



NANYANG JUNIOR COLLEGE
JC2 Timed Practice 2026
General Certificate of Education Advanced Level
Higher 3

CANDIDATE
NAME

CIVICS
GROUP

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REGISTRATION
NUMBER

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PHYSICS

9814/01

Paper 1

09 July 2026

1 hour 30 min

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected where appropriate.

Answer **all** questions.

For Examiner's Use	
1	10
2	12
3	10
4	20
Total	52

Data

speed of light in free space,	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
elementary charge,	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant,	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant,	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall,	$g = 9.81 \text{ m s}^{-2}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$	work done on/by a gas	$W = p \Delta V$
	$v^2 = u^2 + 2as$	Pressure	$p = \frac{F}{A}$
moment of inertia of rod through one end	$I = \frac{1}{3}ML^2$	gravitational potential	$\phi = -\frac{Gm}{r}$
moment of inertia of hollow cylinder through axis	$I = \frac{1}{2}M(r_1^2 + r_2^2)$	temperature	$T/K = T/^{\circ}\text{C} + 273.15$
moment of inertia of solid sphere through centre	$I = \frac{2}{5}MR^2$	pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
moment of inertia of hollow sphere through centre	$I = \frac{2}{3}MR^2$	mean translational kinetic energy of an ideal gas particle	$E = \frac{3}{2}kT$

displacement of particle in s.h.m.	$x = x_0 \sin \omega t$	alternating current/voltage,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$	magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
electric current,	$I = Anvq$	magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
resistors in series,	$R = R_1 + R_2 + \dots$	magnetic flux density due to a long solenoid	$B = \mu_0 nI$
resistors in parallel,	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$	energy in an inductor	$U = \frac{1}{2} LI^2$
capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$	RL series circuits	$\tau = \frac{L}{R}$
capacitors in parallel	$C = C_1 + C_2 + \dots$	RLC series circuits (underdamped)	$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$
energy in a capacitor	$U = \frac{1}{2} QV$ $= \frac{1}{2} \frac{Q^2}{C}$ $= \frac{1}{2} CV^2$	energy states for quantum particle in a box	$E_n = \frac{h^2}{8mL^2} n^2$
charging a capacitor	$Q = Q_0 \left[1 - e^{-\frac{t}{\tau}} \right]$	radioactive decay	$x_0 = x_0 e^{-\lambda t}$
discharging a capacitor	$Q = Q_0 e^{-\frac{t}{\tau}}$	radioactive decay constant	$\lambda = \frac{\ln 2}{t_{1/2}}$
RC time constant	$\tau = RC$	Lorentz factor	$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$	length contraction	$L = \frac{L_0}{\gamma}$
electric field strength due to a long straight wire	$E = \frac{\lambda}{2\pi\epsilon_0 r}$	time dilation	$T = \gamma T_0$
electric field strength due to a large sheet	$E = \frac{\sigma}{2\epsilon_0}$	Lorentz transformation equations (1 dimension)	$x' = \gamma(x - vt)$ $t' = \gamma\left(t - \frac{vx}{c^2}\right)$ $u' = \frac{(u - v)}{\left(1 - \frac{uv}{c^2}\right)}$
		mass-energy equivalence	$E^2 = (pc)^2 + (mc^2)^2$

Answer **all** questions.

- 1 Two perfectly elastic balls, A and B, are held above the ground at a height h , such that h is much greater than the diameter of each ball. The balls are almost touching, with ball A directly above ball B.

The balls are released simultaneously. Ball A rebounds to a maximum height H above the ground.

- (a) Sketch a labelled diagram to show the velocities of the balls relative to the ground just before they collide with each other.

Hence show that when the balls collide with each other, they do so with relative velocity

$$v_{rel} = \sqrt{8gh}$$

[3]

- (b) The mass of the lower ball m_B is greater than or equal to the mass of the upper ball m_A so that:

$$\frac{m_B}{m_A} = n \quad \text{and} \quad n \geq 1$$

Determine an expression for the velocity of the centre of mass frame v_{CoM} relative to the ground immediately before the two balls collide.

[2]

- (c) (i) Determine an expression for the ratio of the rebound height H to the drop height h .

[3]

- (ii) Deduce the maximum value of $\frac{H}{h}$ for $n \geq 1$.

maximum value of $\frac{H}{h} = \dots\dots\dots$ [2]

[Total: 10]

- 2 A consequence of special relativity is that observers in different inertial reference frames disagree on the lengths of objects and the times between events.

(a) State what is meant by an inertial observer.

.....
 [1]

(b) An inertial reference frame (x, y, z, t) has Earth as its origin.

Ignore the rotational motion of Earth as negligible on the length scale of interest.

In this reference frame, the star Proxima Centauri is a distance of 4.25 light years (ly) along the positive x -axis, as shown in Figure 2.1.

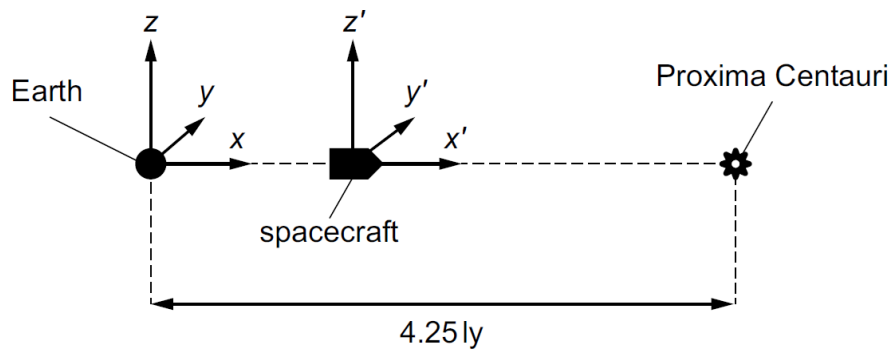


Figure. 2.1

A spacecraft leaves Earth at $t = 0$ and travels directly to Proxima Centauri at a speed of $\frac{c}{2}$.

Assume that there is negligible relative motion between Earth and Proxima Centauri.

The origin of an inertial reference frame (x', y', z', t') moving with the spacecraft coincides with the origin of the Earth's reference frame at the moment the spacecraft leaves the Earth.

- (i) Write down the x and t coordinates of the spacecraft in Earth's reference frame at the moment of departure from Earth and at the moment of arrival at Proxima Centauri.

Use units of light years (ly) for x and years (yr) for t . In these units, $c = 1$.

x at departure = ly

t at departure = yr

x at arrival = ly

t at arrival = yr
[3]

- (ii) Use the Lorentz transformation equations to write down the x' and t' coordinates of the spacecraft at the moment of departure from Earth and at the moment of arrival at Proxima Centauri.

Use units of light years (ly) for x' and years (yr) for t' . In these units, $c = 1$.

x' at departure = ly

t' at departure = yr

x' at arrival = ly

t' at arrival = yr
[4]

- (iii) Using your answer in **2(b)(ii)** or otherwise, calculate the distance from Earth to Proxima Centauri in the (x', y', z', t') frame.

distance = ly [1]

- (iv) The spacecraft returns immediately to Earth at the same speed of $\frac{c}{2}$.

Explain why, for an inertial observer onboard the spacecraft, this journey could be considered a form of time travel.

Support your explanation with calculations.

.....

.....

.....

[3]

[Total: 12]

3 Fig. 3.1 shows a side view and top view of a helicopter hovering stationary in mid-air.

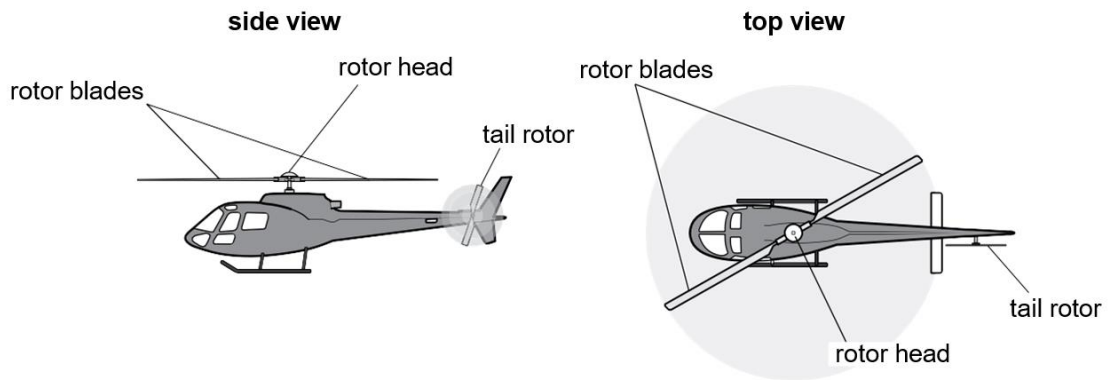


Fig. 3.1

The two rotor blades of the helicopter can be modelled as uniform thin rectangular plates of length R and width c , as shown in Fig. 3.2.

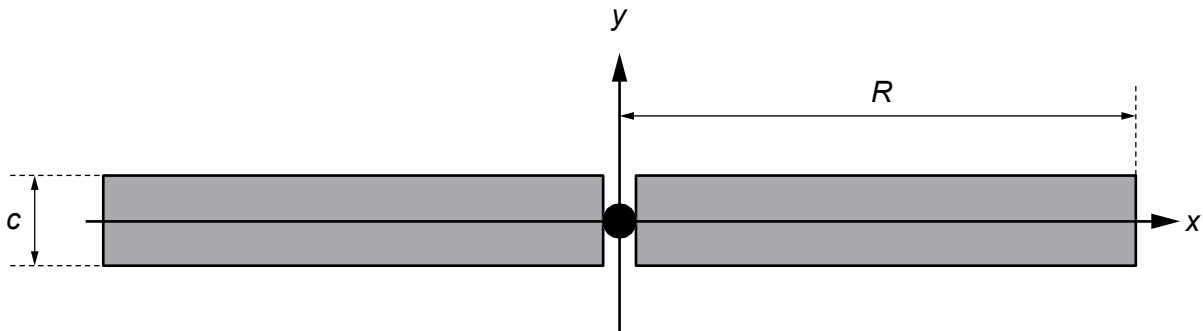


Fig. 3.2 (not to scale)

The gap between the two rotor blades is negligible when compared with the total length of the blades.

- (a) Show, from first principles, that the moment of inertia, I_x , of the rotor blades about the x-axis in Fig. 3.2 is given by

$$I_x = \frac{1}{12} M c^2$$

where M is the **total** mass of the rotor blades.

- (b) The total lift force on the helicopter can be calculated by summing the lift on infinitesimal elements of the blade.

Fig. 3.3 shows an element of the rotor blade with width c and length dr at a distance r from the axis of rotation.

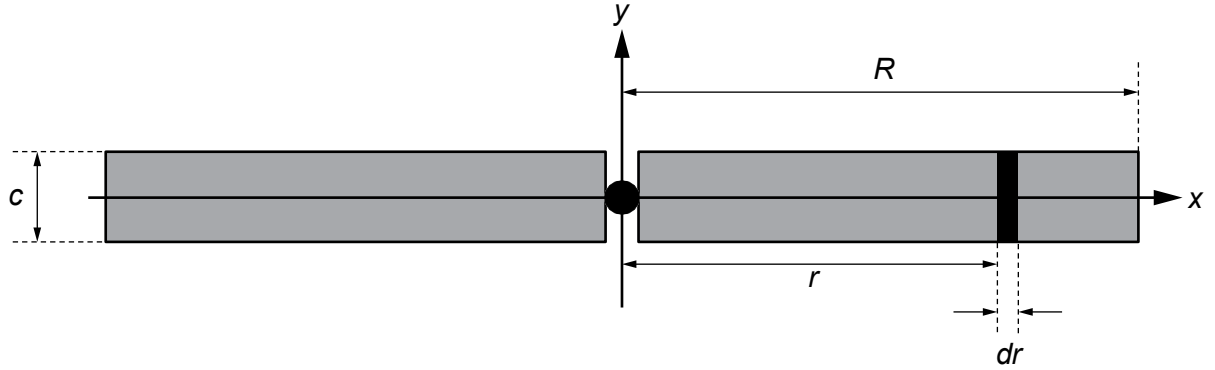


Fig. 3.3 (not to scale)

The lift dL on the blade element is given by the equation:

$$dL = \frac{1}{2} C_L \rho (r \omega)^2 c dr$$

where:

C_L is the coefficient of lift

ρ is the density of air and can be taken to be 1.25 kg m^{-3}

ω is the angular velocity of the rotor blades.

- (i) Show that the coefficient of lift C_L is dimensionless.

[1]

- (ii) Show that the total lift force L generated by the two rotor blades is given by:

$$L = \frac{1}{3} C_L \rho \omega^2 c R^3$$

[3]

- (c) Coning is an effect where the rotor blades of the helicopter tilt upwards from the horizontal, as shown in Fig. 3.4.

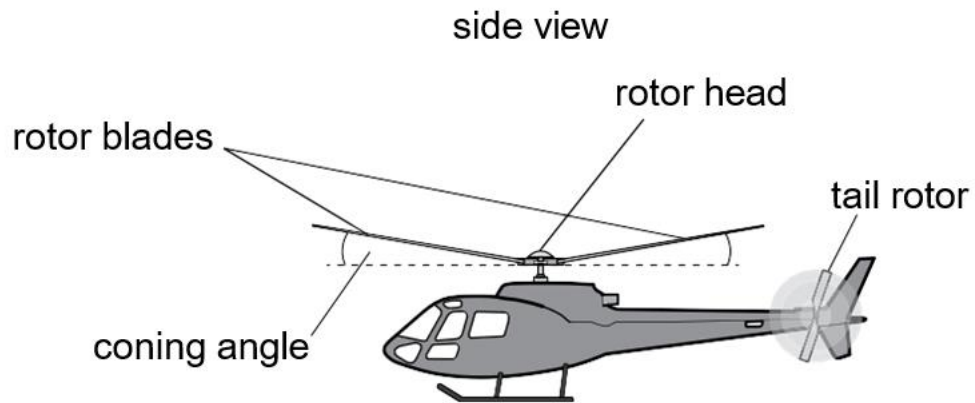


Fig. 3.4

- (i) Explain why coning occurs.

.....

 [1]

- (ii) The total mass of the helicopter, including blades, is 2500 kg.

Calculate the angular velocity ω of the rotor blades, in rpm, required for the helicopter to hover at a constant height above the ground with a coning angle of 10.0° .

Use a typical value for C_L of 0.400, $R = 3.84$ m and width $c = 20$ cm.

$\omega =$ rpm [2]

[Total: 10]

- 4 A uniformly charged thin disc of radius R lies in the x - y plane as shown in Fig. 4.1.

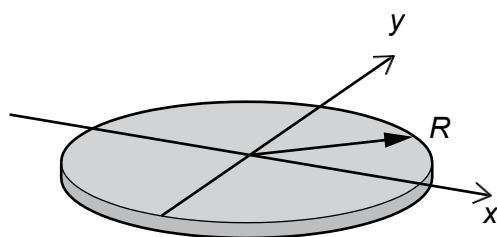


Fig. 4.1

The total amount of charge on the disc is Q .

- (a) (i) State an expression for the surface charge density σ in terms of Q and R .

[1]

- (ii) Use your answer in **4(a)(i)** and apply Gauss's law with an appropriately chosen Gaussian surface to show that an approximation for the electric field at the position $(0,0,z)$, where $z \ll R$, is given by:

$$E_z = 2\pi k\sigma$$

where k is a constant you need to determine.

You may wish to draw a diagram to help your answer.

[6]

- (iii) Determine an expression for the electric potential at the point $(0,0,z)$ relative to the origin.

[2]

- (b) The electric field can be determined more accurately than determined in 4(a) by superimposing the point charge fields of infinitesimal charge elements. This can be done by summing the fields of charged rings of width dr , as shown in Fig. 4.2.

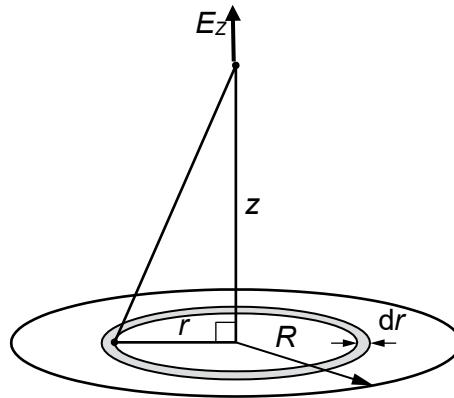


Fig. 4.2

- i. Show that the electric field at position $(0,0,z)$ is given by:

$$E_z = \frac{\sigma}{2\epsilon_0} \left[1 - \frac{z}{\sqrt{z^2 + R^2}} \right]$$

[5]

ii. Determine an expression for E_z when $z \ll R$.

[2]

iii. Determine a non-zero expression for E_z when $z \gg R$.
 You may wish to use the approximation shown when x is small.
 $(1 + x)^n \approx 1 + nx$

[2]

iv. Comment on the form of the expressions in **4(b)(ii)** and **4(b)(iii)**.

.....

[2]

[Total: 20]

END OF PAPER