Centre No.						Paper Reference	Surname	Initial(s)
Candidate No.						6 7 3 6 / 0 1	Signature	

Paper Reference(s)

6736/01

Edexcel GCE

Physics

Advanced Level

Unit Test PHY6

Thursday 29 January 2009 – Afternoon

Time: 2 hours

Examiner's use only

Team Leader's use only

Question Number	Leave Blank
1	
2	
3	
4	
Total	

Materials required for examination	Items included with question papers
Nil	Insert for use in Question 1

Instructions to Candidates

In the boxes above, write your centre number, candidate number, your signature, your surname and initial(s).
Answer **ALL** questions in the spaces provided in this question paper.
In calculations you should show all the steps in your working, giving your answer at each stage.
Calculators may be used.
Include diagrams in your answers where these are helpful.

Information for Candidates

This question paper is designed to give you the opportunity to make connections between different areas of physics and to use skills and ideas developed throughout the course in new contexts. You should include in your answers relevant information from the whole of your course, where appropriate.
The marks for individual questions and the parts of questions are shown in round brackets.
There are four questions in this paper. The total mark for this paper is 80.
The list of data, formulae and relationships is printed at the end of this booklet.
The passage for use with Question 1 is on the enclosed insert. The insert is NOT to be returned with the paper.

Advice to Candidates

You will be assessed on your ability to organise and present information, ideas, descriptions and arguments clearly and logically, taking account of your use of grammar, punctuation and spelling.

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SECTION I

1. Read the passage on the separate Insert and then answer the Section I questions.

(a) (i) Calculate the time t it takes for an atom moving at $840\ \text{m s}^{-1}$ to cross the inside of the rotating drum in method 1.

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(ii) Through what angle will the drum rotate while such an atom crosses the drum?

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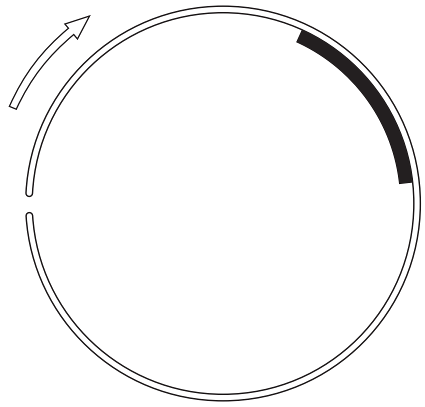
(iii) Add to the drawing of the rotating drum below to show how a bunch of atoms in method 1 is 'smeared out' as it crosses the drum. Label fast and slow atoms.



(6)

N 3 0 6 1 7 A 0 3 2 4

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(b) A pressure p measured in mmHg can be converted to pascals using the relation

$$p = \rho g h$$

where ρ is the density of mercury, h is the distance (e.g. 10^{-4} mm in a pressure of 10^{-4} mmHg) converted to metres and g has its usual meaning.

(i) A pressure of 1.0×10^{-4} mmHg is equivalent to 0.013 Pa.

Calculate a value for the density of mercury.

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(ii) Show that the relation $p = \rho g h$ is homogeneous with respect to units.

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(4)

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(c) (i) At one point on their path from the oven to the wire detector (method 2) the atoms are moving horizontally.

State where this point is (do **not** mark it on the diagram on the Insert).

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(ii) State what is meant by the phrase 'ionises the atoms' in method 2.

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(2)

(d) In method 2 the highest current registered by the detection system is 180 pA. This corresponds to the detector being a distance d = 0.11 mm below the level of the slits C_1 and C_2.

(i) Show that a body in free fall takes about 5 ms to fall 0.11 mm from rest.

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(ii) Calculate how many singly ionised atoms per unit time are required to form a current of 180 pA.

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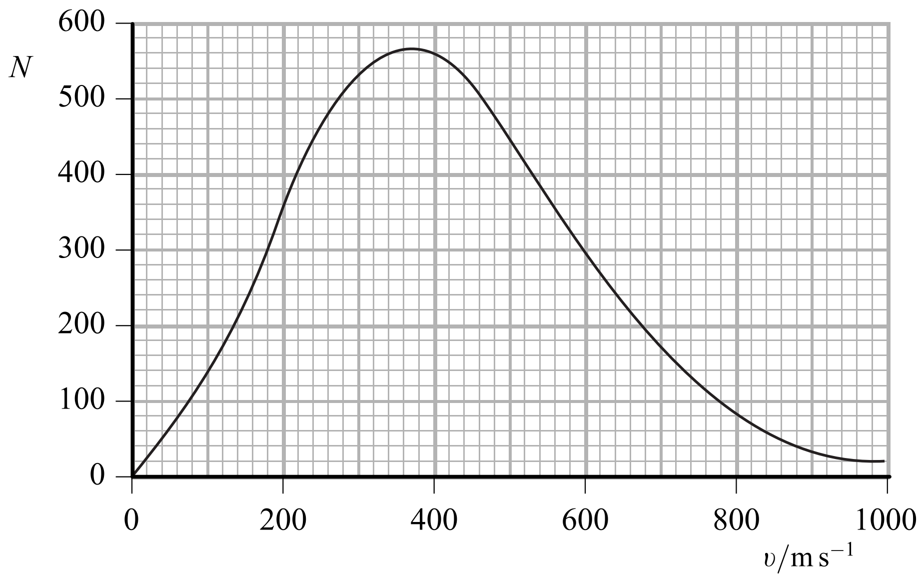
(e) The graph shows the Maxwellian distribution for 250 000 oxygen molecules at 0 °C. N on the vertical axis represents the number of molecules N with a speed within $\pm 0.5\ \text{m s}^{-1}$ of υ, e.g. at $\upsilon = 200\ \text{m s}^{-1}$, there are 360 molecules with speeds between $199.5\ \text{m s}^{-1}$ and $200.5\ \text{m s}^{-1}$.



(i) Estimate the mean (average) speed $\langle c \rangle$ of the 250 000 oxygen molecules.

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Use this mean speed to determine an approximate value for the quantity p/ρ (pressure ÷ density) for oxygen molecules at 0 °C.

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(ii) Estimate how many of these 250 000 oxygen molecules have a speed of less than 200 m s^{-1} at 0 °C. Explain how you made your estimate.

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(3)

(iii) Add to the graph a second curve showing the approximate shape of the Maxwellian distribution for 250 000 oxygen molecules at 100 °C.

(iv) Explain why the area under your graphs should be the same.

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(4)

N 3 0 6 1 7 A 0 7 2 4

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(f) A further method, the *Spectral Line Method*, involves measuring the broadening of a single line in the infra-red emission spectrum of a hot gas. Because of the random motion of the gas atoms there is a Doppler broadening of this line, and the broadening can be interpreted in terms of the speeds of the gas atoms that are emitting the radiation.

(i) Suggest a wavelength λ for an infra-red spectral line.

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(ii) Calculate the percentage Doppler shift in this wavelength when the line is emitted by a gas atom moving away from the spectrum detector at 840 m s^{-1}.

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(4)

Q1

(Total 32 marks)

TOTAL FOR SECTION I: 32 MARKS

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SECTION II

(Answer ALL questions)

2. (a) (i) Describe the analogy between the properties of springs and capacitors by completing the table below.

	Springs	Capacitors
The mathematical models		
The way in which energy is stored		
Series and parallel arrangements		

(6)

(ii) The behaviour of a spring is limited by Hooke's law. What is the analogous property exhibited by a capacitor?

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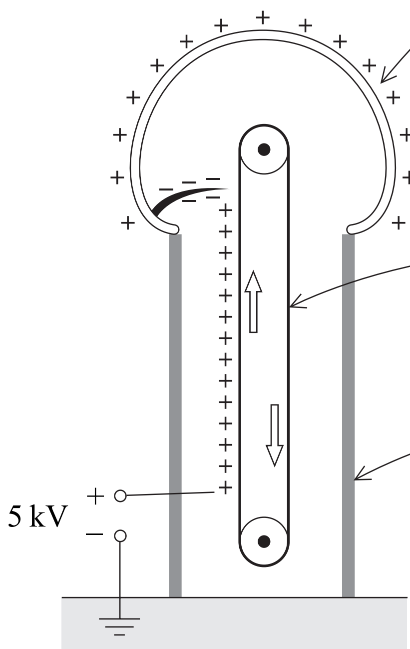
(b) The diagram shows a Van de Graaff generator capable of producing a potential difference between part A and earth of over one megavolt.



A .... dome

B .... belt

C .... support

(i) Complete the labels to parts A, B and C of the diagram.

(ii) The charge on the belt is repelled by the charge accumulated on the dome. Where does the energy to do work against this repulsion come from?

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(4)

(iii) When the generator is switched on for 6.0 s the rate of flow of charge to the dome is 0.80 μA and the p.d. between the dome and earth rises from zero to 0.5 MV.

Show that the dome is acting as a capacitor of capacitance approximately 10 pF.

State any assumption you have made in your calculation.

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(4)

Q2

(Total 15 marks)

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3. (a) (i) Explain how a simple pendulum may be used to determine a value for the acceleration of free fall *g*.

- List the measurements you would take and state how they would be used in finding *g*.
- Describe the procedures you would take to ensure a reliable value for *g*.

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(ii) A physicist commented that the measured value of the acceleration of free fall in the UK was not quite the same as the Earth's gravitational field strength in the UK.

Explain this apparent anomaly.

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(2)

(b) Two students use a pendulum to measure the acceleration of free fall g at two places A and B a vertical distance h apart in a very tall building. They predict that the difference in their two values will be

$$\Delta g = g_A - g_B = \frac{2Gm_E h}{r_E^3}$$

where r_E, the radius of the Earth, is 6.4×10^6 m.

The students do not know the value of Gm_E, but they do know that the value of g in the building is 9.8 m s^{-2} to 2 s.f.

Calculate the difference Δg that the students expect to find in the building when the vertical distance between A and B is 260 m.

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(c) The students then wonder whether a pendulum, made from thin brass wire and a heavy bob, will vary in its period of oscillation T when the temperature changes.

A data book tells them that the fractional increase in length Δl of a brass wire of length l is 1.8×10^{-5} for each degree Celsius rise in temperature.

(i) Show that a brass wire of length 1.200 m will expand by less than 0.5 mm when heated from 15 °C to 35 °C.

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(ii) Discuss whether any noticeable change in T will result from the temperature change stated in part (i) above.

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Q3

(Total 16 marks)

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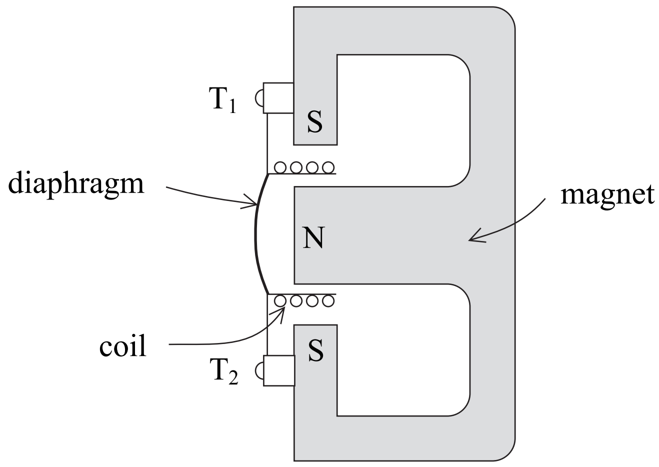
4. The diagram shows, in cross-section, the structure of a moving-coil microphone. A sound wave incident on the diaphragm causes the coil, to which the diaphragm is attached, to oscillate between the poles of the permanent magnet. The coil is electrically connected between the terminals T_1 and T_2.



(a) State and explain what happens across the terminals T_1 and T_2 when the coil is displaced a small distance to the right.

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(3)

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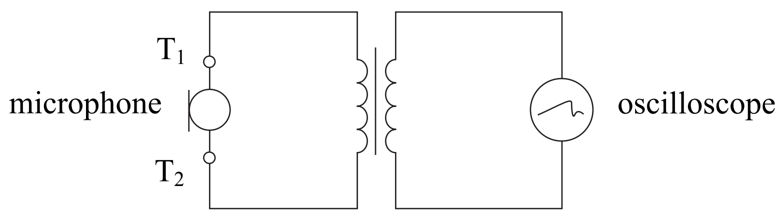
(b) The moving-coil microphone is connected via a high-ratio step-up transformer to an oscilloscope.



(i) Explain, giving a quantitative example, the meaning of the phrase 'high-ratio step-up' when used to describe a transformer. You may be awarded a mark for the clarity of your answer.

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(4)

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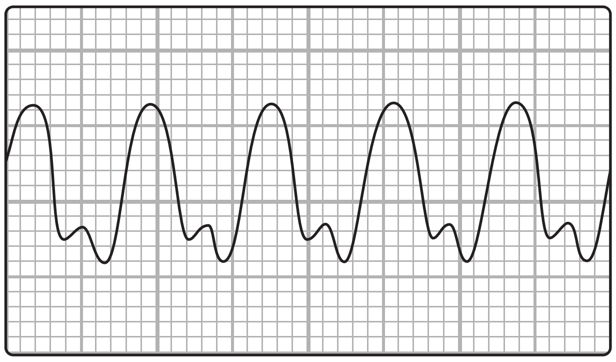
(ii) For a particular sound wave incident on the microphone the trace on the oscilloscope is as shown below.



The settings on the oscilloscope are: vertically 50 mV cm^{-1}

horizontally 2.0 ms cm^{-1}

Estimate the amplitude of the output voltage of the transformer and determine the frequency of the sound wave.

Amplitude: ....

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Frequency: ....

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(iii) The oscilloscope trace shows that this sound is the result of the superposition of two waves.

State what is meant by 'the superposition of two waves' and describe how you would demonstrate wave superposition in the laboratory.

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(5) **Q4**

(Total 17 marks)

TOTAL FOR SECTION II: 48 MARKS

TOTAL FOR PAPER: 80 MARKS

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N 3 0 6 1 7 A 0 1 8 2 4

List of data, formulae and relationships

Data

Speed of light in vacuum	$c = 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{N\ m^{2}\ kg^{-2}}$	
Acceleration of free fall	$g = 9.81\ \mathrm{m\ s^{-2}}$	(close to the Earth)
Gravitational field strength	$g = 9.81\ \mathrm{N\ kg^{-1}}$	(close to the Earth)
Elementary (proton) charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$	
Electronic mass	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$	
Electronvolt	$1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\ s}$	
Unified atomic mass unit	$\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$	
Molar gas constant	$R = 8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$	
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$	
Coulomb law constant	$k = 1/4\pi\varepsilon_0$ $= 8.99 \times 10^{9}\ \mathrm{N\ m^{2}\ C^{-2}}$	
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{N\ A^{-2}}$	

Rectilinear motion

For uniformly accelerated motion:

$$v = u + at$$

$$x = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2ax$$

Forces and moments

Moment of F about O = $F \times$ (Perpendicular distance from F to O)

Sum of clockwise moments about any point in a plane = Sum of anticlockwise moments about that point

Dynamics

Force $\quad F = m\dfrac{\Delta v}{\Delta t} = \dfrac{\Delta p}{\Delta t}$

Impulse $\quad F\Delta t = \Delta p$

Mechanical energy

Power $\quad P = Fv$

Radioactive decay and the nuclear atom

Activity $\quad A = \lambda N \quad$ (Decay constant λ)

Half-life $\quad \lambda t_{\frac{1}{2}} = 0.69$

Electrical current and potential difference

Electric current $I = nAQv$

Electric power $P = I^2 R$

Electrical circuits

Terminal potential difference $V = \mathcal{E} - Ir$ (E.m.f. $\mathcal{E}$; Internal resistance r)

Circuit e.m.f. $\Sigma\mathcal{E} = \Sigma IR$

Resistors in series $R = R_1 + R_2 + R_3$

Resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Heating matter

Change of state: energy transfer $= l\Delta m$ (Specific latent heat or specific enthalpy change l)

Heating and cooling: energy transfer $= mc\Delta T$ (Specific heat capacity c; Temperature change ΔT)

Celsius temperature $\theta/°\mathrm{C} = T/\mathrm{K} - 273$

Kinetic theory of matter

Temperature and energy $T \propto$ Average kinetic energy of molecules

Kinetic theory $p = \frac{1}{3}\rho\langle c^2\rangle$

Conservation of energy

Change of internal energy $\Delta U = \Delta Q + \Delta W$ (Energy transferred thermally ΔQ; Work done on body ΔW)

Efficiency of energy transfer $= \frac{\text{Useful output}}{\text{Input}}$

Heat engine maximum efficiency $= \frac{T_1 - T_2}{T_1}$

Circular motion and oscillations

Angular speed $\omega = \frac{\Delta\theta}{\Delta t} = \frac{v}{r}$ (Radius of circular path r)

Centripetal acceleration $a = \frac{v^2}{r}$

Period $T = \frac{1}{f} = \frac{2\pi}{\omega}$ (Frequency f)

Simple harmonic motion:

displacement $x = x_0 \cos 2\pi ft$

maximum speed $= 2\pi f x_0$

acceleration $a = -(2\pi f)^2 x$

For a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$

For a mass on a spring $T = 2\pi\sqrt{\frac{m}{k}}$ (Spring constant k)

Waves

Intensity	$I = \dfrac{P}{4\pi r^2}$	(Distance from point source r; Power of source P)

Superposition of waves

Two slit interference	$\lambda = \dfrac{xs}{D}$	(Wavelength λ; Slit separation s; Fringe width x; Slits to screen distance D)

Quantum phenomena

Photon model	$E = hf$	(Planck constant h)
Maximum energy of photoelectrons	$= hf - \varphi$	(Work function φ)
Energy levels	$hf = E_1 - E_2$	
de Broglie wavelength	$\lambda = \dfrac{h}{p}$	

Observing the Universe

Doppler shift	$\dfrac{\Delta f}{f} = \dfrac{\Delta\lambda}{\lambda} \approx \dfrac{v}{c}$	
Hubble law	$v = Hd$	(Hubble constant H)

Gravitational fields

Gravitational field strength	$g = F/m$	
for radial field	$g = Gm/r^2$, numerically	(Gravitational constant G)

Electric fields

Electric field strength	$E = F/Q$	
for radial field	$E = kQ/r^2$	(Coulomb law constant k)
for uniform field	$E = V/d$	
For an electron in a vacuum tube	$e\Delta V = \Delta(\frac{1}{2}m_e v^2)$	

Capacitance

Energy stored	$W = \frac{1}{2}CV^2$	
Capacitors in parallel	$C = C_1 + C_2 + C_3$	
Capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$	
Time constant for capacitor discharge	$= RC$	

Magnetic fields

Force on a wire	$F = BIl$	
Magnetic flux density (Magnetic field strength)		
in a long solenoid	$B = \mu_0 nI$	(Permeability of free space μ_0)
near a long wire	$B = \mu_0 I / 2\pi r$	
Magnetic flux	$\Phi = BA$	
E.m.f. induced in a coil	$\varepsilon = -\dfrac{N\Delta\Phi}{\Delta t}$	(Number of turns N)

Accelerators

Mass-energy	$\Delta E = c^2 \Delta m$
Force on a moving charge	$F = BQv$

Analogies in physics

Capacitor discharge	$Q = Q_0 e^{-t/RC}$
	$\dfrac{t_{\frac{1}{2}}}{RC} = \ln 2$
Radioactive decay	$N = N_0 e^{-\lambda t}$
	$\lambda t_{\frac{1}{2}} = \ln 2$

Experimental physics

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty} \times 100\%}{\text{Average value}}$$

Mathematics

$$\sin(90° - \theta) = \cos\theta$$

$$\ln(x^n) = n \ln x$$

$$\ln(e^{kx}) = kx$$

Equation of a straight line	$y = mx + c$	
Surface area	cylinder $= 2\pi rh + 2\pi r^2$	
	sphere $= 4\pi r^2$	
Volume	cylinder $= \pi r^2 h$	
	sphere $= \frac{4}{3}\pi r^3$	
For small angles:	$\sin\theta \approx \tan\theta \approx \theta$	(in radians)
	$\cos\theta \approx 1$	

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