

**PHYSICS ADMISSIONS TEST**  
**November 2021**

**Time allowed: 2 hours**

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

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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.

**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.**

2

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3

1. What is the next number in the sequence? 1, 32, 243, 1024, 3125

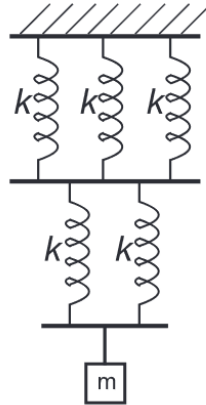
[2]

A	B	C	D	E
5040	6225	7164	7776	8192

4

2. What is the effective spring constant of the combination of springs shown in the diagram, if each spring has spring constant  $k$ ?

[2]



A	B	C	D	E
$\frac{5}{6}k$	$k$	$\frac{6}{5}k$	$2k$	$5k$

5

3. Evaluate  $\sum_{n=1}^{10} (2 - \frac{n}{2} + 2^n)$ .

[2]

A	B	C	D	E
$2^{10} - \frac{11}{2}$	$2^{12} - \frac{19}{2}$	$2^{11} - \frac{19}{2}$	$2^{10} - \frac{11}{4}$	$2^{11} - \frac{11}{2}$

6

4. Five different ions are accelerated from rest by the same potential difference. Which will have the smallest final velocity?

[2]

A	B	C	D	E
${}^6_3\text{Li}^{2+}$	${}^7_3\text{Li}^{2+}$	${}^7_3\text{Li}^{3+}$	${}^9_4\text{Be}^{3+}$	${}^9_4\text{Be}^{4+}$

7

5. Gravity on the Moon satisfies

$$g_{Moon} = \frac{1}{6}g_{Earth}.$$

A ball dropped on Earth from a height  $h$  takes a time  $t$  to reach the ground. From which height should it be dropped on the Moon so that it takes the same time  $t$  to reach the surface? You can neglect all effects of air resistance.

[2]

A	B	C	D	E
$\frac{1}{36}h$	$\frac{1}{6}h$	$\frac{1}{\sqrt{6}}h$	$h$	$6h$

8

6. Two unbiased dice are rolled and the numbers obtained are added. If the probability of getting the sum  $S$  is  $P(S)$ , which of the following statements are true? [2]

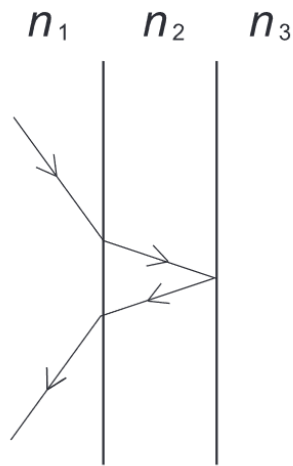
1.  $P(10) + P(11) = P(6)$
2.  $P(6) > P(8)$
3.  $P(2) + P(3) + P(4) > P(7)$
4.  $P(7) = \frac{3}{2}P(5)$
5.  $P(11) = P(3)$

A	B	C	D	E
1,2,4	3,4,5	2,3,4	1,3,5	1,4,5



9

7. A light ray follows a path through three media separated by plane boundaries as shown in the diagram, with refractive indices  $n_1$ ,  $n_2$  and  $n_3$ .



Which of the following sequences puts the refractive indices in order of increasing value?

[2]

A	B	C	D	E
$n_1, n_2, n_3$	$n_2, n_1, n_3$	$n_1, n_3, n_2$	$n_3, n_1, n_2$	$n_3, n_2, n_1$

10

8. If  $f(x) = x^2$  and  $g(x) = x + 3$ , find  $\frac{dy}{dx}$  where  $y = f(g(x)) - g(f(x))$ .

[2]

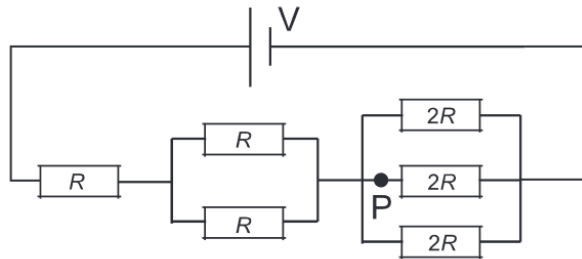
A	B	C	D	E
6	$2x + 5$	$2x - 1$	$6x + 6$	2

11

9. What is the current at the point P in the diagram?

[2]

A	B	C	D	E
$\frac{2V}{13R}$	$\frac{2V}{11R}$	$\frac{V}{9R}$	$\frac{6V}{13R}$	$\frac{6V}{11R}$



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10. Which of these represents a simpler form for  $\cos(\sin^{-1}(x))$ ?

[2]

A	B	C	D	E
$\sqrt{1-x^2}$	$\sqrt{1+x^2}$	$\sqrt{1-x}$	$1-x^2$	$\sqrt{x-1}$

11. Consider the following five graphs.

1. Force ( $y$ -axis) against distance ( $x$ -axis)
2. Force ( $y$ -axis) against time ( $x$ -axis)
3. Velocity ( $y$ -axis) against time ( $x$ -axis)
4. Mass ( $y$ -axis) against velocity squared ( $x$ -axis)
5. Voltage ( $y$ -axis) against charge ( $x$ -axis)

For which graphs could the area under the graph potentially be a measurement of energy?

[2]

A	B	C	D	E
1, 4, 5	1, 5	1, 4	1, 3, 4	All of them.

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12. Which of the following integrals are equal to zero (you do **not** need to evaluate the integrals explicitly)?

[2]

1.  $\int_{-\pi/2}^{\pi/2} \sin(3x) \, dx$
2.  $\int_{-\sqrt{7}}^{\sqrt{7}} \frac{1}{9}x^5 - \frac{1}{7}x^3 + \frac{1}{21}x \, dx$
3.  $\int_0^1 \cos x \, dx$
4.  $\int_{-2}^2 \frac{1}{4}x^4 + \frac{1}{12}x^2 \, dx$
5.  $\int_{-90}^{90} \sin(5x) - \frac{1}{2} \sin x \, dx$

A	B	C	D	E
1,2	3,4	1	1,2,5	1,5

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**13.** A toilet roll is made up of an inner cardboard tube, diameter  $x$  cm, with toilet paper wrapped around it to give an overall diameter of  $y$  cm. The length of the cardboard tube is  $z$  cm. Suppose the diameter of the inner tube is reduced from  $x$  cm to  $(x - 1)$  cm, but the volume of toilet *paper* is kept the same. What is the difference in the *total* volume of the roll?

[3]

16

14. A machine requires 10kW of electrical power when operating at 100V.

- (a) If power is delivered through a cable with resistance  $100\Omega$ , how much power is lost to the cable's resistance? [2]
- (b) In order to reduce power loss, a transformer is used between the cable and the machine. What ratio of turns is required on the transformer in order to reduce power loss on the cable by a factor of  $10^4$ ? [2]



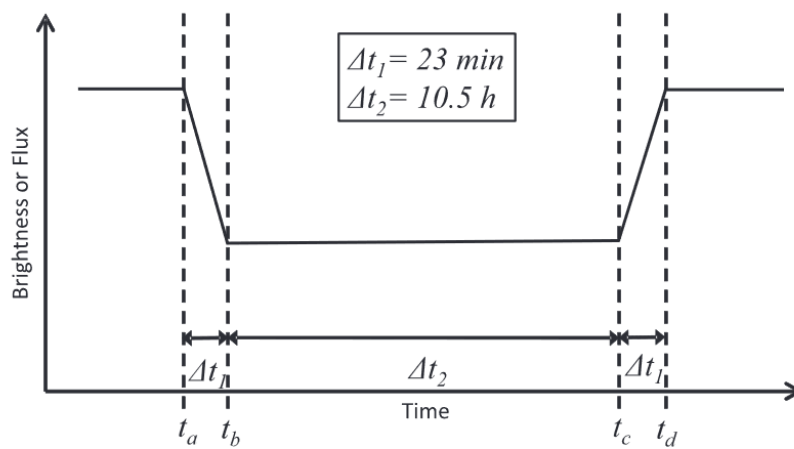
15. The observed brightness of a Sun-like star shows periodic dips. The time period between these dips  $T = 225$  days.

- (a) If these dips are interpreted as being due to the transits of a planet in a circular orbit around the star, estimate the radius  $R$  of that orbit.

You may assume that the star has the same mass as the Sun and that the planet's mass is much smaller than the mass of the star. You can take the mean radius of the Earth's orbit around the Sun to be approximately  $R_E = 1.5 \times 10^{11}$  m.

[5]

- (b) A model of a transit and its effect on the star's brightness is shown in the figure below. Assuming that we observe the system in the plane of the planet's orbit, draw the relative positions of the planet and the star at the times  $t_a$  to  $t_d$  and calculate the radii of the planet,  $R_P$  and the star,  $R_S$ .



[5]

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16. A vehicle travels in a fixed direction at a velocity  $v(t)$  that varies with time as follows:

$$\begin{array}{ll} t < t_1 & v(t) = At^2 \\ t_1 < t < t_2 & v(t) = C - B(t - t_2)^2 \\ t > t_2 & v(t) = v_2. \end{array}$$

Here  $A$ ,  $B$ ,  $C$  and  $v_2$  are constants.

- (a) Find  $A$ ,  $B$  and  $C$  such that both the velocity and acceleration are continuous at  $t = t_1$  and  $t = t_2$ . [3]
- (b) Sketch the velocity and acceleration as a function of time. [3]
- (c) Find the total distance travelled between  $t = 0$  and  $t = t_3$ , where  $t_3 > t_2$ . [4]

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17. In Einstein's theory of gravity, light passing a star of mass  $M$ , at a distance  $R$  from the centre of the star, is bent by an angle  $\theta$  (measured in radians,  $2\pi$  radians =  $360^\circ$ ) as shown in the diagram.

- (a) Assume that  $\theta$  depends on the gravitational constant  $G$  and also depends on the mass of the star  $M$ , the distance  $R$  and the speed of light  $c = 3 \times 10^8 \text{ m s}^{-1}$ , as

$$\theta = \lambda GM^\alpha R^\beta c^\gamma,$$

where  $\lambda$  is an undetermined dimensionless constant.

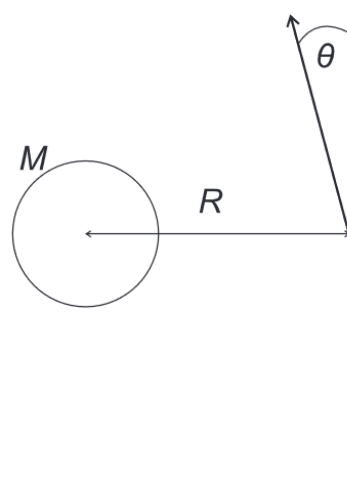
By considering the dimensions of these quantities determine  $\alpha, \beta$  and  $\gamma$ .

[4]

- (b) In SI units the numerical value of  $G$  is  $6.67 \times 10^{-11}$ .

Neglecting any spatial extent to the star, and taking  $\lambda = 1$  and  $M = 2 \times 10^{30} \text{ kg}$ , determine the distance  $R$  such that light is bent so much that it falls directly into the star.

[3]



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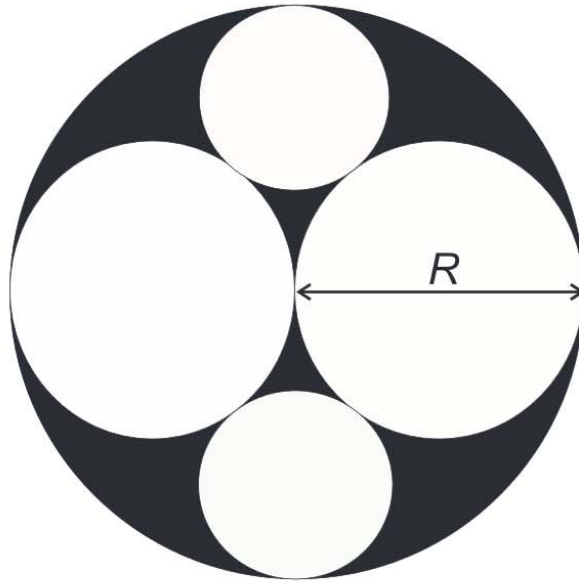
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18. Find the area of the dark regions of this figure in terms of the overall radius of the outer circle (denoted  $R$ ).

[5]



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**19.** Sand is poured at a constant rate onto a flat horizontal surface. It forms a pile in the shape of a cone with a constant slope.

- (a) If  $r$  is the radius of the base of the cone, find how  $r$  varies with  $t$ , given that  $r(0) = 0$ . [3]
- (b) If it takes a time  $t_1$  for  $r$  to reach  $r_1$ , how long does it take for the radius to reach  $2r_1$  (in terms of  $t_1$ )? [2]

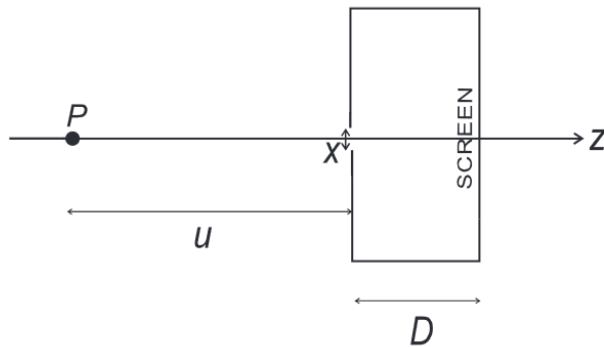
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**20.** Expand  $(a + bx)^c$ , where  $c$  is a positive integer, as a polynomial in  $x$  up to and including terms involving  $x^2$ .

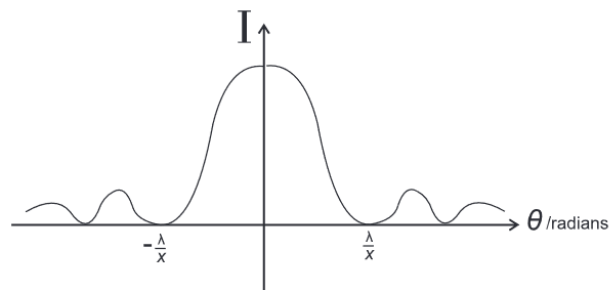
If the coefficient of the  $x^0$  term is equal to  $\frac{1}{16}$ ,  $b = \frac{1}{4}$  and the coefficient of the  $x^2$  term is  $\frac{3}{32}$ , find  $a$  and  $c$ .

[4]

21. A pinhole camera consists of a box with a small aperture (of diameter  $x$ ). A point light source  $P$  is at a distance  $u$  from the aperture outside the box. It projects an image on the screen, which is inside the box at a distance  $D$  from the aperture.



- (a) If diffraction is ignored, what is the diameter  $s_1$  of the spot projected on the screen? [2]
- (b) If  $D \gg x$ , diffraction of light of wavelength  $\lambda$  by the aperture produces a distribution of intensity that varies with angle  $\theta$  (measured in radians from the  $z$  axis marked on the diagram;  $2\pi$  radians = 360 degrees) approximately as shown below:



What is the approximate diameter,  $s_2$ , of the central peak of the diffraction pattern projected on the screen? [2]

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- (c) Assume that the effects in part (a) and (b) can be combined to give a total diameter  $s_3$ , where

$$s_3^2 = s_1^2 + s_2^2.$$

Find the pinhole size that produces the sharpest image of the light source on the screen.

[4]

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**22.**

- (a) Sketch the functions  $f(x) = x^2 + 2x - 7$  and  $g(x) = \frac{2}{x}$  on the same graph. [2]
- (b) Determine the coordinates of the points of intersection of the two curves and label their exact values. You are **not** required to determine coordinates of intersections with  $x$  or  $y$  axes. [4]
- (c) Evaluate the finite area enclosed between the two curves. [4]

You are expected to show clear working for all parts.



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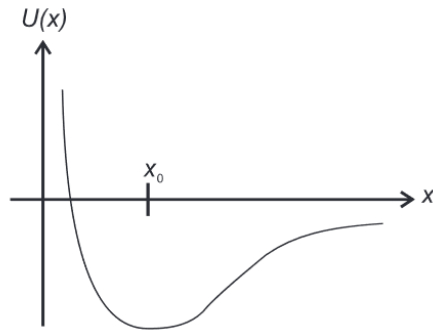
23. The potential energy for a system of two atoms separated by a distance  $x$  is  $U(x)$  (shown below).

Sketch  $-\frac{dU}{dx}$ .

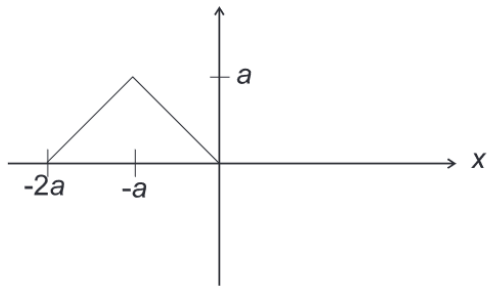
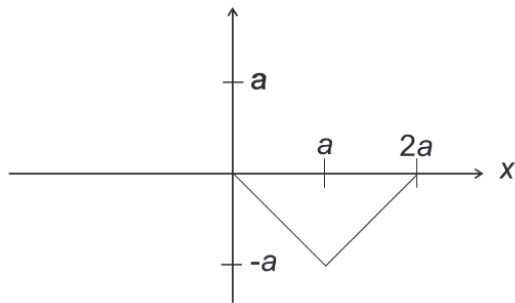
[2]

What does this new curve represent physically and what does the point  $x_0$  represent?

[2]



36

24. If  $f(x)$  isand  $g(x)$  is

then sketch  $f(x - ct) + g(x + ct)$  for  $t = a/2c$ ,  $3a/4c$  and  $a/c$ . Each sketch should be done separately with its own set of axes.

[6]

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