H2 PHYSICS

Exam papers with worked solutions

(Selected from Top JC)

SET D

PAPER 2

Compiled by

THE PHYSICS CAFE

INSTRUCTIONS TO CANDIDATES

Do Not Open This Booklet Until You Are Told To Do So.

1. Write your name, class, tutor's name and calculator model clearly on this cover page.
2. Check that you have the correct number of pages for this question booklet.
3. **Answer ALL questions**.
4. For numerical answers, **all** working should be shown.
5. You may use a soft pencil for any diagrams, graphs or rough working.
6. Do not use paperclips, highlighters, glue or correction fluid.
7. A data and formula list is provided on page 2.
8. You are reminded of the need for clear presentation and good English.

INFORMATION FOR CANDIDATES

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

Name of Student :	
Class:	
Name of Tutor :	
Calculator model:	
For Examiner's Use :	
1	**/ 8**
2	**/ 8**
3	**/ 8**
4	**/ 7**
5	**/ 8**
6	**/ 6**
7	**/ 15**
Deductions	
ISP Test Bonus	
Paper 2	**/60**

Data

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

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

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

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

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

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

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

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

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

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

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

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

acceleration of free fall, $g = 9.81$ 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 $p = \rho g h$

gravitational potential, $\phi = -Gm/r$

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

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

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

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

electric potential, $V = Q/4\pi\varepsilon_o r$

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

transmission coefficient, $T = \exp(-2kd)$

where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$

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

decay constant, $\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$

1 In a telematch, contestants are provided with styrofoam blocks of dimension 20 cm x 10 cm x 10 cm. The blocks have density of 200 kg m^{-3}. Contestants are also provided with thin, light but strong string to tie the blocks together if necessary.

Each contestant is to use the blocks to construct a float with which they will use to cross a river. Take density of river water as 1024 kg m^{-3}.

(a) (i) Explain what is meant by the term '*upthrust*' on a floating object.

____

____

____ [2]

(ii) Draw a diagram to show the forces acting on a freely floating styrofoam block.

[1]

(iii) Calculate the depth of immersion of this block, *x*, when it floats at equilibrium in the river, as shown in Figure 1.1.

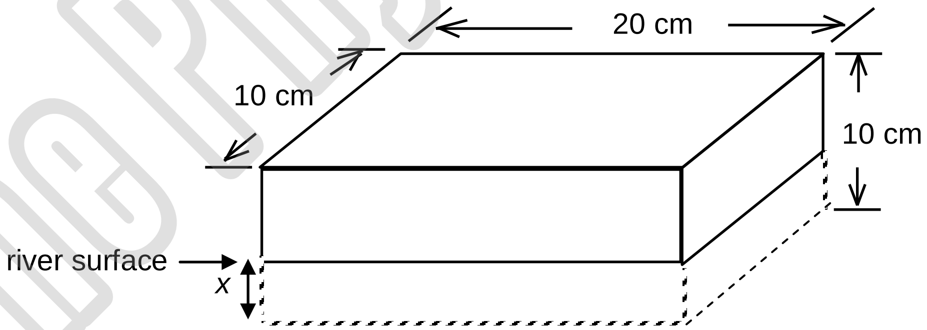


Figure 1.1

x = ______________ m [2]

(b) Calculate the *minimum* number of blocks needed to make a float that can carry a person of mass 90 kg across a river, while keeping the person out of the water.

minimum number of blocks = _________ [3]

2 (a) Define the following terms:

(i) gravitational field strength

____

____

____ [1]

(ii) gravitational potential

____

____

____ [2]

(b) The Earth may be considered as an isolated sphere with a radius of 6.4×10^3 km and a mass of 6.0×10^{24} kg which is concentrated at its centre. An object, projected vertically from the surface of the Earth, reaches a maximum height of 1.3×10^4 km.

Neglecting the effects of air resistance, determine

(i) the change in the gravitational potential of the object.

change in gravitational potential = ________________ J kg^{-1} [3]

(ii) the initial projection speed of the object from the Earth's surface. Ignore the rotation of the Earth.

initial projection speed = ____________ m s^{-1} [2]

3 The needle-carrier of a sewing machine is constrained to move in a vertical line by fixed guides as shown in Figure 3.1. The simple harmonic motion of the needle-carrier is produced by a peg attached to the rim of a rotating disc which moves in a circle and engages the slot of the needle-carrier. Figure 3.2 shows the front view of the positions of the peg and needle-carrier at intervals of a quarter period.

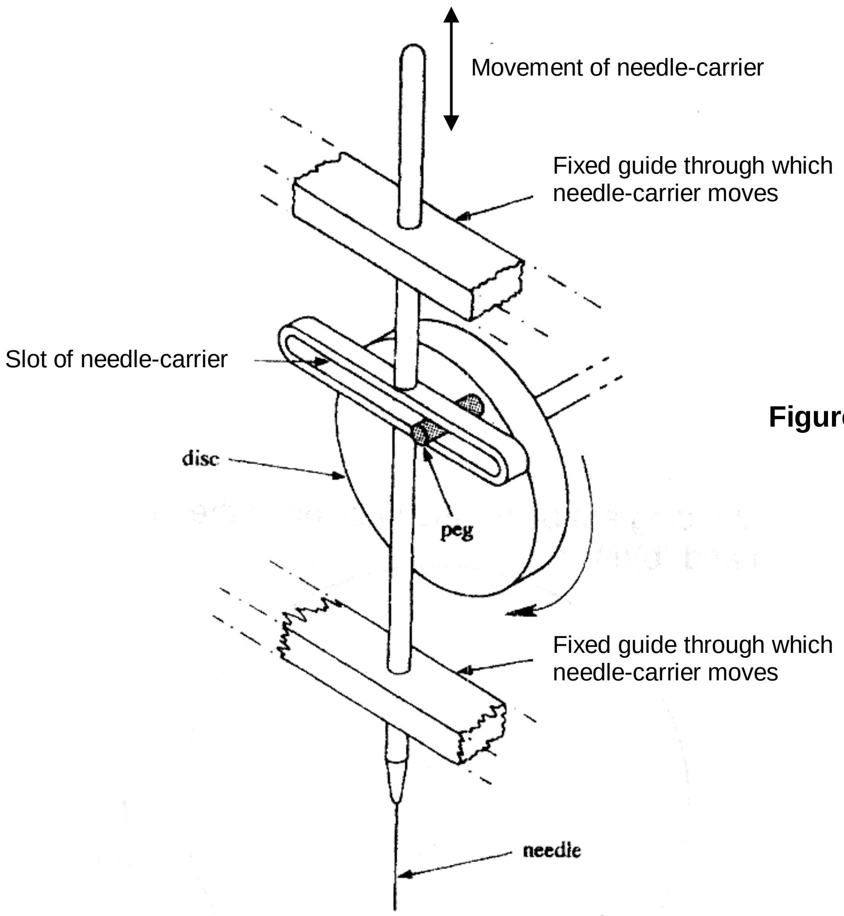


Figure 3.1

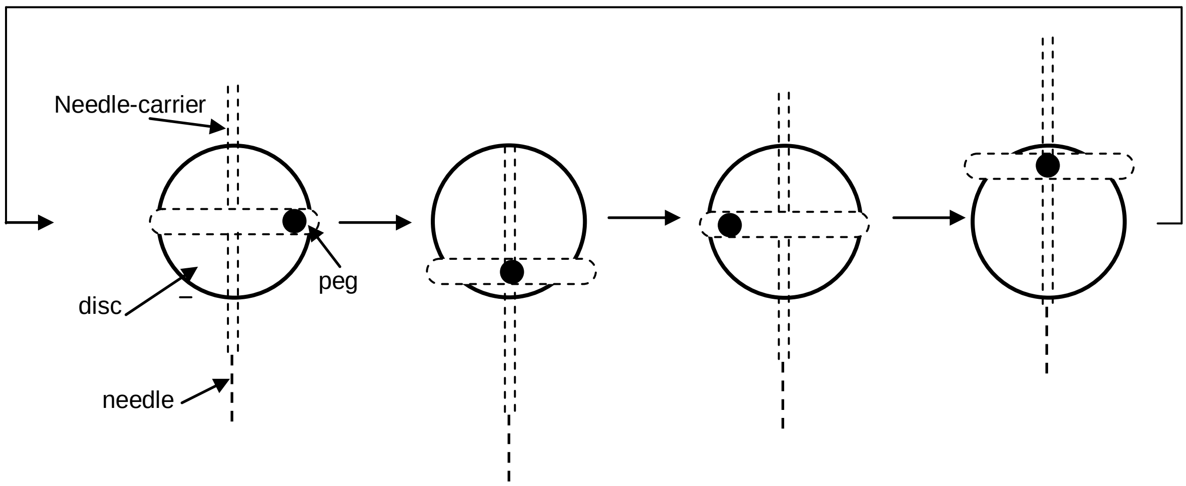


Figure 3.2

(a) Calculate the angular speed of the peg's circular motion which corresponds to the machine's maximum rate of 12 stitches per second.

angular speed = ____________ rad s^{-1} [1]

(b) (i) Label with an 'X' on Figure 3.3 below, the position of the peg at which it exerts maximum contact force on the slot of the needle carrier.

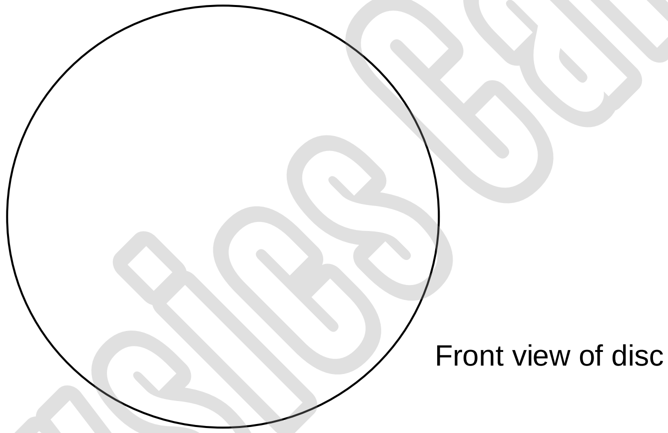


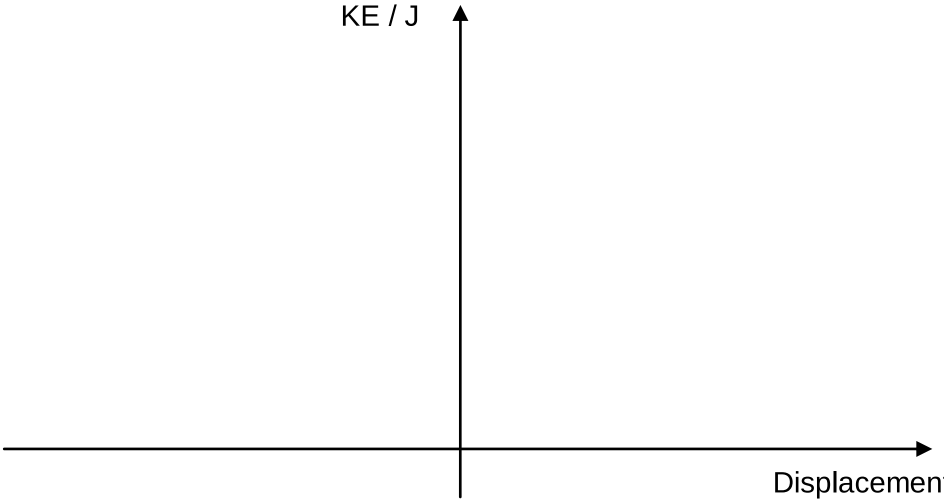
Figure 3.3

[1]

(ii) The needle-carrier and needle have a total mass of 25 g and the needle point moves a distance of 32 mm between the extremities of its motion. Assuming that the fabric being sewn requires negligible force for the needle to penetrate, calculate the maximum contact force acting on the slot of the needle-carrier by the peg.

maximum contact force = _____________ N [3]

(c) Sketch on the axes below a labeled graph of the kinetic energy of the needle-carrier and needle against its vertical displacement, indicating all relevant values.



[3]

4 In an electron microscope, an electron lens has two cylinders which are at potentials of +500 V and -100 V respectively. An electron beam passes at high speed into the lens from the top. A cross-section of the two cylinders is shown ***in full scale*** in Figure. 4.1. The dotted lines are equipotential lines.

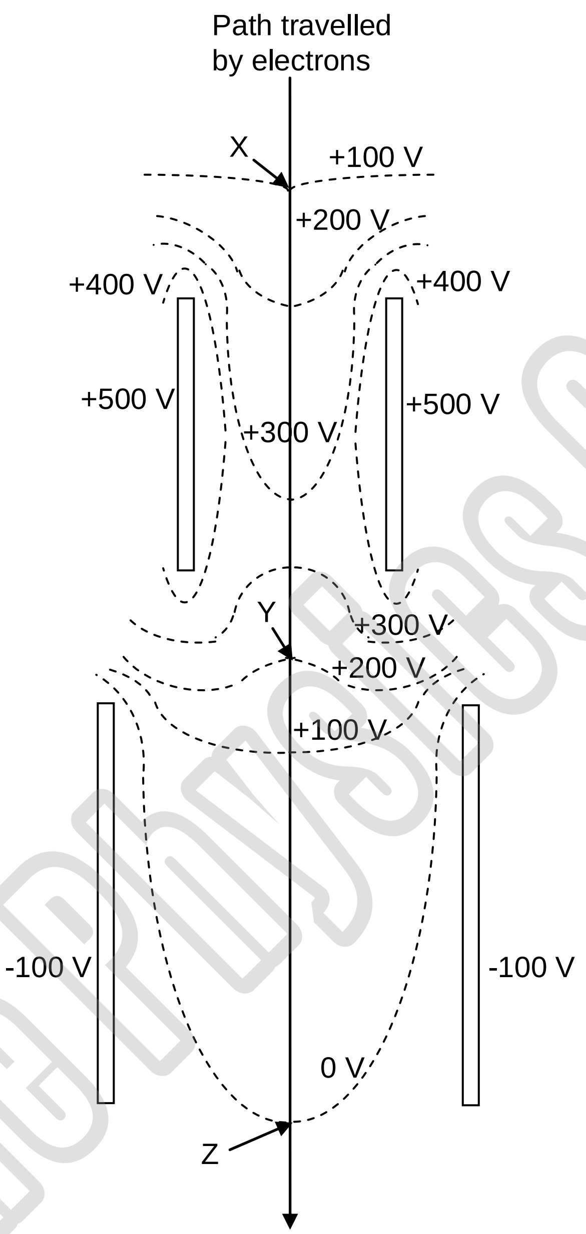


Figure 4.1 Equipotential lines drawn to scale

(a) Find the loss in kinetic energy of an electron moving from X to Z.

loss in kinetic energy = _______________ J [2]

(b) (i) Estimate the electric field strength at Y.

electric field strength = ______________ V m^{-1} [2]

(ii) Indicate the direction of the electric field strength at Y in Figure 4.1. [1]

(c) Hence, determine the magnitude and direction of the electric force on an electron at Y.

magnitude of force = _________________ N

direction of force =__________________ [2]

5 Figure 5.1 shows two circuits P and Q set up by a student using a battery of *three* identical cells. You may assume that the voltmeters in the circuits are ideal. Their readings are shown in Figure 5.1.

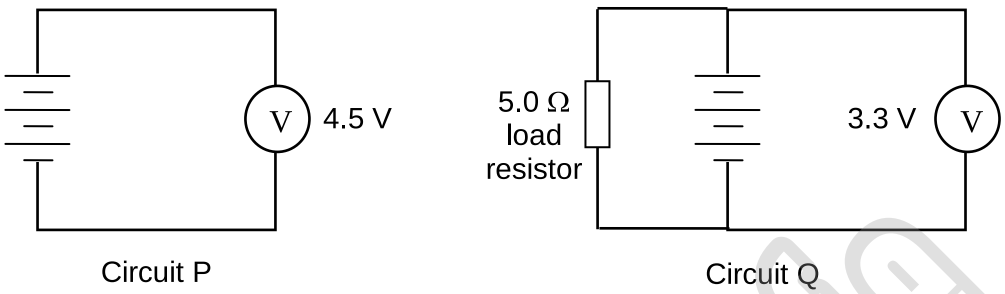


Figure 5.1

(a) Explain the difference between the voltages recorded in the two circuits.

____

____

____

____ [2]

(b) With reference to circuit Q, calculate the internal resistance of a single cell.

internal resistance = ______________ Ω [2]

(c) One of the cells in the battery is reversed in both circuits P and Q. Determine

(i) the new reading on the voltmeter in circuit P.

new reading = ______________ V [1]

(ii) the current in circuit Q.

current = ______________ A [2]

(d) The load resistor in circuit Q is replaced by an unknown device. The student finds that the voltmeter reading decreases as the device becomes hotter. Suggest what the device is.

____ [1]

6 (a) The tip of a Scanning Tunnelling Microscope (STM) probe is positioned at a distance d above a sample surface which has an energy difference, $U - E$ of 6.0 eV between the potential barrier's height and the most energetic electrons at its surface.

(i) Calculate the value of d at which the tip-surface transmission coefficient T is 0.0001.

d = _______________ nm [2]

(ii) Suppose d decreases by 1 %, calculate the percentage change in transmission coefficient, T.

percentage change = ______________ % [2]

(b) Explain how the STM maintained at a *fixed vertical position* is used to obtain atomic scale images.

____

____

____

____

____ [2]

7 This question is about the homopolar generator.

In principle, a homopolar generator consists of a conducting disc spinning about an axis in a magnetic field parallel to this axis. When the spinning disc is stopped suddenly, all its kinetic energy can be used to generate a large current surge.

In order to spin the disc, a d.c. power supply is connected as shown in Figure 7.1. The magnetic force on the disc due to the current passing from the axle to the rim of the conducting disc provides the necessary accelerating force. As the conducting disc speeds up, however, there is an increasing voltage generated across the terminals T_1 and T_2. When the power supply is disconnected, this voltage can be used to drive a current through a resistor connected between them as shown in Figure 7.2.

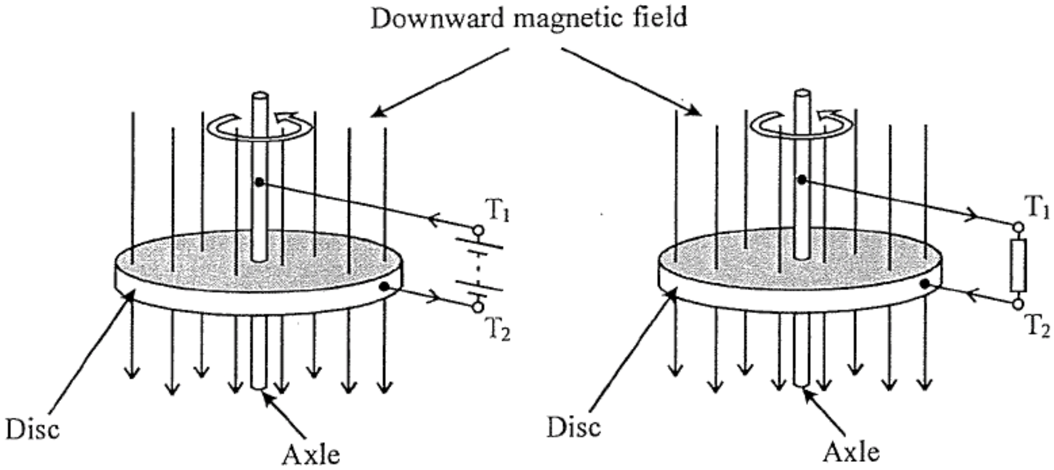


Figure 7.1 **Figure 7.2**

The magnitude of the voltage V can be calculated from the relationship

$$V = \pi(r_d^2 - r_a^2)kB$$

where r_d and r_a are the radii of the disc and axle respectively, and B is the magnetic flux density, assumed to be uniform over the surface of the disc.

The homopolar generator is used as a research tool to produce a huge surge of current when their terminals are suddenly short-circuited. One large homopolar generator in Australia, which is designed to produce a large current surge, measures 3.6 m in diameter, rotates at 15 Hz and is so massive that the kinetic energy it stores at this speed is 580 MJ. When it is short-circuited, the current surge is used to produce short-lived but extremely high magnetic fields in order to study the properties of matter under extreme conditions. It is proposed that such fields could be used in an electromagnetic gun to project a small mass to speeds of over 7 km s^{-1}. This speed is of the order of the speed of satellites in low orbits and hence the projected masses could be used to study the problems encountered by missiles re-entering the atmosphere.

(a) What is meant by the term “short-circuited” as used in the passage?

____

____ [1]

(b) (i) Explain why there is an increasing voltage generated between terminals T_1 and T_2 when the conducting disc speeds up. (Paragraph 3)

____

____

____

____ [2]

(ii) Is the output of a homopolar generator a.c. or d.c.?

____ [1]

(iii) Give two applications which are suggested in the passage for the huge surges of current produced by a homopolar generator.

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____ [2]

(c) Figure 7.3 shows a current surge from a short-circuited homopolar generator.

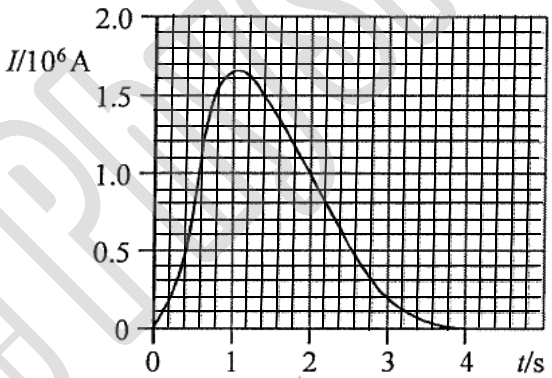

Figure 7.3

(i) Estimate the charge that flows during this surge.

charge = ____________ MC [3]

(ii) Calculate the maximum power dissipated when the terminals T_1 and T_2 of the generator, which has an internal resistance of 0.12 mΩ, are connected together through a negligible external resistance.

maximum power = _______________ W [1]

(d) Using $V = \pi(r_d^2 - r_a^2)kB$, determine the units for *k*. Hence, suggest what physical quantity may be represented by the symbol *k*.

units for *k* = _______________

quantity = _________________ [3]

(e) Describe the energy transformations that take place in the process shown in

(i) Figure 7.1

____

____ [1]

(ii) Figure 7.2

____

____ [1]

- End of Paper -