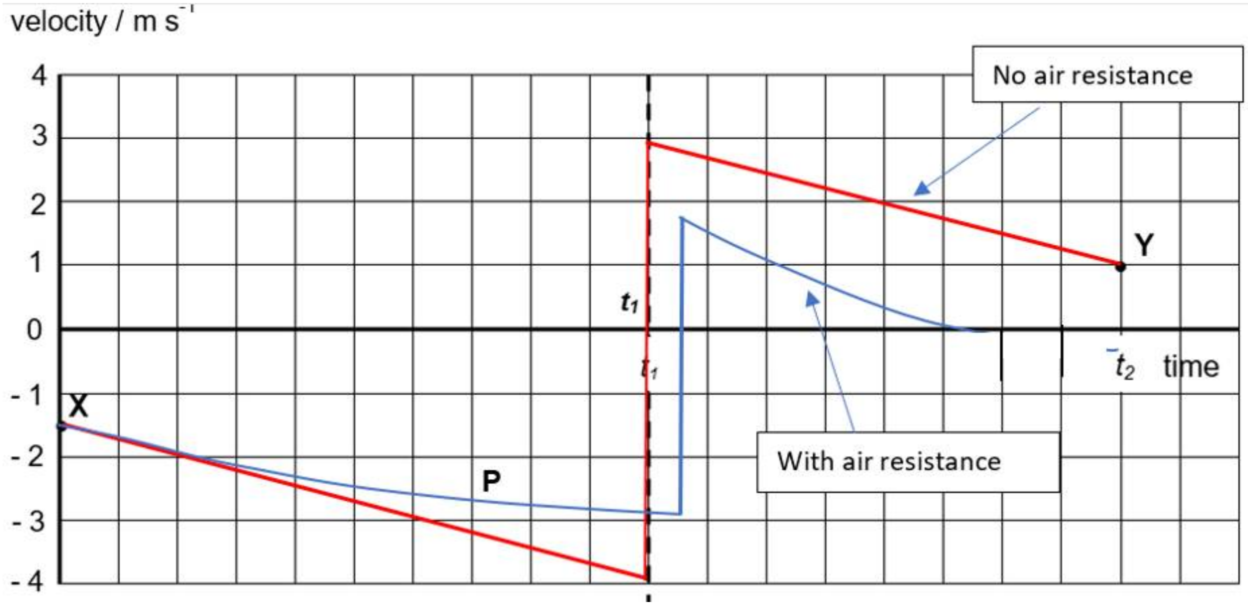
Loss in GPE = Gain in KE

$mgh = \frac{1}{2}m\left(v^2 - u^2\right)$

$9.81(0.65) = \frac{1}{2}\left(v^2 - 1.5^2\right)$ [1]

Final speed = **3.9 m s^{-1}** [1]

Q7(a)(ii)



- Straight line from X to – 3.9 m s^{-1} [1]
- Gradient straight line from t_1 to t_2 must be parallel to line in first segment [1]
- Line at t_1 may join the two straight lines but its width must be narrow. [1]

Q7(a)(iii)
The speed of the ball after rebound is less than the speed just before impact. The ground/Earth is assumed to be stationary, hence there is a loss in the kinetic energy of the system during the bounce. [1]
The bounce is inelastic. [1]

Q7(a)(iv)
- Downward motion: gradient gets less steep with time and is a curve. [1]
- The ball takes a longer time to strike the ground [1]
- Upward motion: speed of rebound should be smaller and the velocity-time curve for upward motion of the ball should cover a smaller area representing a lower maximum height reached [1]

Q7(b)(i) speed = 30 km h^{-1} = $\dfrac{30\times1000}{3600}=8.333\approx8.3$ m s^{-1}

Change in momentum = mass x change in velocity $=0.058\times(8.333-0)$ [1]

$=0.4833\approx$ **0.48 kg m s^{-1}** [1]

Q7(b)(ii) $\text{speed}^2 = (\text{horizontal component})^2 + (\text{vertical component})^2$

horizontal component $= \sqrt{\text{speed}^2 - (\text{vertical component})^2}$

$= \sqrt{8.333^2 - 1.5^2}$ [1]

$= \sqrt{67.194} = 8.197 \approx$ **8.2 m s^{-1}** [1]

Angle $\theta = \sin^{-1}\left(\dfrac{1.5}{8.333}\right)$ [1]

$=10.4^0 \approx$ **10^0** [1]

Q7(b)(iii) By principle of conservation of momentum,
Initial momentum of ball + initial momentum of target = final momentum of the system [1]

$0.058 \times 8.2 + 0.200 \times 0 = (0.058 + 0.200) \times v$

$v = 1.843 \approx$ **1.8 m s^{-1}** [1]

Q7(b)(iv) Option 1: decrease the angle so the vertical component is less than earlier, considering that the ball will reach the target in shorter time.

Option 2: increase the angle significantly such that the tennis ball will reach maximum height and then hit the target on its way down.

[*1 mark each for explanation and answer*]

Q8(a)(i)
Electric field strength at a point is defined as the electric force per unit charge that a positive test charge will experience when placed at that point. [1]

Q8(a)(ii) The magnetic fux density is the magnetic force per unit length of a conductor which carries a unit current, [1]
when the conductor is placed perpendicular to the magnetic field. [1]

Q8(a)(iii) The tesla is defined as the magnetic flux density such that a magnetic force of **1 newton per metre** is experienced by a straight current-carrying conductor carrying a current of **1 ampere** when the conductor is placed perpendicular to the magnetic field.

[*Each concept in bold is worth one mark.]*

Q8(b)(i)
The magnetic field is directed out of the plane of the paper. [1]

Q8(b)(ii)
The protons experience a magnetic force. [1]

As the magnetic force is always perpendicular to the direction of travel of the proton (or the magnetic force is always directed towards a point – the centre of a circle), the proton moves in a circular motion. [1]

Q8(b)(iii)

The magnetic force provides centripetal force for circular motion of the protons. [1]

$$Bev = m\frac{v^2}{r}$$

$$r = \frac{mv}{Be}$$ [1]

Q8(b)(iv)

$$\text{Time spent in one semi-circle} = \frac{\text{0.5 x circumference}}{\text{speed}}$$

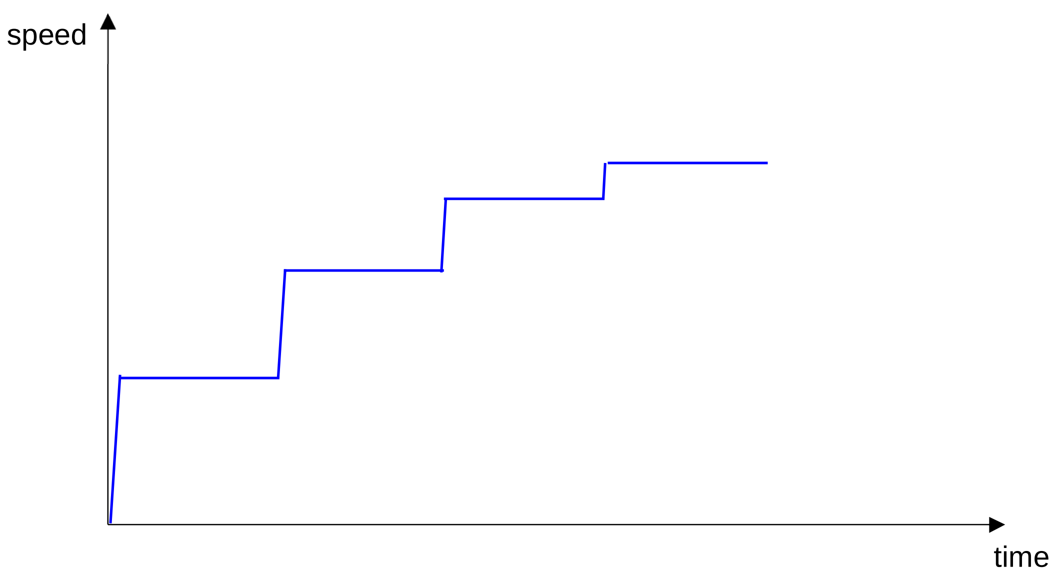
$$\text{OR: time spent in one semi-circle} = \frac{\text{period}}{2}$$ [1]

$$t = \frac{\pi r}{v} = \frac{\pi}{v}\left(\frac{mv}{Be}\right) = \frac{\pi m}{Be}$$ [1]

Q8(b)(v)

The time of travel in the dee, $t = \frac{\pi m}{Be}$, is independent of the speed of the proton. [1]

Q8(b)(vi)



4 steps (as asked in question) [1]
Duration of each step constant (as discussed in (b)(v)) [1]
Step-up progressively smaller * [1]

Q8(c)(ii)

The output energy of the particle is the kinetic energy when the particle moves in the biggest semi-circle available at radius *R.*

$$R = \frac{mv}{Be}$$

$$v^2 = \frac{B^2e^2R^2}{m^2}$$ [2]

$$E = \frac{1}{2}mv^2 = \frac{B^2e^2R^2}{2m}$$

[*1 mark to show to substitute r with R. 1 mark to substitute the expression into KE =* $\frac{1}{2}mv^2$]

Q8(b)(iii) $E = \dfrac{B^2q^2R^2}{2m} = \dfrac{(2.0)^2(1.6\times10^{-19})^2(2.3)^2}{2(1.67\times10^{-27})} = 1.62\times10^{-10}$ J [1]

***E* = 1.01 x 10^3 MeV** [1]

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