

OXFORD COLLEGES PHYSICS APTITUDE TEST (PAT)

Please fill in your name, the name of your school or college, and if you know them your UCAS number and Oxford College of preference, in the boxes below.

Name

School/College

--

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.

UCAS Number

(if known)

--

Oxford College of Preference

Special Provision

For the use of teachers/invigilators only. Please indicate any special provision made for the candidate (e.g. extra time, use of wordprocessor, etc.) adding a note of the reason for it.

the 1990s, the number of people in the United States who are 65 years of age or older has increased by 50 percent, and the number of people 75 years of age or older has increased by 100 percent. The number of people 85 years of age or older has increased by 200 percent. The number of people 90 years of age or older has increased by 400 percent. The number of people 95 years of age or older has increased by 800 percent. The number of people 100 years of age or older has increased by 1,600 percent. The number of people 105 years of age or older has increased by 3,200 percent. The number of people 110 years of age or older has increased by 6,400 percent. The number of people 115 years of age or older has increased by 12,800 percent. The number of people 120 years of age or older has increased by 25,600 percent. The number of people 125 years of age or older has increased by 51,200 percent. The number of people 130 years of age or older has increased by 102,400 percent. The number of people 135 years of age or older has increased by 204,800 percent. The number of people 140 years of age or older has increased by 409,600 percent. The number of people 145 years of age or older has increased by 819,200 percent. The number of people 150 years of age or older has increased by 1,638,400 percent. The number of people 155 years of age or older has increased by 3,276,800 percent. The number of people 160 years of age or older has increased by 6,553,600 percent. The number of people 165 years of age or older has increased by 13,107,200 percent. The number of people 170 years of age or older has increased by 26,214,400 percent. The number of people 175 years of age or older has increased by 52,428,800 percent. The number of people 180 years of age or older has increased by 104,857,600 percent. The number of people 185 years of age or older has increased by 209,715,200 percent. The number of people 190 years of age or older has increased by 419,430,400 percent. The number of people 195 years of age or older has increased by 838,860,800 percent. The number of people 200 years of age or older has increased by 1,677,721,600 percent. The number of people 205 years of age or older has increased by 3,355,443,200 percent. The number of people 210 years of age or older has increased by 6,710,886,400 percent. The number of people 215 years of age or older has increased by 13,421,772,800 percent. The number of people 220 years of age or older has increased by 26,843,545,600 percent. The number of people 225 years of age or older has increased by 53,687,091,200 percent. The number of people 230 years of age or older has increased by 107,374,182,400 percent. The number of people 235 years of age or older has increased by 214,748,364,800 percent. The number of people 240 years of age or older has increased by 429,496,729,600 percent. The number of people 245 years of age or older has increased by 858,993,459,200 percent. The number of people 250 years of age or older has increased by 1,717,986,918,400 percent. The number of people 255 years of age or older has increased by 3,435,973,836,800 percent. The number of people 260 years of age or older has increased by 6,871,947,673,600 percent. The number of people 265 years of age or older has increased by 13,743,895,347,200 percent. The number of people 270 years of age or older has increased by 27,487,790,694,400 percent. The number of people 275 years of age or older has increased by 54,975,581,388,800 percent. The number of people 280 years of age or older has increased by 109,951,162,777,600 percent. The number of people 285 years of age or older has increased by 219,902,325,555,200 percent. The number of people 290 years of age or older has increased by 439,804,651,110,400 percent. The number of people 295 years of age or older has increased by 879,609,302,220,800 percent. The number of people 300 years of age or older has increased by 1,759,218,604,441,600 percent. The number of people 305 years of age or older has increased by 3,518,437,208,883,200 percent. The number of people 310 years of age or older has increased by 7,036,874,417,766,400 percent. The number of people 315 years of age or older has increased by 14,073,748,835,532,800 percent. The number of people 320 years of age or older has increased by 28,147,497,671,065,600 percent. The number of people 325 years of age or older has increased by 56,294,995,342,131,200 percent. The number of people 330 years of age or older has increased by 112,589,990,684,262,400 percent. The number of people 335 years of age or older has increased by 225,179,981,368,524,800 percent. The number of people 340 years of age or older has increased by 450,359,962,737,049,600 percent. The number of people 345 years of age or older has increased by 900,719,925,474,099,200 percent. The number of people 350 years of age or older has increased by 1,801,439,850,948,198,400 percent. The number of people 355 years of age or older has increased by 3,602,879,701,896,396,800 percent. The number of people 360 years of age or older has increased by 7,205,759,403,792,793,600 percent. The number of people 365 years of age or older has increased by 14,411,518,807,585,587,200 percent. The number of people 370 years of age or older has increased by 28,823,037,615,171,174,400 percent. The number of people 375 years of age or older has increased by 57,646,075,230,342,348,800 percent. The number of people 380 years of age or older has increased by 115,292,150,460,684,697,600 percent. The number of people 385 years of age or older has increased by 230,584,300,921,369,395,200 percent. The number of people 390 years of age or older has increased by 461,168,601,842,738,790,400 percent. The number of people 395 years of age or older has increased by 922,337,203,685,477,580,800 percent. The number of people 400 years of age or older has increased by 1,844,674,407,370,955,161,600 percent. The number of people 405 years of age or older has increased by 3,689,348,814,741,910,323,200 percent. The number of people 410 years of age or older has increased by 7,378,697,629,483,820,646,400 percent. The number of people 415 years of age or older has increased by 14,757,395,258,967,641,292,800 percent. The number of people 420 years of age or older has increased by 29,514,790,517,935,282,585,600 percent. The number of people 425 years of age or older has increased by 59,029,581,035,870,565,171,200 percent. The number of people 430 years of age or older has increased by 118,059,162,071,741,130,342,400 percent. The number of people 435 years of age or older has increased by 236,118,324,143,482,260,684,800 percent. The number of people 440 years of age or older has increased by 472,236,648,286,964,521,369,600 percent. The number of people 445 years of age or older has increased by 944,473,296,573,929,042,739,200 percent. The number of people 450 years of age or older has increased by 1,888,946,593,147,858,085,478,400 percent. The number of people 455 years of age or older has increased by 3,777,893,186,295,716,170,956,800 percent. The number of people 460 years of age or older has increased by 7,555,786,372,591,432,341,913,600 percent. The number of people 465 years of age or older has increased by 15,111,572,745,182,864,683,827,200 percent. The number of people 470 years of age or older has increased by 30,223,145,490,365,729,367,654,400 percent. The number of people 475 years of age or older has increased by 60,446,290,980,731,458,735,308,800 percent. The number of people 480 years of age or older has increased by 120,892,581,961,462,917,470,617,600 percent. The number of people 485 years of age or older has increased by 241,785,163,922,925,834,941,235,200 percent. The number of people 490 years of age or older has increased by 483,570,327,845,851,669,882,470,400 percent. The number of people 495 years of age or older has increased by 967,140,655,691,703,339,764,940,800 percent. The number of people 500 years of age or older has increased by 1,934,281,311,383,406,679,529,881,600 percent. The number of people 505 years of age or older has increased by 3,868,562,622,766,813,359,059,763,200 percent. The number of people 510 years of age or older has increased by 7,737,125,245,533,626,718,119,526,400 percent. The number of people 515 years of age or older has increased by 15,474,250,491,067,253,436,239,052,800 percent. The number of people 520 years of age or older has increased by 30,948,500,982,134,506,872,478,105,600 percent. The number of people 525 years of age or older has increased by 61,897,001,964,269,013,744,956,211,200 percent. The number of people 530 years of age or older has increased by 123,794,003,928,538,027,489,912,422,400 percent. The number of people 535 years of age or older has increased by 247,588,007,857,076,054,979,824,844,800 percent. The number of people 540 years of age or older has increased by 495,176,015,714,152,109,959,649,689,600 percent. The number of people 545 years of age or older has increased by 990,352,031,428,304,219,919,299,379,200 percent. The number of people 550 years of age or older has increased by 1,980,704,062,856,608,439,838,598,758,400 percent. The number of people 555 years of age or older has increased by 3,961,408,125,713,216,879,677,197,516,800 percent. The number of people 560 years of age or older has increased by 7,922,816,251,426,433,759,354,395,033,600 percent. The number of people 565 years of age or older has increased by 15,845,632,502,852,867,518,708,790,067,200 percent. The number of people 570

Signature of Invigilator:

For Oxford use only below this line

[illegible]

THE COLLEGES OF OXFORD UNIVERSITY

PHYSICS

Wednesday 7 November 2012

Time allowed: 2 hours

*For candidates applying for Physics, Physics and Philosophy, Engineering or
Materials*

There are two parts (A and B) to this test, carrying equal weight.

Answers should be written on the question sheet in the spaces provided and you should attempt as many questions as you can from each part.

Marks for each question are indicated in the right hand margin. There are a total of 100 marks available and total marks for each section are indicated at the start of a section. You are advised to divide your time according to the marks available, and to spend equal effort on parts A and B.

No calculators, tables or formula sheets may be used.

Answers in Part A should be given exactly unless indicated otherwise. Numeric answers in Part B should be calculated to 2 significant figures.

Use $g = 10 \text{ m s}^{-2}$.

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

Part A: Mathematics for Physics [50 Marks]

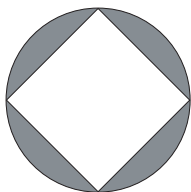
1. Find the area between $y = x^2$ and $y = |x|$. [4]

2. (i) Write down the binomial expansion of $(4 + x)^4$.
(ii) Hence or otherwise evaluate $(4.2)^4$ to 2 d.p (decimal places). [4]

3. Evaluate $\sum_{r=1}^8 (2 + 4^r)$.

[3]

4. Consider a square inside a circle of radius r as shown. What is the shaded area in terms of r ? [3]



5. Show $x = 1$ is a solution to $x^3 - 6x^2 - 9x + 14 = 0$ and find the other solutions. [4]

6. Find the equation of the line passing through $(0, 2)$ and just touching $y = (x - 2)^2$ at $x > 0$. [4]

7. If $5 = \log_2 16 + \log_{10} \sqrt{0.01} + \log_3 x$, determine x . [4]

8. Consider two dice – one contains the numbers 1-6, the other contains only 1,2,3 each shown twice (i.e. 1,2,3,1,2,3). What is the probability that when we roll the two dice we will obtain a score of 7? [4]

9. Solve $\cos^2 \theta + \sin \theta = 0$ for θ . Leave your answer in terms of $\sin \theta$. [4]

10. Sketch an example of a real function $f(x)$ defined for all real arguments x , which has all of the following properties:

- (a) $f(x) > 0$ for all x ,
- (b) $f(x)$ is a continuous function,
- (c) $\frac{df}{dx} = 0$ only for $x = 4$,
- (d) $\frac{d^2f}{dx^2} = 0$ only for $x = 2$ and $x = 6$.

[4]

11. Solve $-1 < -\frac{1}{x} + 2x < 1$.

[6]

12. Sketch $y = \frac{1 - x - x^2}{x^2}$.

[6]

Part B: Physics [50 Marks]

Multiple choice (10 marks)

Please circle **one** answer to each question only.

13. A vintage steam locomotive made of iron has a mass of 6.5×10^4 kg and is 10 m long. How long is its scale model which is also made out of iron and has a mass of 1 kg?

A $\simeq 4$ cm	B $\simeq 20$ cm	
C $\simeq 25$ cm	D $\simeq 30$ cm	[2]

14. A gas cylinder has a volume of 0.02 m^3 and contains 88 g of carbon dioxide at a temperature of 27°C . The molar gas constant $R \simeq 8.3 \text{ J mol}^{-1} \text{K}^{-1}$. What is the gas pressure?

A $\simeq 101$ kPa	B $\simeq 149$ kPa	
C $\simeq 201$ kPa	D $\simeq 249$ kPa	[2]

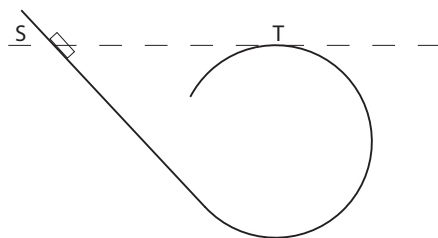
15. An electric car has a battery pack delivering 160 V and 100 A of steady current when moving at 36 km/h. What is the air resistance, assuming 100 % efficiency?

A $\simeq 440$ N	B $\simeq 1600$ N	
C $\simeq 2000$ N	D $\simeq 3200$ N	[2]

16. A cube painted black is cut into 125 identical cubes. How many of them are not painted at all?

A 21	B 25	
C 27	D 30	[2]

17. A massive slider starts from rest from a point S (which is at the same height as a point T at the top of the track) and slides along a frictionless circular track as sketched in figure below. The slider
- A does not get to T.
 - B gets to T and falls straight down.
 - C gets to T but then, leaves the track and falls down following a parabola trajectory to the left.
 - D passes T staying on the track all the way through.
- [2]



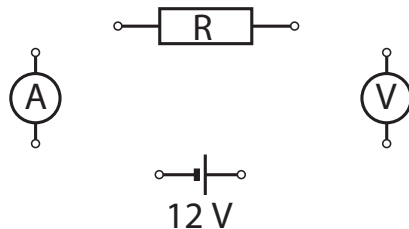
Written answers (20 marks)

18. A 12V battery, a voltmeter, an ammeter and a resistor $R = 2 \text{ k}\Omega$ are sketched in figure (a) below.

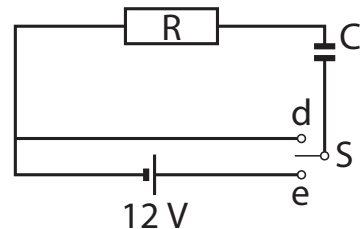
Sketch connections to create a circuit to measure a potential difference across the resistor and an electric current. How big is the current? [1]

A capacitor $C = 4 \text{ }\mu\text{F}$ and a switch S, as sketched in figure (b), are inserted into the circuit. Sketch how the current depends on time from the moment t_e when the switch is moved to e closing the circuit. Estimate the time T after which the current is not changing significantly. After a time t_d much longer than T , the switch is moved to d . Sketch the current from that moment until the moment when the current is not changing significantly, indicating on your sketch the time interval T . [3]

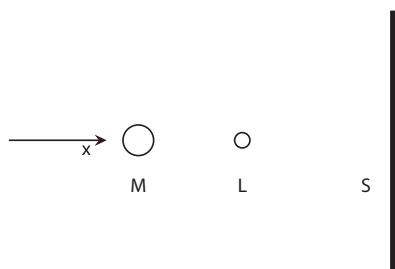
(a)



(b)



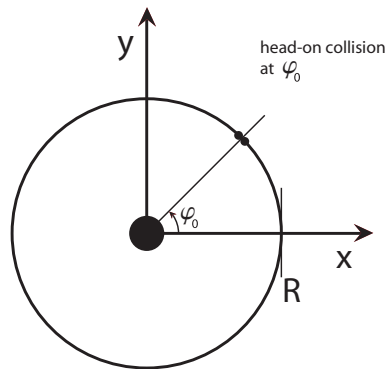
19. A loudspeaker L is placed between a microphone M and a screen S reflecting sound waves as sketched below. The loudspeaker emits sound of fixed wavelength λ in all directions. When the screen is moving slowly, to the right along the x direction (slowly in comparison with the speed of sound), the microphone records minima and maxima of the sound intensity. What is the distance between two screen positions giving two successive maxima? Would the microphone record minima and maxima if (a) the loudspeaker or (b) the microphone is moving along x direction instead of the screen? [4]



20. The ^{238}U isotope has a half-life $T_{238} = 4.5 \times 10^9$ years and the ^{235}U has $T_{235} = 7.0 \times 10^8$ years. $N_{238}(t)$ is the number of ^{238}U nuclei at time t and $N_{235}(t)$ is the corresponding number for ^{235}U . The relative abundance $r(t)$ is defined as $r(t) = \frac{N_{235}(t)}{N_{238}(t)}$. At present, $r = 0.0072$. Estimate the relative abundance of these two isotopes 10^9 years ago. You might use the following approximations: $e^x \simeq 1 + x$ for small x , $e \simeq 2.7$ and $\ln 2 \simeq 0.7$. [4]

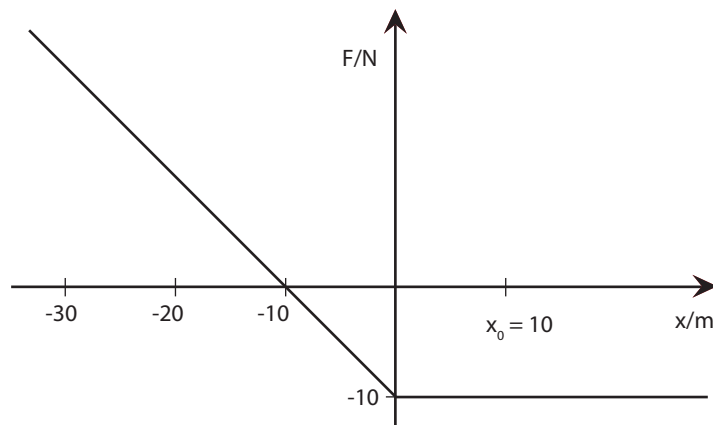
21. A meteoroid of mass m is on a circular Earth orbit of radius R which is a few (> 2) times larger than the radius of the Earth R_E . Derive an expression for the meteoroid's speed. State the meanings of all symbols used. [2]

Another meteoroid of the same mass is on the same orbit, in the same plane but rotating in the opposite direction. At an azimuthal angle φ_0 , see figure below, the two meteoroids collide head-on and coalesce (combine). Sketch the complete trajectory of the newly formed double mass meteoroid showing how the azimuthal angle φ depends on the distance r . Sketch also its kinetic energy and expected meteoroid surface temperature as a function of r . Give a very brief explanation of why you expect the temperature to depend on r that way. For $r < 2R_E$ effects due to the Earth's atmosphere can not be neglected; r is the distance from the Earth's centre. [6]



Long question (20 marks)

22. A point like object with mass $m = 1$ kg starts from rest at point $x_0 = 10$ m and moves without any friction under a force F which depends on the coordinate x as illustrated in figure below. The motion is confined to one dimension along x .



a1 What is its speed at $x = 0$?

[2]

a2 Sketch its kinetic energy as a function of x .

[4]

a3 Sketch its velocity as well as its acceleration as a function of time t . [6]

Now consider a case when, in addition, a friction force of a magnitude of 1 N is present for $x \geq 0$.

b1 Sketch how the velocity depends on x in that case. [6]

b2 How many meters this point like object travelled during the time when its position coordinate x was ≥ 0 ? [2]