



OXFORD UNIVERSITY

PHYSICS APTITUDE TEST

Wednesday 30 October 2019

Time Allowed: 2 hours

Question Paper and Answer Booklet

Surname	
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Other names	
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School/College name*	
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*If you are an individual candidate, taking this test away from a school or college, please write the name of your examination centre in this box.

Centre Number						Candidate Number	P						
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UCAS Number (if known)				-				-				
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Date of Birth							
	d	d		-	m	m	
				-	y	y	

Oxford College of Preference	
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Total 24 questions [100 Marks]

Answers should be written on the question sheet in the spaces provided and you are encouraged to show your working.

You should attempt as many questions as you can. Please use black pen, or soft pencil for diagrams or sketches.

Answers should be given exactly and in simplest terms unless indicated otherwise. Indicate multiple-choice answers by circling the best answer.

Partial credit may be given for correct workings in multiple choice questions.

The numbers in the margin indicate the marks expected to be assigned to each question. You are advised to divide your time according to the marks available.

Only calculators meeting the specifications for PAT are allowed.

No tables or formula sheets may be used.

Please tick the box to show which course you have applied for:

Physics or Physics and Philosophy <input type="checkbox"/>	Engineering <input type="checkbox"/>	Materials <input type="checkbox"/>
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1	2	3	4	5	6	7	8	9	10	11	12	M-total	P-Total					
13	14	15	16	17	18	19	20	21	22	23	24	M-total	P-Total					
<table border="1" style="margin-left: 20px;"> <tr> <td>Maths Total</td> <td></td> </tr> <tr> <td>Physics Total</td> <td></td> </tr> </table> <p>Comments</p>													Maths Total		Physics Total			
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PHYSICS ADMISSIONS TEST
Wednesday, 30 October 2019

Time allowed: 2 hours

*For candidates applying to Physics, Physics and Philosophy,
Engineering, or Materials Science*

Total 24 questions [100 Marks]

Answers should be written on the question sheet in the spaces provided,
and you are encouraged to show your working.
You should attempt as many questions as you can.

No tables, or formula sheets may be used.

Answers should be given exactly and in simplest terms
unless indicated otherwise.

Indicate multiple-choice answers by circling the best answer.
Partial credit may be given for correct workings in multiple choice questions.

The numbers in the margin indicate the marks expected to be assigned
to each question. You are advised to divide your time according to
the marks available.

You may take the gravitational field strength
on the surface of Earth to be $g \approx 10 \text{ m s}^{-2}$

Do NOT turn over until told that you may do so.

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1. What is the next number in the sequence? -972, 324, -108, 36, -12

[2]

A	B	C	D	E
-4	-3	3	4	9

2. Which values of x and y solve the following equations simultaneously:

[2]

$$\log x + 2 \log y = \log 32$$

$$\log x - \log y = -\log 2$$

A	B	C	D	E
$x = 2$ $y = 4$	$x = -2$ $y = -4$	$x = 2$ $y = -4$	$x = -2$ $y = 4$	no solution exists

3. Consider a system of many interacting particles. Let each particle have a potential energy $V(r)$ with respect to any other particle, where $V(r) \propto r^n$ where r is the distance to another particle and n is an integer. For such systems the Virial Theorem relates the time averaged total kinetic energy of all particles T_{tot} to the time averaged total potential energy V_{tot} as follows:

$$2 T_{tot} = n V_{tot}$$

If the particles in our system interact only via gravity, what is the time averaged total energy E_{tot} of the system?

[2]

A	B	C	D	E
$E_{tot} = 0$	$E_{tot} = 2 V_{tot}$	$E_{tot} = V_{tot} / 2$	$E_{tot} = -\langle V_{tot} \rangle$	$E_{tot} = -2 V_{tot}$

4. The acceleration g due to gravity on a spherical planet in any universe is given by:

$$g = \frac{GM}{R^2}$$

where M is the mass, R the radius of the planet and G is the gravitational constant in that planet's universe.

In a different universe the gravitational constant is G and has twice the value of the gravitational constant in our Universe G .

Find the ratio $\frac{g_{\text{planet}}}{g_{\text{Earth}}}$ for a planet in the different universe which has half the radius and twice the density of the Earth.

[2]

A	B	C	D	E
$\frac{g_{\text{planet}}}{g_{\text{Earth}}} = 2$	$\frac{g_{\text{planet}}}{g_{\text{Earth}}} = 1$	$\frac{g_{\text{planet}}}{g_{\text{Earth}}} = \frac{1}{2}$	$\frac{g_{\text{planet}}}{g_{\text{Earth}}} = 4$	$\frac{g_{\text{planet}}}{g_{\text{Earth}}} = \frac{1}{4}$

5. In which range of α does the following equation have real solutions?

[2]

$$\sec^2 \theta + \alpha \tan \theta = 0$$

A	B	C	D	E
$\alpha \leq -2$ or $\alpha \geq 2$	$\alpha \leq -2$	$\alpha \geq 2$	$\alpha \geq -0$	$\alpha \leq 0$

6. A bag contains b blue balls and r red balls. If two balls are picked at random and removed from the bag, what is the probability P that they are different colours?

[2]

A	B	C	D	E
$\frac{2br}{(b+r)(b+r-1)}$	$\frac{br}{(b+r)(b+r-1)}$	$\frac{br}{(b+r)^2}$	$\frac{2br}{(b+r)^2}$	$2br$

7. We wish to represent integer numbers by using our ten fingers. A finger is assumed to be either stretched out or curled up. How many different integers can we represent with our fingers?

[2]

A	B	C	D	E
10	512	1000	20	1024

8. Without explicit calculation state which integrals are non-zero.

$$I_1 = \int_{-3\pi}^{3\pi} x^2 \sin(x) dx \quad (1)$$

$$I_2 = \int_{-\infty}^{\infty} e^{-x^2} dx \quad (2)$$

$$I_3 = \int_{3\pi/2}^{-3\pi/2} \cos^2(x) dx \quad (3)$$

$$I_4 = \int_{-\infty}^{\infty} xe^{-x^2} dx \quad (4)$$

[2]

A	B	C	D	E
2 and 3	1 and 4	1 and 3	2 and 4	all

9. A long, thin, straight wire carrying an electric current I causes a magnetic field of flux density B at a perpendicular distance r from the wire. The magnitude of this flux density is given by the following relation:

$$B = \frac{\alpha I}{r}$$

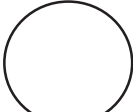




where α is a constant. The magnetic field points circumferentially around the wire. A second, identical wire is placed parallel to the first one at a distance D . Find the current I_2 that has to flow in the second wire if the flux density at a line half way between and parallel to the wires is to double, compared to the flux density from only one wire at current I .

[2]

A	B	C	D	E
$I_2 = I$	$I_2 = 2I$	$I_2 = -2I$	$I_2 = -I$	$I_2 = -I/2$

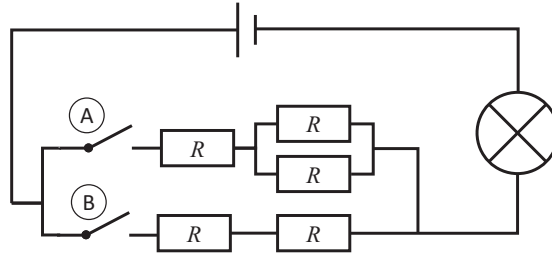
10. When the phase of the Moon as seen from the Earth is Full, what phase of the Earth is seen by an observer on the Moon?

[2]

A	B	C	D	E
				
Full	Gibbous	Quarter r 'half')	Crescent	New

The symbols above show phases of the Earth as seen from the Moon

11. In the circuit shown below all resistors have the same resistance R and the light bulb has a fixed resistance. You wish to change the state of the switches so that the brightness of the bulb increases from its minimum to its maximum. Which sequence of switch states will achieve this? [2]



	A	B	C	D	E
1.	both closed	both closed	only B closed	only A closed	all states give the same brightness
2.	only A closed	only B closed	only A closed	only B closed	
3.	only B closed	only A closed	both closed	both closed	

12. An organ pipe is open at one end and closed at the other. The lowest note you can play on this pipe has frequency f_{min} . If the speed of sound in the pipe is v , what is the length L of the pipe?

[2]

A	B	C	D	E
$L = \frac{v}{2f_{min}}$	$L = \frac{v}{4f_{min}}$	$L = \frac{v}{f_{min}}$	$L = \frac{2v}{f_{min}}$	$L = \frac{4v}{f_{min}}$

13.

- (a) Sketch the graphs of $y = (1 + x)^n$ for integer values of n from 0 to 3, each on a separate set of axes. Which point(s) are common to all the graphs ? [4]
- (b) Describe two of the further features common to the graphs for integer $n > 1$. [2]

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14. A radioactive sample contains two isotopes, A and B . Isotope A decays to isotope B with a half life of $t_{1/2}$. Isotope B is stable.

(a) The number of atoms of A left after a time t is given by:

$$N_A(t) = N_{A0} e^{-\lambda t}$$

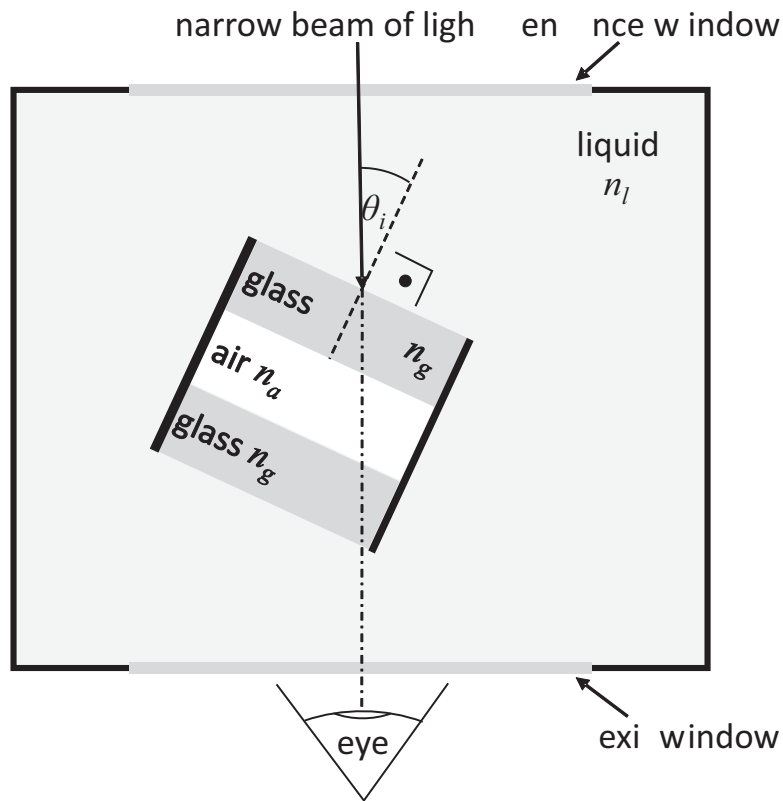
where N_{A0} is the initial number of atoms of A . Derive an expression for λ in terms of $t_{1/2}$. [2]

(b) Initially the number of B atoms in the sample is $N_B(t = 0) = N_{B0}$. Let $N_B(t)$ be the time dependent number of B atoms in the sample. Write down an expression for $N_B(t)$ in terms of λ , N_{B0} , N_{A0} and t . [1]

(c) At the start there are x times as many A atoms in the sample as there are B atoms. How long does it take until this ratio is reversed? [3]

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15. The diagram below shows an air-cell refractometer.

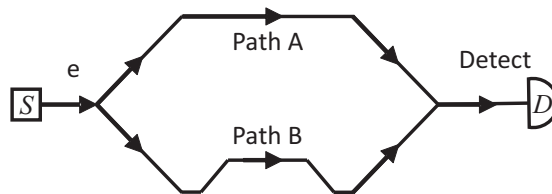


A narrow beam of light enters the entrance window at normal incidence and you can observe the light leaving the exit window by eye. The outer box is filled with a liquid of unknown refractive index n_l . The glass of the air cell has refractive index n_g and the cell is filled with air of refractive index n_a . The air-cell in the liquid filled vessel makes angle θ_i with respect to the incoming beam of light, as shown in the diagram. This angle can be precisely adjusted and measured.

- (a) On the diagram provided on the next page, draw the refracted path of the beam through the air cell. For this diagram you should assume $n_g > n_l > n_a$. [3]
- (b) Describe qualitatively what you will observe at the exit window as you increase θ_i from zero and hence explain how this instrument could be used to determine the refractive index of the liquid n_l in the chamber. Find the relation between n_l and a special value of θ_i . [3]
- (c) Suggest with reasons, a way to modify the apparatus or its use to improve the measurement. [2]

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20. The diagram below shows an interferometer with two paths (Path A and Path B) which a wave can take from its source S to a detector D.



The lengths of the paths differ by an amount L which can change with time. The intensity at the detector I is measured and varies as a function of L as follows:

$$I = I_p + I_q \cos(kL)$$

In the above k is the wavenumber of the wave which relates to the wavelength λ via $k = 2\pi/\lambda$. I_p and I_q are constants.

- (a) Sketch the intensity as a function of L in the range from 0 to 2λ . Label both axes and identify I_p and I_q in the sketch. [3]

We wish to use the interferometer to measure how the path length difference L changes with time by measuring the intensity at the detector as a function of time. The change in path length difference is ΔL .

- (b) Indicate on your sketch the biggest ΔL you can infer unambiguously from a measurement of intensity. [2]

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21. You wish to build an adjustable delay line using electrical switches as shown in the diagram below.



Its purpose is to adjust the delay of an electrical signal through the delay line by switching different amounts of delay into the signal path.

The delay line should use the minimum amount of switches.

The delay line should have a minimal delay of L_{min} and a maximal delay of $L_{max} \leq L_{min} + \Delta L$. We refer to ΔL as the delay range.

The delay should be adjustable in increments of δL so that the line can achieve an evenly spaced set of delays between L_{min} and L_{max} with a resolution of δL .

For all segments in the line you have to determine a common, small delay l which is active when its switch is in the lower position.

You further have to determine a larger, individual delay of $L_i + l$ for each segment which is active when its switch is in the upper position.

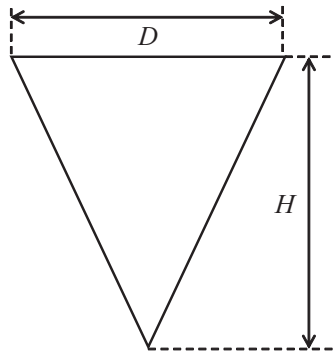
For a line with n segments to satisfy the demands on the minimum number of switches, minimum delay L_{min} , delay range ΔL and delay resolution δL :

- (a) Find a value for l in terms of L_{min} and n . [1]
- (b) Find the delays of each segment L_i in terms of δL . [3]
- (c) Find the minimum necessary n in terms of ΔL and δL . [3]

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22. A conical cup has dimensions as shown in the diagram of its cross-section below. The cup can hold a maximum volume V when filled to its full depth H . Find an expression for the depth h to which you have to fill the cup so that it contains a volume of liquid equal to $V/2$. Your expression for h should only depend on the dimensions of the cup.

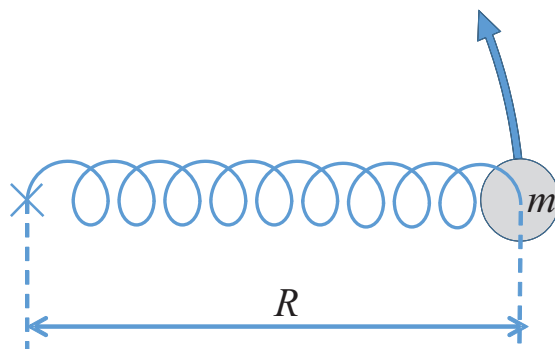
[4]



23. In an imaginary water filtration process a fraction of $1/n$ of an impurity is removed in the first pass of the water through the system. In each succeeding pass, the amount of impurity removed is $1/n$ of the amount removed in the preceding pass. Show that if $n = 2$ the water can be made arbitrarily pure but if $n = 3$, at least half of the impurity will remain.

[5]

24. The sketch below shows a ball of mass m on a spring of unextended length R_0 and spring constant k . The spring is pivoted on the left on a central axis marked with a cross. The axis is perpendicular to the plane of the sketch. The ball and spring rotate around the central axis on a smooth horizontal table as indicated by the arrow in the sketch. The spring will break if it is stretched with a force larger than F_{max} .



- (a) Find the equilibrium extension R of the system when it rotates with angular frequency ω . [3]
- (b) Find the equilibrium angular frequency ω_c at which the spring will break. [1]
- (c) Sketch ω_c against F_{max} in the range from zero to one Newton for the following parameters $m = 1$ kg, $R_0 = 1$ m, $k = 1$ N m⁻¹. Label your axes. [2]
- (d) Under some conditions the system can only achieve a maximum angular frequency $\omega_i < \omega_c$. Find a relationship between k , m and ω_i and explain what happens to the system as the angular frequency increases to ω_i . [4]

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