2018 SINGAPORE-CAMBRIDGE A LEVEL H2 PHYSICS P3 SUGGESTED ANSWER KEY (9749)

Written and Prepared by Mr Mitch Peh

Preface

Dear JC students in Singapore,
Hope you will find this A Level examination solution set useful for your revision.

The answers and comments to this solution set are personally crafted and written by Mr Mitch Peh, an experienced former MOE JC lecturer and tutor in Singapore. Currently, Mr Peh is a full time A Level private tutor, specialising in the teaching of A Level subjects: Physics, Chemistry, Mathematics and Economics at both H1 and H2 Levels. You can find the A Level solutions for the other subjects under the various subject tabs at www.jcpcme.com.

Mr Peh has a proven track record in helping his students achieve success for the A Levels and internal school examinations including promos, advancement tests to JC2, block tests, mid years and prelims. Most of Mr Peh's students achieve "A's and 'B's grades for the A Level examinations. During his stint teaching at St Andrew's Junior College, Mr Peh has helped his classes achieve 100% promotion to JC2 on multiple occasions, attain close to 100% "A"s for H1 Project Work, clinch accolades like "Most Improved Class Award" and "Best Performing Class of the Cohort" for many of the internal school examinations. Mr Peh also has former students who subsequently went on to pursue H3 subjects and enroll in prestigious university courses like Dentistry, Medicine and Law.

If you are interested to be coached by Mr Peh for your preparations towards the A Levels, these are 3 more reasons why you should join Mr Peh's classes:

1. Lessons can be fully customised to your needs

- You have the full autonomy to decide the subject(s), content and pace that you want to cover for each lesson, out of any of the 4 subjects: Physics, Chemistry, Mathematics or Economics.
- Mr Peh will help to analyse your weaknesses in each individual subject and provide personalised feedback and suggestions for improvement.

2. **Answers to your questions can be addressed outside of the classroom**

- If you face any difficulty or challenge doing any of your tutorial questions, simply take a screenshot with your phone and send it to Mr Peh via Whatsapp. Mr Peh will answer your questions in the earliest possible time when he is available.

3. **You only pay the price of 1 subject but enjoy premium coverage for all 4 subjects**.

- Mr Peh provides resources for all 4 subjects including summarised notes, compiled topical questions sourced from past year school prelim examinations, Practical guides for Chemistry & Physics, examination checklists, mock papers etc.
- This is probably the only tuition service in Singapore which allows you to enjoy such extensive coverage and benefits.

Note that Mr Peh only takes in a limited number of students each year. You can find his lesson slots available under "Tuition Services" tab at www.jcpcme.com. For any further enquiries, you can directly whatsapp him at 9651 7737.

For the solution set below, if you find any discrepancies or you have any feedback or comments, please kindly direct them to Mr Peh through Whatsapp at 9651 7737.

The question paper has been omitted due to copyright reasons.

Analysis of 2018 H2 Physics Paper 2 and 3

- In general for A Level Physics, the topics that have not been tested in Paper 2 would be tested in Paper 3. Hence, after sitting for A Level Physics Paper 2, you should study smart and focus on revising the topics that have not been tested before your Paper 3.

Topics tested in 2018 Paper 2	Topics tested in 2018 Paper 3
• Forces • Work, Energy and Power • Circular Motion • Superposition • Current and Electricity • DC Circuit • Electric Field (Minimal) • Quantum Physics • Graphical Analysis Skills • Data Analysis Skills	• Kinematics • Dynamics • Gravitation • Electric Field • Electromagnetism • Electromagnetic Induction • Alternating Current • Quantum Physics • Nuclear Physics • Oscillation (Section B) • Thermal Physics and Ideal Gas (Section B)

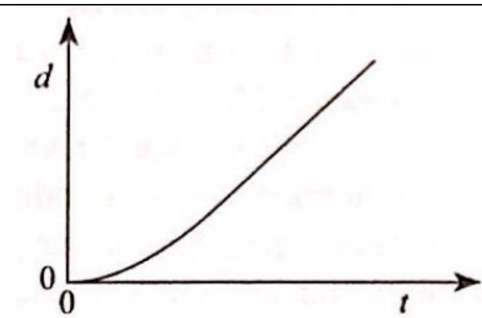
- For A Level Physics, definition questions can take up quite a significant proportion of the marks and they are placed at the beginning of questions so you must remember to study them before the exams. It is also not necessarily true that the definitions tested in the previous year would not be repeated and tested again.
- In this 2018 Paper 2 and 3, 26 marks out of a possible 180 marks were set aside on definitions alone. Definitions tested include principle of moments, Hooke's law, diffraction, threshold frequency, gravitational field (also tested in 2017 paper), magnetic flux density, magnetic flux linkage, root mean square value of alternating current (also tested in 2017 paper), photon, random process, spontaneous process, internal energy, first law of thermodynamics, ideal gas, simple harmonic motion were tested.
- Due to this emphasis on definitions for the A Levels, I have personally prepared definition lists for my students to make it easier and more efficient for your revision.
- Calculation questions are generally manageable, other than P3/Q6(c), so you should be able to solve most of them, just be vigilant and careful to avoid careless mistakes.
- A Levels also like to place some emphasis on graphical sketching and graphical analysis skills so make sure you are comfortable with interpreting graphs especially for the gradient of the graph and the area under graph.
- For explanation questions, the topics that they like to ask include electromagnetic induction with the use of Faraday's law and Len's Law (Tested in P3/Q4b), Quantum Physic (Tested in P2/Q4), explain whether motion can be considered as simple harmonic (Tested in P3/Q9). Hence, you should be well prepared for these topics.
- Overall, I would say that the 2 papers are very manageable and you should have ample time to complete and double check your answers. Good and targeted preparation are key to excel in this paper.

2018 A Level H2 Physics P3 Suggested Answer Key (9749)

Section A
Answer all the questions in the space provided

Q1 Topics: Kinematics, Electromagnetism on path of charged particle in magnetic field

<table>
<tr><td>(a)</td><td>



Comments

- Even though this question does not require an explanation for the shape of the distance against time graph, it will be good to understand as A Levels has tested the following explanation in some years.
- For the initial motion, the velocity of the ball will increase as its weight is greater than the air resistance acting on the ball, resulting in an acceleration on the ball downwards. Hence, the gradient becomes steeper as time progresses.
- As the velocity of the ball increases, air resistance acting on the ball will also increase.
- The ball will eventually reach terminal velocity when weight is equal to the air resistance acting on the ball. Then, the gradient of the distance-time graph becomes a constant value.

</td><td>[2]</td></tr>
<tr><td>(b)</td><td>

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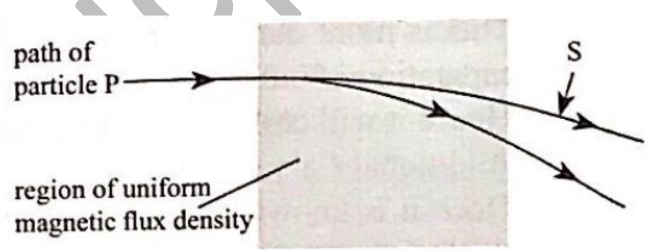
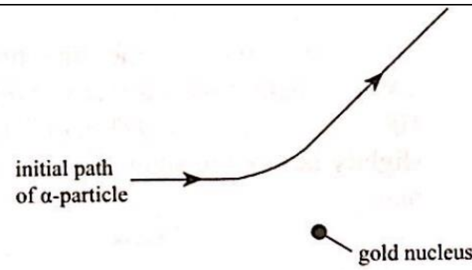


Comments

- Again, even though this question does not require an explanation for the shape of the path of particle S, it will be good to understand.
- The radius of the path of particle in magnetic field is given by $r = \frac{mv}{Bq}$. Hence, when the speed is doubled, the radius of the path of particle P increases, resulting in less deviation compared to the original path.
- Note that you must show that particle P will continue in a straight line after exiting the magnetic field as there is no longer any net force acting on the particle.

</td><td>[2]</td></tr>
</table>

(c)	 <u>Comments</u> Both the alpha particle and gold nucleus are positively charged. Hence, they will repel each other and the alpha particle will move away from the gold nucleus.	[2]
		[Total: 6]

Q2 Topic: Gravitation

(a)	A gravitational field is a region of space in which a mass experience a gravitational force of attraction due to the presence of other masses, with gravitational field strength given as force per unit mass.	[2]
(b) (i)	The separation between the Sun and Proxima Centauri is much greater than their diameters. Hence, they behave like point masses and Newton's law of gravitation can be used to calculate the force between them. <u>Comments</u> This question tests the condition required for applying Newton's law of gravitation	[1]
(ii)	$F = \frac{GMm}{R^2} = \frac{(6.67\times10^{-11})(2.0\times10^{30})(2.4\times10^{29})}{(4.0\times10^{16})^2}$ $= 2.0\times10^{16}\, N$ <u>Comments</u> • Some common mistake include forgetting to square the distance of separation between Sun and Proxima Centauri and forgetting to convert the unit km to m during the calculation.	[2]
(c)	• The acceleration it causes on the Sun is very small as the Sun is very massive. a = F/m = 1.0×10^{-14} ms^{-2}. • Hence, the effect of the force on the motion of the Sun is negligible.	[2]
		[Total:7]

Q3 Topics: Electric Field and Kinematics

(a) (i)	$F = qE = q\dfrac{V}{d} = \left(3.2\times10^{-19}\right)\left(\dfrac{900}{3.6\times10^{-2}}\right) = 8.0\times10^{-15}\,N(shown)$	[2]
(ii)	The weight of the particle can be considered as negligible as it is much less compared to the electric force. F_{net}= ma $a = \dfrac{F}{m} = \dfrac{8.0\times10^{-15}}{6.6\times10^{-27}} = 1.21\times10^{12}\,ms^{-2}$	[2]
(b)	• We need to first find the time it takes for the particle to leave the region of parallel plates. • Then, we calculate the vertical distance that the particle would have travelled in this time. If it can travel more than a vertical distance of 1.8cm, it will collide with the lower plate. $s_x = u_x t$ $t = \dfrac{s_x}{u_x} = \dfrac{7.5\times10^{-2}}{4.1\times10^{5}} = 1.8293\times10^{-7}\,s$ Hence, $s_y = \dfrac{1}{2}a_y t^2 = (0.5)\left(1.21\times10^{12}\right)\left(1.8293\times10^{-7}\right)^2$ $= 0.0202cm$ This is more than 1.8cm so it will collide with the lower plate <u>Comments</u> • Note that we should be comparing with the vertical distance of 1.8cm and not 3.6cm because the particle is travelling exactly in the middle of the 2 plates.	[3]
		[Total:7]

Q4 Topic: Electromagnetic Induction

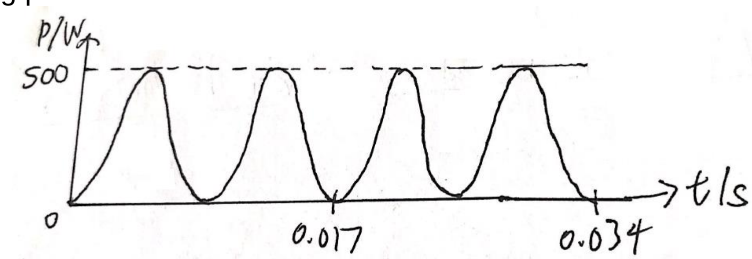
(a)(i)	• Magnetic flux density of a magnetic field is the magnetic force per unit length on a long straight conductor carrying unit current placed perpendicular to the magnetic field. • The magnetic force will be acting perpendicular to both the current and the magnetic field.	[3]
(ii)	• Magnetic flux linkage is the product of the magnetic flux linking the coil and the number of turns of the coil. • Magnetic flux through the coil is the product of the component magnetic flux density perpendicular to the plane of the coil and the area of the coil.	[2]
(b)	• When the switch is closed, there will be an increase in current which causes an increase in magnetic field by the coil. • This results in an increase in the magnetic flux linkage through the aluminium ring. • Furthermore, the soft iron core concentrates the magnetic field, causing the increase in the magnetic flux linkage through the aluminium ring to be large.	

	• By Faraday's law of electromagnetic induction, there will be an induced e.m.f in the aluminium ring which is proportional to the rate of change of magnetic flux linkage.
	• Since the ring is a conductor of electricity, a current is induced in it.
	• By Len's law, the induced current will flow such that it produces a magnetic force that opposes the change in magnetic flux linkage.
	• This results in magnetic poles of the same polarity on facing sides of the aluminium ring and the coil, causing a magnetic force to act on the aluminium ring upwards.
	• Thus, the aluminium ring will move vertically upwards.
	
	<u>Comments</u>
	• You should remember the general steps to explain how induced current is formed in an electrical component.
	  ○ Explain the change in magnetic flux linkage cutting through the component
	  ○ Use Faraday's law to explain the formation of induced e.m.f
	  ○ Explain the formation of induced current due to the circuit being closed or the component is good conductor of electricity
	  ○ If the question requires us to do so, we continue to use Len's law to explain the direction of magnetic force experienced by the electrical component.
	• Over here, initially, the aluminium ring is in equilibrium where contact force is equal to the weight. Once there is an additional magnetic force present, the aluminium ring will be able to move upwards.
		[4]

(c)	• The insulator ring does not move. Even though there is an induced e.m.f in it, current cannot flow through an insulator. • Hence, there is no induced current and no repelling magnetic poles produced in the ring. • As a result, there is no magnetic force produced which can cause the ring to move vertically upwards.	[2]
		[Total: 11]

Q5 Topic: Alternating Current

(a)	• Root mean square value of alternating current is the equivalent value of steady direct current that produces the same heating effect at the same average rate as the alternating current, in a given resistor. <u>Comments</u> • The direct current being steady must be mentioned here.	[2]
(b)(i)	From the given equation, $V = 170\sin 377t$, we can deduce that: V_0=170V $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120V$	[1]
(ii)	From the given equation, $V = 170\sin 377t$, we can deduce that: $2\pi f = 377$ $f = \frac{377}{2\pi} = 60Hz$	[2]

(iii)	$P_{ave} = \frac{V_{rms}^2}{R} = \frac{120^2}{58} = 248W$	[2]
(c)	Use your answer in (b) to sketch, on the axes of Fig 5.2, the variation with time t of the power transferred in the resistor. Include on your graph a time equal to two periods of the alternating potential difference.  <u>Comments</u> There should be four smooth curves and the peak power is (248)(2)=496W which is approximately 500W.	[3]
	[Total: 10]	

Q6 Topics: Quantum Physics, Dynamics

(a)	A photon is a discrete packet of energy of an electromagnetic radiation with energy, E=hf where h is the Planck's constant and f is the frequency of the radiation.	[2]
(b) (i)	Energy of a photon of the laser light is given by: $E = \frac{hc}{\lambda} = \frac{\left(6.63\times10^{-34}\right)\left(3\times10^{8}\right)}{680\times10^{-9}} = 2.93\times10^{-19}\ J$	[2]
(ii)	To find the number of photons incident per unit time on the surface, $I = \frac{nhf}{tA} \Rightarrow \frac{n}{t} = \frac{IA\lambda}{hc} = \frac{\left(3.1\times10^{3}\right)\pi\left(0.6\times10^{-3}\right)^2\left(680\times10^{-9}\right)}{\left(6.63\times10^{-34}\right)\left(3\times10^{8}\right)} = 1.2\times10^{16}\ s^{-1}$ (shown)	[2]
(c)	We have to consider the change in momentum for the photons which are reflected and absorbed separately. By de Broglie wavelength formula, $mv = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{680\times10^{-9}} = 9.75\times10^{-28}\ kgms^{-1}$ For the photons which are absorbed, the change in momentum is $9.75\times10^{-28}\ kgms^{-1}$ Hence, the vertical component of the force experienced is: $F = \frac{\Delta nmv}{\Delta t}\cos 52^0 = \left(1.2\times10^{16}\right)\left(0.45\right)\left(9.75\times10^{-28}\right)\cos 52^0$ $= 3.2415\times10^{-12}\ N$ For the photons which are reflected, the change in momentum can be given as $\left(2\right)\left(9.75\times10^{-28}\right)\cos 52^0$	[6]

<table>
<tr><td></td><td>Hence,
$F=\frac{\Delta nmv}{\Delta t}=\left(1.2\times10^{16}\right)\left(0.55\right)\left(2\right)\left(9.75\times10^{-28}\right)\cos52^{0}$
$=7.9236\times10^{-12}N$

Thus the total force acted by the surface on the photons is
$3.2415\times10^{-12}+7.9236\times10^{-12}=1.12\times10^{-11}N$

By Newton's third law, the photons will exert a force of the same magnitude but in the opposite direction on the surface which is $1.12\times10^{-11}N$

<u>Comments</u>
• This is the most difficult question in the 2018 H2 Physics Paper 2 and 3.
• Remember that for the absorbed photons, we have to consider the component of the force which is acting vertically as well.
• This is because the question has stated explicitly that we want to find the force F <u>normal</u> to the surface exerted by the laser light on the surface.</td><td></td></tr>
<tr><td colspan="3" align="right">[Total:12]</td></tr>
</table>

Q7 Topic: Nuclear Physics

<table>
<tr><td>(a)</td><td>• Random: The actual decay deviates from a smooth exponential graph with fluctuations in between so that it is impossible to predict exactly when a particular radioactive nucleus will disintegrate.
• Spontaneous: The rate of decay is unaffected by external stimuli such as temperature and pressure. Chemical reactions also does not affect the rate of decay.</td><td>[2]</td></tr>
<tr><td>(b)
(i)</td><td>From Fig 7.1, the half-life is about 15 days.
$\lambda=\frac{\ln2}{t_{0.5}}=\frac{\ln2}{15\times24\times60\times60}=5.3\times10^{-7}s^{-1}$ (shown)
<u>Comments</u>
We do not have to take into account background count rate in this question.</td><td>[3]</td></tr>
<tr><td>(ii)</td><td>From Fig 7.1, the initial activity is $5.8\times10^{5}s^{-1}$,
$A=\lambda N\Rightarrow N=\frac{A}{\lambda}=\frac{5.8\times10^{5}}{5.3\times10^{-7}}=1.0943\times10^{12}$
Hence, the initial mass is given by:
$\frac{1.0943\times10^{12}}{6.02\times10^{23}}\times32=5.82\times10^{-11}g$

<u>Comments</u>
• Note that since the question in (i) already provided the value of decay constant as 5.3 x 10^{-7} s^{-1}, we should just use this value in our calculations.
• If we had used the more exact value of 5.348 x 10^{-7} s^{-1}, we will obtain initial mass to be 5.76x10^{-11}g.</td><td>[2]</td></tr>
</table>

		[Total:7]

Section B
Answer one question from this Section in the spaces provided.

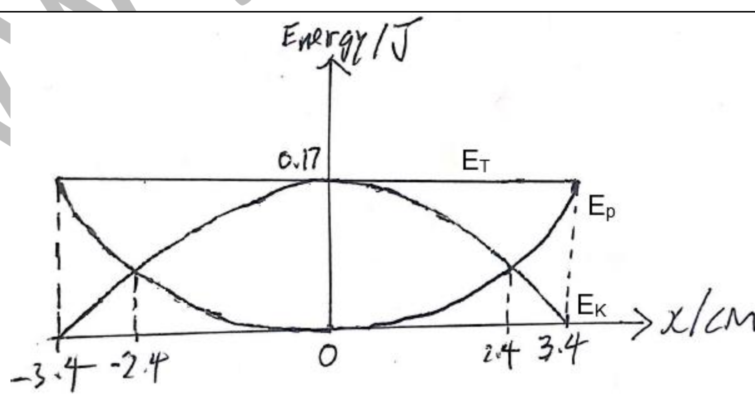
Q8 Topics: Thermal Physics and Ideal Gas

(a) (i)	• Internal energy of a system is the sum of the molecular kinetic energy due to the random motion of the molecules and the molecular potential energy due to intermolecular forces of attraction.	[2]
(ii)	+q: Thermal system supplied to the system by heating +w: Work done on the system	[2]
(b) (i)	An ideal gas is a hypothetical gas that obeys the equation of state of an ideal gas pV=nRT for all pressure p, volume V, amount n and temperature T.	[2]
(ii)	Number of molecules $pV = NkT \Rightarrow N = \frac{pV}{kT} = \frac{(5.4\times10^5)(1.2\times10^4\times10^{-6})}{(1.38\times10^{-23})(273+57)}$ $=1.4229\times10^{24}$ $=1.42\times10^{24}$ molecules $(3s.f.)$ Mean KE of one molecule $KE = \frac{3}{2}kT = \frac{3}{2}(1.38\times10^{-23})(273+57)$ $=6.8310\times10^{-21}$ $=6.83\times10^{-21}(3s.f.)$ Total internal energy For ideal gas, molecular potential energy is negligible as the intermolecular forces of attraction between molecules is negligible. Hence, total internal energy = total molecular kinetic energy $=(1.4229\times10^{24})(6.8310\times10^{-21})$ $=9.7198\times10^3\,J$ $=9.72\times10^3\,J\,(3s.f.)$ Comments • We need to remember to convert the temperature in Degree Celsius to thermodynamic temperature in Kelvin.	[3] [2] [2]

(c) (i)	$\Delta U = \frac{3}{2}Nk\Delta T = \frac{3}{2}\left(1.4229\times10^{24}\right)\left(1.38\times10^{-23}\right)\left(155-57\right)$ $= 2.8865\times10^{3}\,J$ $= 2.89\times10^{3}\,J\,(3s.f.)$ Comments • Some students may use the longer method of finding the total internal energy at 155^0C and minus the value obtained in (b)(ii).	[3]
(ii) 1.	Volume must be constant so that no work is done and hence, increase in internal energy is equal to the thermal energy supplied to the constant mass during the heating process.	[2]
2.	The thermal energy supplied to the constant mass of gas during the heating process, Q, and molar heat capacity, C, can be related through the following: $Q = nC\Delta T \Rightarrow C = \frac{Q}{n\Delta T}$ where n = $\frac{\text{Number of molecules}}{6.02\times10^{23}}$ $C = \frac{\left(2.8865\times10^{3}\right)\left(6.02\times10^{23}\right)}{\left(1.4229\times10^{24}\right)\left(155-57\right)} = 12.5\,Jmol^{-1}K^{-1}$ Comments • This question requires some thinking skills as the formula for thermal energy here is a modification of the formula that you usually see in the lecture notes.	[2]
		[Total: 20]

Q9 Topic: Oscillations

(a)(i)	• Simple harmonic motion is an oscillatory motion in which acceleration is directly proportional to the displacement from equilibrium position and acceleration is always directed towards the equilibrium position.	[2]
(ii)	• The mass is oscillating as the sign of the acceleration is always opposite to the sign of the displacement. Hence, the acceleration is always directed towards the equilibrium position. Also, the magnitude of the acceleration increases as the magnitude of the displacement increases. Hence, this causes the mass to be oscillating. • The oscillations are not considered simple harmonic as the acceleration is not directly proportional to the displacement from equilibrium position. This is shown as the graph is not a straight line passing through the origin, but instead there is a curved portion at the right end of the graph.	[2]
(b)(i) 1	• The position of the plate for the sand to lose contact with the plate is at the maximum height. Comments • For the sand to lose contact with the plate, we need acceleration of the plate to be downwards and of at least the same magnitude as gravitational acceleration, g = $9.81ms^{-2}$.	[1]

	• At the highest point, the acceleration of the plate downwards is of the greatest magnitude since $a = -\omega^2 x$	
2	$a = \omega^2 x \Rightarrow x = \dfrac{a}{\omega^2}$ $x = \dfrac{9.81}{\left(2\pi(13)\right)^2}$ $= 1.4704 \times 10^{-3} m = 1.47 mm$	[3]
(ii)	• When the sand is replaced by pebbles, the minimum amplitude of oscillations would not be different. • This is because the condition for losing contact with the plate is when acceleration of the plate downwards, a, is at least of the same magnitude as gravitational acceleration, g i.e. $\lvert a \rvert \geq \lvert g \rvert$ which is independent of the mass of the object.	[2]
(c) (i)	<u>Total energy E_T</u> $E_T = \dfrac{1}{2} m\omega^2 x_0^2 = (0.5)(1.2)(2\pi \times 2.5)^2 (3.4 \times 10^{-2})^2$ $= 0.17114 J = 0.171 J (3 s.f.)$ <u>The displacement d at which the potential energy E_p and the kinetic energy E_k of the oscillations are equal.</u> When KE and PE are equal, PE is equal to half the E_T $\dfrac{1}{2} m\omega^2 x^2 = (0.171)(0.5)$ $x = \sqrt{\dfrac{0.171}{(1.2)(2\pi \times 2.5)^2}} = 2.4032 \times 10^{-2} m = 2.40 cm$	[2] [2]
(ii)	 <u>Comments</u> • E_T has a constant value of 0.17J • E_p is a parabola of the form $\dfrac{1}{2} m\omega^2 x^2$	[6]

	• E_K is an inverted parabola of the form $\frac{1}{2}m\omega^2\left(x_0^2 - x^2\right)$	
		[Total: 20]

End of solutions