



JURONG JUNIOR COLLEGE

Preliminary Examination 2009

Name: _____

Class: 08 _____

PHYSICS
Higher 2

9745/02

Paper 2

26 Aug 2009

1 hour 15 min

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your **name** and **class** in the spaces provided at the top of this page.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.
Do not use highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
1	/6
2	/6
3	/6
4	/8
5	/6
6	/6
7	/8
8	/14
Total	/60

(This question paper consists of **xx** printed pages)

Data

speed of light in free space,	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1} = (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant,	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant,	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall,	$g = 9.81 \text{ m s}^{-2}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p \Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$v = \pm \omega \sqrt{(x_0^2 - x^2)}$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$
alternating current / voltage,	$x = x_0 \sin \omega t$
transmission coefficient,	$T = \exp(-2kd)$
	where $k = \sqrt{\frac{8\pi^2 m(U - E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

- 1 (a) State the principle of conservation of *linear momentum*. [1]

Soln

Total linear momentum of a system of interacting bodies is constant provided that there is **no external resultant force acting on the system**.

- (b) A railway truck of mass 22000 kg and moving at a speed of 3 m s^{-1} catches up and collides with a truck of mass 66 000 kg moving at 1 m s^{-1} moving in the same direction as shown in Fig.1.1.

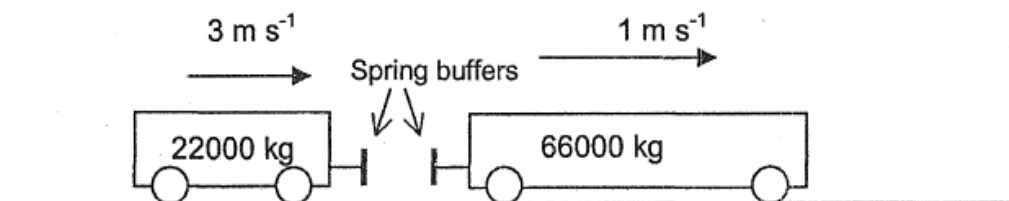


Fig.1.1

Fig.1.2 shows the speeds of the trucks before, during and after the collision.

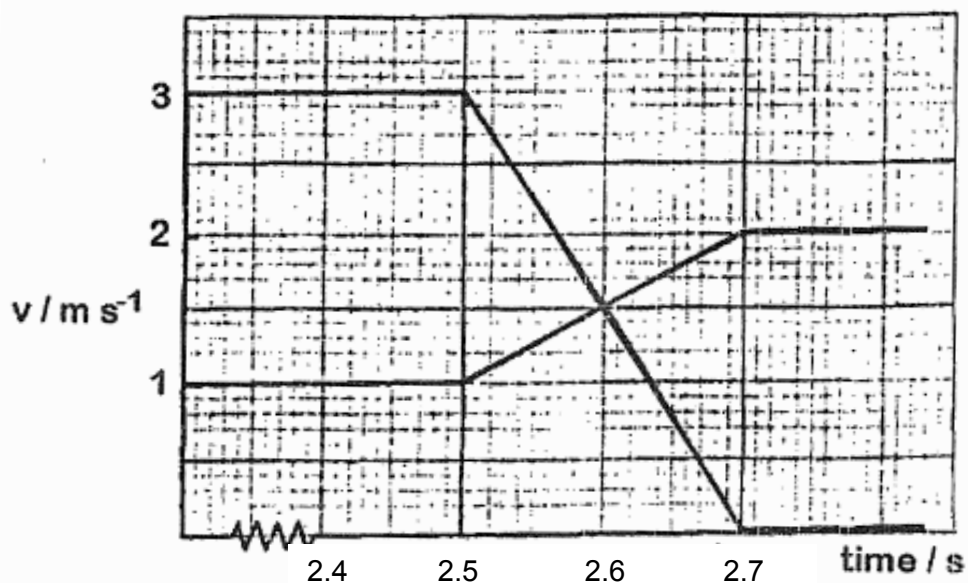


Fig.1.2

- (i) Calculate the magnitude of the impulse exerted by the lighter truck on the heavier truck during the collision. [2]

Soln:

$$\text{Impulse} = \text{change in momentum} = 22000 (3) - 0 = 66\,000 \text{ Ns}$$

- (ii) Use the information from Fig1.2 to determine whether the collision is elastic. [2]

Soln:

$$\text{Total KE before collision} = \frac{1}{2} (22000)(3)^2 + \frac{1}{2} (66000) (1)^2 = 132\,000 \text{ J}$$

$$\text{Total KE after collision} = 0 + \frac{1}{2} (66000) (2)^2 = 132\,000 \text{ J}$$

Since Total KE before and after collision are the same,
OR relative speed of approach = relative speed of separation

$= 3 - 1 = 2 - 0 = 2 \text{ m s}^{-1}$
the collision is **elastic**

- (iii) The total kinetic energy at the instant halfway through the collision at $t = 2.6 \text{ s}$ is **lower** than the total kinetic energy of the trucks after the collision. Suggest a reason for this difference. [1]

Soln:

Difference in energy is stored as **elastic potential energy in the springs.**

- 2 One of the late Michael Jackson's famous dance moves was the seemingly physics-defying 45° leaning dance move where he leaned his body forward at 45° to the ground and remained in equilibrium in that position for a few seconds without falling forward as shown in the Fig.2.1.



Fig.2.1

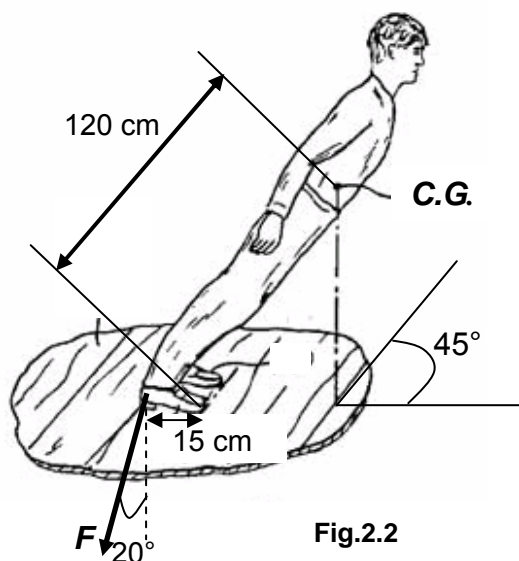


Fig.2.2

In fact, the dance was only made possible due to specially-made shoes which were hitched to the floor, preventing Michael from falling forward onto the ground.

Fig.2.2 shows the force F acting on the body by the hitching mechanism which is 20° from the vertical and the position of the centre of gravity (C.G.) which is 120 cm from the tip of the shoe. The horizontal distance between the tip of the shoe to the hitching mechanism is 15 cm.

- (a) State the two conditions necessary for a body to be in equilibrium. [1]

The resultant force is zero. &
The resultant torque is zero. [1]

- (b) (i) Taking the tip of the shoe to be the pivot and the weight of Michael to be 570 N, calculate the value of F when Michael was doing the 45° leaning dance move. [2]

Clockwise moment = anti-clockwise moment
 $570 \times 120 \sin 45^\circ = F \times \cos 20^\circ \times 15$ ----- [1]
 $F = 3430 \text{ N}$ -----[1]

- (ii) Determine the magnitude of the force acting on the tip of the shoe by the ground. [3]

Vertically: $R_y = 3430 \cos 20^\circ + 570 = 3790 \text{ N}$

Horizontally: $R_x = 3430 \sin 20 = 1170 \text{ N}$

$$R = \sqrt{(3790)^2 + (1170)^2} \quad \text{working--}[2]$$

$$= 3970 \text{ N} \quad \text{answer- [1]}$$

- 3 (a) Explain what is meant by *simple harmonic motion* performed by an object. [1]

The acceleration of the object is directly proportional to its displacement from equilibrium position but in the opposite direction.

- (b) An object oscillates with simple harmonic motion horizontally with an amplitude of 30 mm and a frequency of 5.0 Hz. Determine its

- (i) angular velocity. [1]

$$\omega = 2\pi f = 2\pi(5) = 31.4 \text{ rad s}^{-1}$$

answer:1

- (ii) acceleration at a position midway between the equilibrium position and amplitude position. [2]

$$a = \omega^2 x = (31.4)^2 (0.015) = 14.8 \text{ m s}^{-2} \quad \text{substitution:1, answer:1}$$

- (iii) speed at a position midway between the equilibrium position and amplitude position. [2]

$$v = \omega \sqrt{x_0^2 - x^2} = (31.4) \sqrt{(0.030)^2 - (0.015)^2} = 0.816 \text{ m s}^{-1}$$

substitution:1, answer:1

- 4 (a) State two conditions for two-source interference fringes to be *observable*. [2]

Any 2 of the following 5 points.

- The sources must be coherent OR maintain a constant phase difference.
- The 2 waves must meet.
- The principle of superposition must apply OR the sources must produce the same type of waves.
- The sources must have (approximately) the same amplitude.
- For transverse waves, the sources must be unpolarised or polarised in the same plane.

- (b) Fig.4 below shows an arrangement for observing interference fringes.

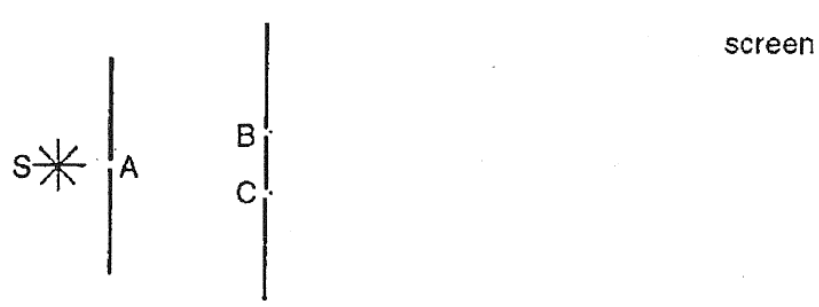


Fig.4

A monochromatic light source S illuminates a narrow slit A which acts as a source for the narrow double-slit B and C to produce fringes on the screen.

State and explain what change(s), if any, will be observed in the fringe pattern on the screen when each of the following changes is made independently. (Changes to brightness in fringe patterns need not be considered even if applicable.)

- (i) Increasing the distance between the double slit and the screen. [1]

Fringe separation increases since it is proportional to slit-screen distance.
[A1]

- (ii) Shifting slit A a small distance towards the double slit (towards right of page). [1]

No change in fringe separation since no change in slit-screen distance.
[A1]

- (iii) Shifting slit A a small distance upwards (towards top of page). [2]

Fringe pattern shifts downwards. [A1]

Path AB is shorter than AC, hence central maximum (for which path difference is zero) will shift downwards. [A1]

- (iv) Replacing source S with a white light source. [2]

A continuous coloured spectrum will be observed for each maximum or the central maximum being a narrow white fringe. [A1]

Different wavelengths of light have different fringe separation. [A1]
All the different wavelengths of light will interfere constructively at the central maxima.

- 5 Fig.5.1 shows the position of a fixed point charge of $+q$ at position Z and another point charge of -2.0 C at position Y which is 0.30 m apart.

Fig.5.2 shows the variation with displacement d of the electric field strength E due to the fixed point charge $+q$ at Z.

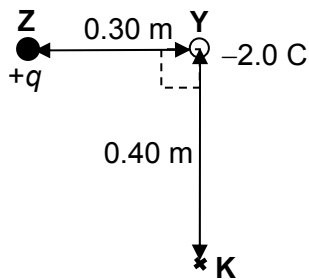


Fig.5.1

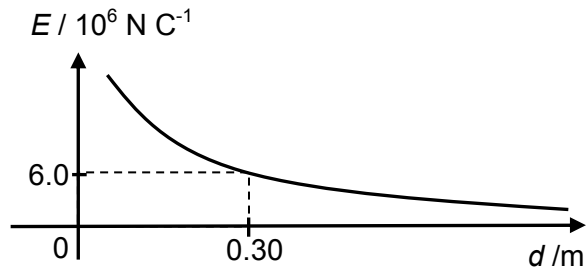


Fig.5.2

- (a) Calculate the magnitude of the fixed point charge $+q$ at Z. [1]
- (b) Calculate the magnitude of the electric force acting on point charge -2.0 C at position Y. [1]
- (c) On Fig.5.3, sketch a graph showing the variation with d of the electric force acting on this point charge of -2.0 C . [1]

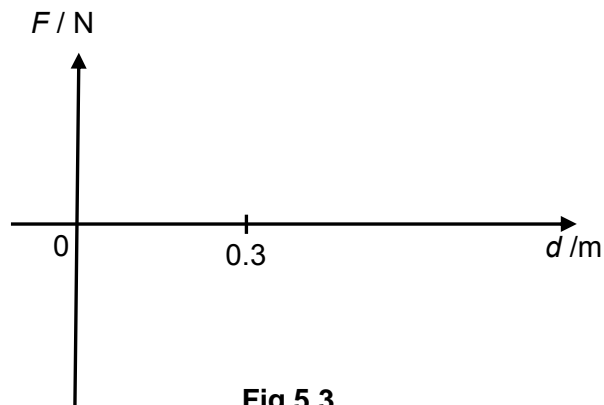


Fig.5.3

- (d) The point charge is displaced from position Y to K. Calculate the work done on this point charge. [3]

Solutions:

- (a) $Q = E (4\pi\epsilon_0 r^2) = (6.0 \times 10^6) \times 4\pi\epsilon_0 \times 0.3^2 = 6.00547 \times 10^{-5} \approx \underline{6.01 \times 10^{-5} \text{ C}}$
 (b) $F = EQ = 6.0 \times 10^6 \times 2 = \underline{1.20 \times 10^7 \text{ N}}$
 (c)

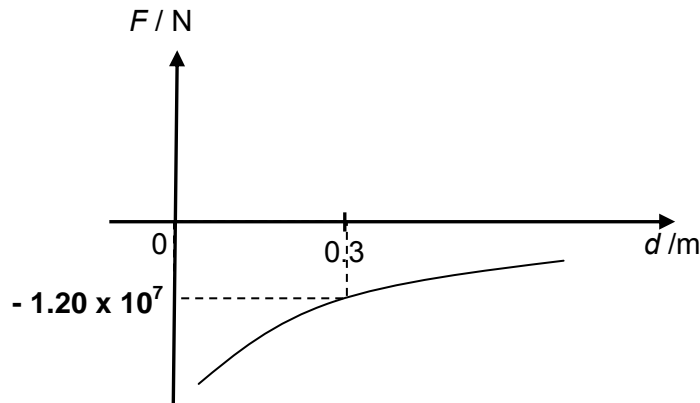


Fig.5.3

(d)

$$r_k = \sqrt{(0.3^2 + 0.4^2)} = 0.5 \text{ m}$$

$$\text{Work done} = Q (\Delta V) = \{Q_1 Q_2 / (4\pi\epsilon_0)\} (1/r_k - 1/r_y) \text{-----[1]}$$

$$= \{(-2) \times (6.01 \times 10^{-5}) / (4\pi\epsilon_0)\} \times \{(1/0.5) - (1/0.3)\} \text{-----[1]}$$

$$= \underline{+ 1.44 \times 10^6 \text{ J}} \text{-----[1]}$$

- 6 (a) State two conditions required to produce a laser beam. [2]

The excited state of the system must be in a metastable state.
 The system must undergo population inversion.
 Emitted photons are confined between two reflecting surfaces + long enough to allow them to stimulate further emission from other excited atoms.

Any 2 conditions -- [2]

- (b) State two differences between the light produced by Neon-Helium Laser and from a LED (Light Emitting Diode) torchlight. [2]

Light from laser is highly directional;
 Light from laser coherent or monochromatic.

[2]

- (c) A typical helium-neon laser emits laser light at a wavelength of 638 nm and has a power of 1.4 mW. Calculate the rate of emission of photons. [2]

$$P = \frac{E}{t} = \frac{n \times \frac{hc}{\lambda}}{t}$$

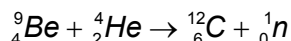
$$\frac{n}{t} = \frac{P}{\frac{hc}{\lambda}} = \frac{1.4 \times 10^{-3}}{\frac{6.63 \times 10^{-34} \times 3 \times 10^8}{638 \times 10^{-9}}} \text{---[1]}$$

$$= 4.49 \times 10^{15} \text{ s}^{-1} \text{---[1]}$$

- 7 (a) Explain the term *nuclear binding energy*. [2]

Nuclear binding energy of a nucleus is the minimum energy required to break the nucleus into its individual nucleons. (2 or 0)

- (b) When a beryllium nucleus is bombarded with an α -particle, a carbon nucleus is produced, represented by the equation



The masses of the nuclei are:

nuclei	mass / u
beryllium	9.01212
α -particle	4.00260
carbon	12.00000
neutron	1.00867

- (i) Calculate the loss of mass which takes place in the reaction. [2]

$$\begin{aligned} \text{loss of mass, } \Delta m &= 9.01212 + 4.00260 - 12.00000 - 1.00867 && \text{working (1)} \\ &= \underline{\underline{0.00605 \text{ u}}} && \text{answer (1)} \end{aligned}$$

- (ii) Calculate the energy equivalent of this mass. [2]

$$\begin{aligned} E = mc^2 &= (0.00605)(1.66 \times 10^{-27})(3.00 \times 10^8)^2 && \text{working (1)} \\ &= \underline{\underline{9.04 \times 10^{-13} \text{ J}}} && \text{answer (1)} \end{aligned}$$

- (c) Explain why fusion of nuclei having high nucleon numbers is not associated with a release of energy. [2]

When fusion of nuclei having high nucleon numbers takes place, the product has an even higher nucleon number. The products of fusion have a total mass that is larger than the reactants, so energy is absorbed instead of being released in fusion.

OR The products are nuclei with lower binding energy per nucleon, which are more unstable, i.e. with higher energy content. So energy is absorbed instead of being released.

- 8 Many years ago, Johannes Kepler suggested that planet's orbits about the Sun are not really circular in nature. Instead, they should follow the relation $T^2 \propto d^3$, whereby T refers to the period and d the mean distance from the planet to the centre of the Sun. This became to be known as Kepler's third law.

A student wishes to test whether Kepler's third law applies to some of the satellites orbiting Uranus. The student obtains the data shown in Fig.8.1 for the mean distance d of the satellite from Uranus and the period T of the revolution of the satellite about Uranus.

Name of satellite	d / km	T / day	$\lg (d/\text{km})$	$\lg (T/\text{day})$
Rosalind	69 930	0.558	4.845	-0.475
Belinda	75 260	0.624	4.877	-0.205
Puck	86 010	0.762	4.935	-0.118
Miranda	129 780	1.414	5.110	0.150
Ariel	191 240	2.520	5.282	0.401
Titania	435 840	8.706	5.639	0.940
Oberon	582 600	13.463	5.765	1.129

Fig.8.1

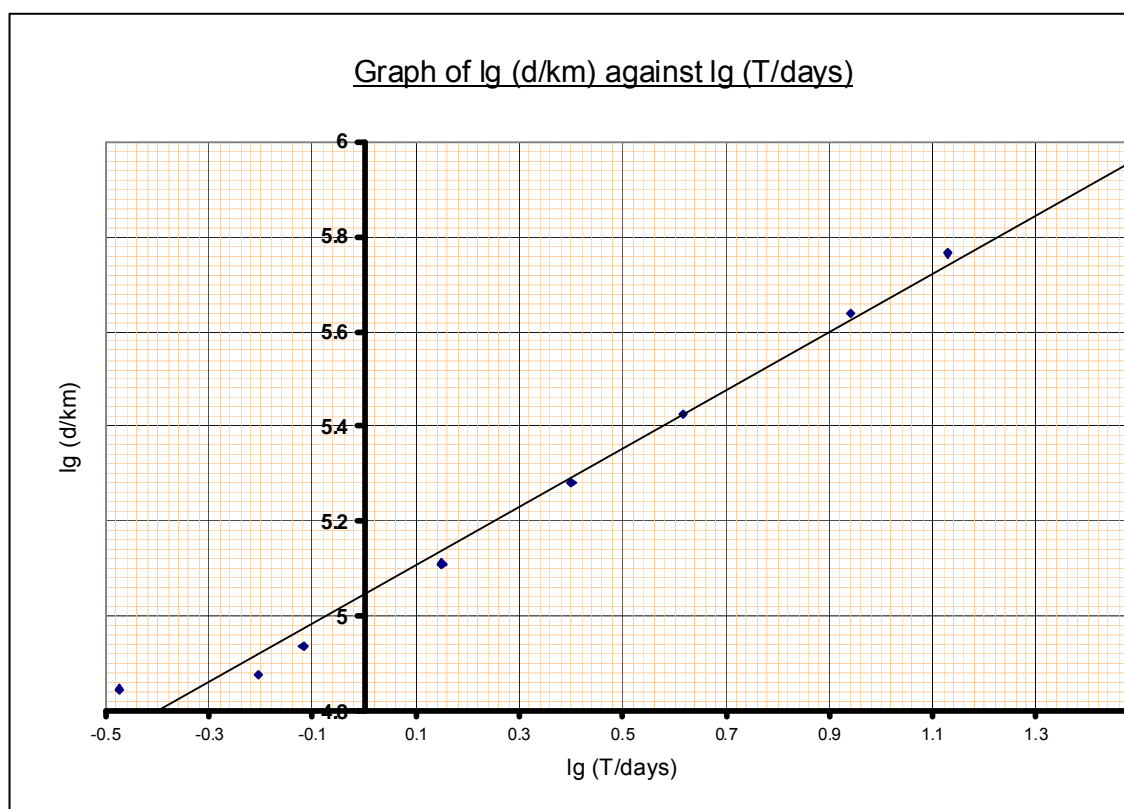


Fig.8.2

The student also included values of $\lg d$ and $\lg T$ to plot a suitable graph as shown in Fig.8.2.

- (a) Suggest an advantage of plotting a graph of $\lg d$ vs. $\lg T$ over a graph of T^2 vs. d^3 . [1]

If $d = kT^n$, taking log on both sides, $\lg d = \lg k + n \lg T$
 n will be the gradient of the graph which allows us to determine the exact relationship.

Plotting a graph of T^2 vs d^3 can only prove or disprove this relation, the log

graph is a better one to plot since it can determine the general relationship.
Or

The data covers a large range of values, the logarithm reduces them to a manageable range.

- (b) Use the graph provided in Fig.8.2 to determine whether Kepler's third law applies to these satellites. [2]

From a suitably drawn gradient triangle on the graph provided,

Gradient calculated ≈ 0.615 --- 1m

From Kepler's law, $n = 2/3 \approx 0.667$

Therefore, Kepler's law does not apply to satellites above. --- 1m

- (c) Suggest why the conclusion in (b) may not be valid. [2]

d is difficult to measure (either due to the non-circular nature, it is not constant and it is often found using an estimation method)

Precise measurements of the period are questionable or that the orbit is not constant or measurement uncertainty (especially since the observer and the objects are in constant motion)

The relation may not allow a log graph to be plotted such that a constant to be determined.

There may be other unknown satellites that affect the orbits.

There is an anomalous point from the data or the graph is not the best-fit line.

Any two possible answers

- (d) Observation shows that the satellite Umbriel orbits around Uranus with a period of 4.144 days. Use the graph above to estimate the orbital radius of Umbriel. [2]

Period of Umbriel, $T = 4.144$ days, $\rightarrow \lg T = 0.617$

From the graph, $\lg d = 5.425$ ---- working 1m

Therefore, orbital radius of Umbriel = $10^{5.425} = 2.66 \times 10^8$ m ---- answer 1m

- (e) It was reported from another source that the satellite Umbriel has been discovered to orbit Uranus at a height of 2.8×10^8 km above the surface of Uranus. Comment on the validity of this reported height with respect to your calculated answer in (d). [1]

This value is not valid because the radius of Uranus needs to be taken into account. This implies that the radius of Uranus is negative.

- (f) Given that $M = \frac{4\pi^2 r^3}{GT^2}$, estimate the mass of Uranus using the graph shown in Fig.8.4. [4]

Substituting a suitable value or r and T on the graph (take note data from table considered wrong since they do not lie on the line)

$\lg d = 5.1$ km; $\lg T = 0.1$ days. ----- identifying values 1m

Therefore, $d = 10^{5.1} = 125,900$ km = 1.25×10^8 m $\approx r$ ----- manipulation 1m

$T = 10^{0.1} = 1.259$ days = 108,778 s = 1.08×10^5 s

$$G = 6.67 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2} \text{ (given in data sheet)}$$

Substituting into given equation, $M = \underline{9.91 \times 10^{25} \text{ kg}}$ ----- substitution 1m, ans 1m

NB; Real mass of Uranus (from books)

The mass of Uranus is $8.68 \times 10^{25} \text{ kg}$.

Want to put that in perspective? That's 14.536 times more than the mass of Earth. That makes Uranus a pretty massive object.

- (g) Another graph of $\lg d$ vs $\lg T$ is plotted using data on the orbital radii and periods of the moons of Jupiter (of different mass). Compare and comment on the values of the gradient and the y-intercept between the two graphs. [2]

The gradient of the graph is the same because it will always be two thirds (based on Kepler's Law) [1]

The intercept with the y-axis will be different because it is dependent on mass. [1]