HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME: ____________ CT GROUP: 16S

TUTOR NAME: ____________

PHYSICS 9749/02

Paper 2 Structured Questions 13 September 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name, CT class** and **subject tutor's name** in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paperclips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.
You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Paper 1		30
Paper 2		
1		10
2		11
3		10
4		10
5		10
6		10
7		19
Deductions		
Total		80

Data

speed of light in free space, $c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$

permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$

permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
$\approx (1/(36\pi)) \times 10^{-9}\ \mathrm{F\,m^{-1}}$

elementary charge, $e = 1.60 \times 10^{-19}\ \mathrm{C}$

the Planck constant, $h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$

unified atomic mass constant, $u = 1.66 \times 10^{-27}\ \mathrm{kg}$

rest mass of electron, $m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$

rest mass of proton, $m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$

molar gas constant, $R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$

the Avogadro constant, $N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$

the Boltzmann constant, $k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$

gravitational constant, $G = 6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$

acceleration of free fall, $g = 9.81\ \mathrm{m\,s^{-2}}$

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, $\phi = -\frac{Gm}{r}$

temperature $T/\mathrm{K} = T/{}^\circ\mathrm{C} + 273.15$

pressure of an ideal gas $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

mean kinetic energy of a molecule of an ideal gas $E = \frac{3}{2}kT$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t = \pm\omega\sqrt{(x_0^2 - x^2)}$

electric current $I = Anvq$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_0 r}$

alternating current / voltage, $x = x_0 \sin \omega t$

magnetic flux density due to a long straight wire $B = \frac{\mu_0 I}{2\pi d}$

magnetic flux density due to a flat circular coil $B = \frac{\mu_0 NI}{2r}$

magnetic flux density due to a long solenoid $B = \mu_0 nI$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 a) Explain two conditions required for a body to be in a state of equilibrium.

1...

....

2...

....[2]

b) Two smooth spheres M_1 and M_2, both of mass 2.0 kg, are connected by an inextensible bar of negligible mass to form a rigid body. The spheres rest on smooth 45° inclines as shown in Fig. 1.1.

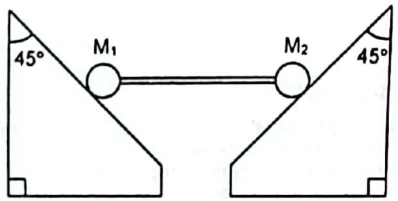

Fig. 1.1

(I) The system (2 spheres and the bar as one rigid body) is in a state of equilibrium when the bar is horizontal. Draw and label clearly the forces acting on the system in Fig 1.1.

[2]

(II) Calculate the contact force that the incline exerts on M_1.

force = ... N [2]

(c) M_2 is now replaced by M_3, a sphere with mass of 4 kg.

(I) Explain why the contact forces that the inclines exert on M_1 and M_3 must be equal in magnitude, for the system to be in a state of equilibrium.

....

....

....[1]

(ii) Explain why, for the system to be in a state of equilibrium, the bar cannot be horizontal.

....

....

....

....[2]

(iii) Hence, sketch in Fig. 1.2 how the system should be placed on the inclines so that the system is in a state of equilibrium. (Label M_1 and M_3)

[1]

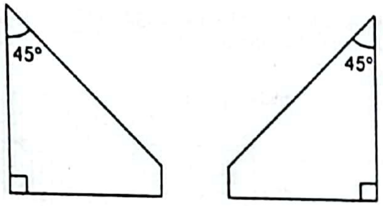

Fig. 1.2

2 (a) Define gravitational field strength.

....

....

....[1]

(b) Consider a satellite of mass *m*, orbiting the Earth of mass M_E, in a circular path of radius *r*, with an orbital period of *T*.

(i) Write down an expression for the acceleration of the satellite in terms of M_E, *r* and G (the gravitational constant).

[1]

(ii) Show that T^2 is proportional to r^3, and obtain an expression for the constant of proportionality.

constant of proportionality = ... [3]

Raduga 5 is a Russian-owned geostationary satellite launched in April 1979.

(iii) Determine the angular velocity of Raduga 5.

angular velocity = ...rad s^{-1} [1]

(iv) Given that the radius of the Earth = 6.4×10^6 m and the mass of the Earth = 6.0×10^{24} kg, determine the altitude that Raduga 5 maintains above the surface of the Earth.

altitude = ...m [3]

(v) Suggest, with a reason, a possible use of the Raduga 5 geostationary satellite.

....

....

....

....[2]

3 One end of a spring is fixed to a support. A mass is attached to the other end of the spring. The arrangement is shown in Fig. 3.1.

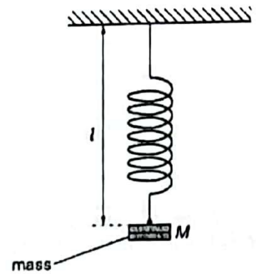

Fig. 3.1

This arrangement is used to determine the length *l* of the spring when mass *M* is attached to the spring. The procedure is repeated for different values of *M*. The variation of mass *M* with length *l* is shown in Fig. 3.2.

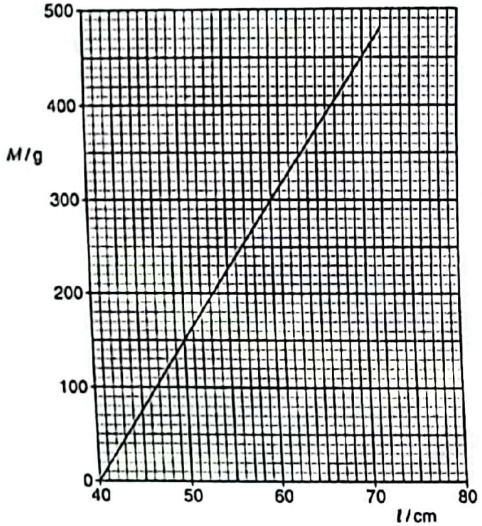

Fig. 3.2

(a) Show that the spring constant *k* of the spring is 14.7 N m^{-1}. [2]

(b) A mass of 450 g is attached to the spring and is held at rest with length *l* of 50.0 cm. The mass is then released and the mass oscillates freely. The angular frequency of the spring-mass system is given by the formula

$$\omega = \sqrt{\frac{k}{m}}$$

(i) Calculate the frequency of the system.

frequency = ...Hz [2]

(ii) Calculate the speed of the mass during its oscillation when the spring is extended to a length *l* of 80.0 cm.

speed = ... m s^{-1} [4]

(c) The spring is assumed to be light. In practice, the spring will have some mass. Assuming that the spring constant *k* is unchanged, suggest and explain the effect on the frequency of oscillation of having a spring with mass.

....

....

....

....[2]

4 (a) State what is meant by *diffraction* and *destructive interference*.

diffraction:..

....

destructive interference: ....

....

....

....

[3]

(b) In Fig. 4.1, a red laser with a frequency of 4.69×10^{14} Hz is incident on a diffraction grating of 3000 lines per cm. The screen 2.30 m from the grating captures the whole interference pattern.

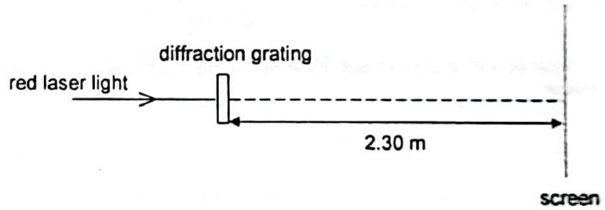

Fig. 4.1

(i) Determine the possible number of intensity maxima on the screen.

possible number of intensity maxima = ... [3]

(ii) Determine the distance of the furthest maximum away from the central maximum on the screen.

distance = ... m [2]

(c) The red laser is replaced with a green laser. How would this affect the pattern on the screen? Explain your answer.

....

....

....[1]

(d) Suggest why it is better to use a diffraction grating than a double slit to determine the wavelength of the laser.

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....[1]

©

5 In order to investigate the photoelectric effect, a student varied the wavelength of the radiation incident on the metal surface. For each value of wavelength λ, the stopping voltage V_s required just to prevent electrons from reaching the electrode was measured. Two such data are shown in Fig. 5.1.

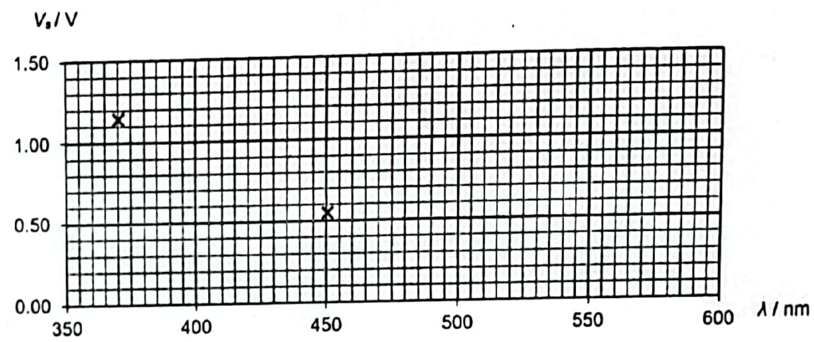

Fig. 5.1

(a) What is the maximum kinetic energy of a photoelectron emitted from the metal surface by radiation of wavelength 370 nm?

maximum kinetic energy = ... J [2]

(b) Calculate the energy of a photon of wavelength 370 nm.

energy of photon = ... J [2]

(c) Using your answers to **(a)** and **(b)**, show that the threshold wavelength is 560 nm.

[2]

(d) Without further calculations, sketch in Fig. 5.1 the graph that the student should obtain at the end of the experiment. [2]

(e) The student decided to repeat the experiment by doubling the intensity of the radiation incident on the metal surface. State and explain whether this change would affect the results obtained in Fig. 5.1.

....

....

....

....[2]

6 **(a)** Isotope X undergoes radioactive decay to form isotope Y. The half-life of isotope X is 2.0×10^5 years. The activity of a pure sample of isotope X extracted from an ore is measured to be 1.1×10^7 Bq.

(i) State what is meant by isotopes.

....

....[1]

(ii) Explain why the measured activity of the sample X is relatively constant.

....

....[1]

(iii) It is discovered that isotope Y undergoes radioactive decay to form isotope Z. The half-life of isotope Y is 1.5 hours.

1. Calculate the decay constant of Y.

decay constant of Y = ... s^{-1} [1]

2. The number of isotope Y in the sample is found to be constant. Explain how this is possible.

....

....

....[1]

3. Hence, determine this amount of Y.

amount of Y = ... atoms [2]

(b) Th-232 decays by alpha-emission with a decay constant of 1.57×10^{-18} s^{-1}. This is the beginning of a decay chain which eventually ends in Pb-208. A sample of rock is found to contain both Th-232 and Pb-208 in the ratio of 5:1.

(i) When the rock was formed, there was no Pb-208 present in the sample. Estimate the age of the rock.

age of rock = ... years [2]

(ii) State the assumption made in **(b)(i)** regarding the intermediate product nuclei.

....

....

....[1]

(iii) State with a reason, whether your answer in **(b)(i)** is an overestimate or an underestimate of the age of the rock if the assumption in **(b)(ii)** is not valid.

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....[1]

7 The article below is freely adapted from "What if I Double It?" by Thomas Humphrey.

Read the article and then answer the questions that follow.

What if I Double It?

Suppose you are responsible for cooking a turkey and have access to a large range of cookbooks. You have a 9.0 kg turkey but the first cookbook you consult only tells you how long it takes to cook a 4.5 kg turkey. Since the 9.0 kg turkey is twice the size of a 4.5 kg bird, at first the answer might seem obvious. Simply double the cooking time suggested for a 4.5 kg turkey. But is this really the right thing to do?

A second cookbook suggests that when you double the weight of a turkey, you don't have to double the cooking time. It indicates a cooking time of 4.0 hours for the small bird and 6.5 hours for the larger bird. So even though the 9.0 kg turkey is twice the weight of the 4.5 kg turkey, you only have to cook it about 1.6 times as long. Why would that be?

A more detailed analysis reveals that a turkey has more features than just its mass. When the mass is doubled other features such as width, surface area and volume are also scaled up. The turkey also has a density, a thermal conductivity (how well it transfers the oven's heat to its interior), and a specific heat capacity (how much heat it needs to climb one degree Celsius in temperature). How do some or all of these factors change in going from a 4.5 kg to a 9.0 kg turkey?

Let's imagine that our turkey is shaped like a cube. This will make it easier to see how the various factors change. Take a look at the cubical turkeys in Fig. 7.1.

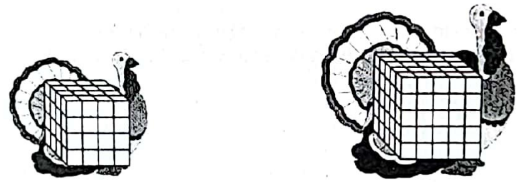

Fig.7.1

If you count the number of small cubes in the 4.5 kg turkey, you will find that there are 4 × 4 × 4, or 64 cubes. The number of cubes in the 9.0 kg turkey is 5 × 5 × 5, or 125 cubes. That's not exactly double, but it's pretty close. So now we know that the 9.0 kg turkey is about twice the volume of the 4.5 kg turkey (that is, it contains twice as many little cubes), and therefore it weighs about twice as much.

So when you double the size of the turkey, what happens to its width and surface area? Do they double too? If you look at the cubical turkeys above, you can see that the widths of the two turkeys are 4 and 5 blocks respectively. So the bigger turkey is about 25% wider than the smaller one. The width did not double.

If we look at surface area, the smaller turkey has 6 sides × 16 blocks per side, or 96 blocks. The surface area of the big turkey has 6 sides × 25 blocks per side, or 150 blocks. That means that the big turkey has about 50 percent more blocks on its surface than the small turkey. The surface area did not double either.

More precisely, on a real turkey, the width and all other linear dimensions increase by a factor of 1.26 and the surface area by a factor 1.59. Now let's analyse how this information allows us to make predictions as to a turkey's cooking times.

The 9.0 kg turkey, because it has doubled in volume, has twice as much stuff in it to be heated up, so we need to put in twice as much heat. How does this heat get into it? It is transferred across the surface of the turkey, traveling from the surface to the core of the bird. The bigger turkey has more surface area. That should speed up the transfer of heat, but the heat has to travel a longer way to the centre. That will slow things down. The net result is that it doesn't take twice as long to cook a twice-as heavy turkey. The physics fits with the information in the cookbook!

If we put the three factors together, the cooking time increases by a factor of 1.59 to 6.4 hours. Our cook book says to increase the time to 6.5 hours, or by a factor of 1.62. (6.5 hrs ÷ 4 hrs = 1.62). That's pretty close!

So now we know how to cook a turkey. We have discovered that the seemingly innocuous question, " What happens if you double it?" has turned out to be rather more complex than we had initially thought. We must be very specific about which feature of the turkey we are doubling because we don't seem to be able to double everything at once!

(a) An important factor is missing from the explanation of specific heat capacity. Modify the statement to make it more accurate (lines 13-14)

....

....[1]

(b) **(i)** Show how the factors 1.26 and 1.59 mentioned in line 32 can be proven mathematically.

[2]

(ii) The smaller (4.5 kg) turkey has a width of 22 cm. Calculate the width of the larger (9.0 kg) turkey (lines 31-33)

width = ... cm [1]

(iii) The larger turkey (9.0 kg) has a surface area of 0.46 m^2. Calculate the surface area of the smaller (4.5 kg) turkey (lines 31-33)

surface area = ... m^2 [1]

(c) The turkeys are considered to be cooked when their average temperature has risen 90 °C.

(i) How much thermal energy does this require for the 9.0 kg turkey? (Specific heat capacity of turkey = 3200 J kg^{-1} °C^{-1}).

energy = ... J [2]

(ii) The electrical power supplied to the cooking oven was 2200 W. If all this energy was transferred as thermal energy to the turkey, how long should the 9.0 kg turkey have taken to cook?

time = ... s [1]

(iii) Suggest two reasons why there is such a large difference between the answer to (c)(ii) and the time given in the passage?

....

....

....

....

....

....[2]

(d) Show mathematically how the three factors discussed in lines 34-40 when combined, lead to the conclusion that the 9.0 kg turkey requires a cooking time 1.59 times longer than for a 4.5 kg turkey.

[2]

(e) The rate of heat transfer through a cylindrical object is given by the equation

$$\frac{\Delta Q}{\Delta t} = kA\frac{\Delta \theta}{\Delta x}$$

where
k is a constant which is the thermal conductivity of the object,
A is the cross-sectional area of the cylinder,
Δx is the length of the cylinder, and
$\Delta \theta$ is the temperature difference across the length of the cylinder.

This equation can be used to provide a crude estimate of the rate of heat conduction from the surface to the core of the turkey.

(i) You may assume that during the cooking of the turkey, the temperature difference ($\Delta\theta$) remains at a constant 140 °C and that this temperature gradient occurs over **half the width of the turkey.** Estimate the rate of heat transfer for the 9.0 kg turkey (with the help of data from **(b)(ii)** and **(b)(iii)**).
(Thermal conductivity, k for the turkey = 0.60 in S.I. units)

rate of heat transfer = ... W [3]

(ii) Assuming that this rate of heat transfer to the turkey remains constant over the cooking time and using your result of **(c)(i)**, calculate the cooking time for the 9.0 kg turkey in hours.

time = ... hr [1]

(iii) Use the answer to **(e)(ii)** to calculate the cooking time for an 18.0 kg turkey.

time = ... hr [1]

(iv) What are the S.I. base units for the constant k?

S.I. base units = ... [2]

End of Paper