NJC Preliminary Examination 2024
H2 Physics Paper 3

Solutions and Mark Scheme

Section A

1 **(a)** change in velocity of the body is always perpendicular to velocity when speed is constant. B1

acceleration and so resultant force [Newton's second] is always perpendicular to the velocity B1

velocity is tangent to circular path, so resultant force (perpendicular to the velocity) directed towards centre of circle B1

(b) **(i)** centripetal acceleration

$$= \frac{\left(\frac{25\times10^3}{60\times60}\right)^2}{7.0}$$ M1

$= 6.9$ m s^{-2} or 6.89 m s^{-2} A1

(ii) force on mass = $0.50 \times 6.889 = 3.4445$ N C1

displacement = $3.4445 \times 5.0 = 17$ mm or 17.2 mm A1

(iii) extension of spring at B > spring at A / spring at B is extended while spring at A is compressed to provide this resultant force (towards B or centre) M1

pointer moves towards A. A1

2 **(a)** The gravitational potential at a point is defined as the work done per unit mass in bringing a small test mass from infinity to that point. B1

(b) **(i)** Increase in potential energy = final potential energy – initial potential energy

$$= -\frac{GMm}{r_2} - \left(-\frac{GMm}{r_1}\right)$$ B1

$$= GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

1 mark for correct potential energy formula (**WITH negative sign**) and substituted correctly.

(ii) **Work is done by thrusters** M1

Hence **total** energy **increases** / **not constant** M1

Increase in potential energy not equal to decrease in kinetic energy A0

(c) Decrease in potential energy = increase of KE

$$0 - \left(-\frac{GM(m_r)}{r_2}\right) = \frac{1}{2}(m_r)v^2 - 0$$ or equate total energy

M1 for correct decrease in potential energy, M1 for correct increase in KE

$$v = \sqrt{\frac{2GM}{r_2}}$$

A1 for the correct final expression for *v*.

3 **(a)** **(i)** Kinetic energy of one gas particle (atom / molecule) = $\frac{1}{2}mc_{rms}^2 = \frac{3}{2}kT$
where m is the mass of one gas particle/atom/molecule. B1

For one mole of gas containing N_A particles, the total kinetic energy is given by:

$\frac{1}{2}N_A mc_{rms}^2 = \frac{3}{2}N_A kT$ ------------------ (1)

From the equation of state of an ideal gas for 1 mole of ideal gas: B1
$pV = (1)RT = N_A kT$

Substituting $N_A kT = RT$ into (1) gives: $\frac{1}{2}N_A mc_{rms}^2 = \frac{3}{2}RT$

Simplifying to get: $c_{rms} = \sqrt{\frac{3RT}{N_A m}} = \sqrt{\frac{3RT}{M}}$

Where $N_A m$ is the mass of 6.02 x 10^{23} particles = molar mass M.

(ii) $c_{r.m.s.} \propto \frac{1}{\sqrt{M}}$ $\frac{c_{r.m.s.}\ of\ oxygen\ molecules}{c_{r.m.s.}\ of\ nitrogen\ molecules} = \sqrt{\frac{28}{32}} = 0.935$ or 0.94
A1

(b) **(i)** $p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle = \frac{1}{3}\rho\langle c^2\rangle = \frac{1}{3} \times 1.50 \times 10^5 \times (4.85 \times 10^5)^2$ M1

= 1.18 x 10^{16} Pa A1

(ii) Forces between nuclei/particles are not negligible. (ignore "attractive") M1

Forces are repulsive (at that density) contributing to an increase in pressure A1

OR

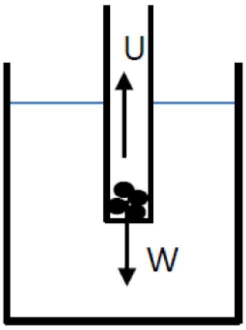
Volume of particles is not negligible (at that density) M1

Resulting in a higher rate (or frequency) of collision compared to the expected rate, causing the actual pressure to be higher than the expected value in (b)(i). A1

(c)

Process	w / kJ	q / kJ	⊗U / kJ
A to B	19.2	67.2	– 48.0 [B1]
B to C	0	48.0	48.0 [B1]
C to A	31.6	31.6	0

4 **(a)** **(i)**



W: Weight of loaded test-tube
or
W_L: weight of lead shots and W_T: weight of test-tube

U: Upthrust / Force by fluid on loaded test-tube

Legend for both W and U — B1

W and U of <u>same length</u> and act <u>along the same vertical line</u> — B1

(*Note that arrow of W should originate from C.G. of loaded test-tube while arrow of U should originate from centre of mass of the displaced fluid.)*

(ii) Summing forces vertically: $mg = Upthrust = \rho ALg$ — M1

mass of loaded test tube, $m = \rho AL$ — A1

(b) **(i)** Resultant force (in vector notation): F = Upthrust + Weight

$$F = -\rho A(L + x)g + mg = -\rho ALg + mg - \rho Axg$$ — M1

Since $mg + (\rho ALg) = 0$ — M1

$$F = -\rho Axg$$ — A0

(ii)

$$F = -\rho Axg = ma$$
$$a = -\left(\frac{\rho Ag}{m}\right)x$$ — M1
$$= -\left(\frac{\rho Ag}{\rho AL}\right)x$$ — M1

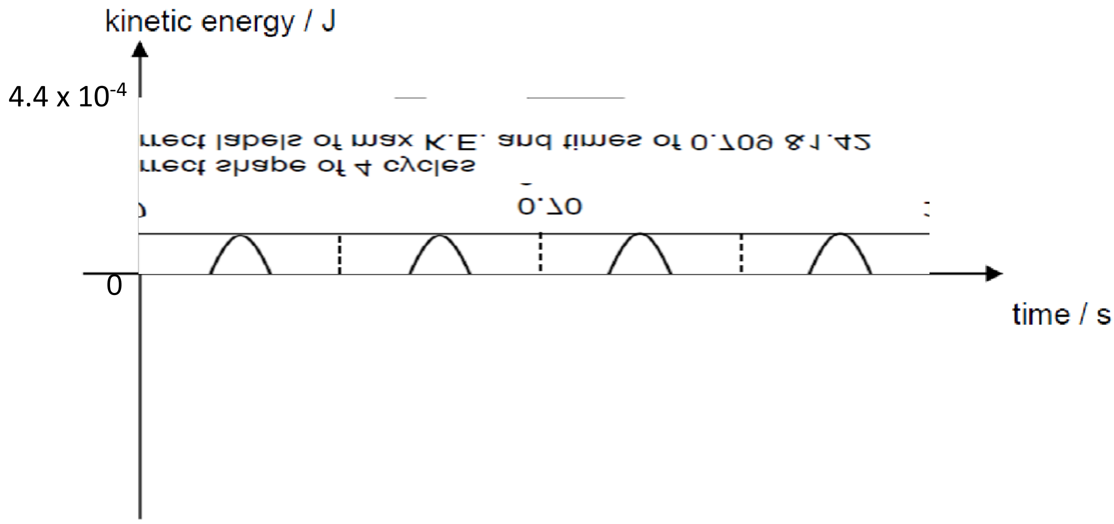
Since loaded test-tube is in SHM: $a = -\omega^2 x$ — M1

$\omega^2 = \dfrac{g}{L}$, so $\omega = \sqrt{\dfrac{g}{L}}$

(iii) Total energy $= ½\, m\, \omega^2\, x_0^2 = ½\, (0.050)(9.81/0.125)(0.015)^2$ — M1

$= 0.00044$ J — A1

(iv)



correct shape ($\sin^2$ not modulus) of 4 “humps” with k.e. starting from zero B1

correct label of max K.E. B1

5 **(a)** **(i)** Waves from the two slits overlap and superpose (debrief point) at points on the screen B1

When path difference from slits to point is multiples of wavelength / phase difference between the two waves is multiples of 2π, constructive interference gives bright fringe B1

(ii) separation $= \frac{(590\times10^{-9})(2.3)}{1.2\times10^{-3}}$ M1

$= 1.1$ mm or 1.13 mm A1

(b) $sin\ sin\ \theta\ = \frac{\lambda}{b} = \frac{590\times10^{-9}}{0.31\times10^{-3}} \approx \frac{x}{D}$ must see sinθ M1

$(tan\ tan\ \theta\ = \frac{x}{D} = \frac{x}{2.3}$ led to $x = \frac{(590\times10^{-9})(2.3)}{0.31\times10^{-3}}$

width = $2x$ M1

= 8.8 mm A0

(c) Diffraction minimum is (8.8 / 2 =) 4.4 mm from P and the fourth order bright fringe is (1.1 × 4 =) 4.4 mm from P B1

Position of 4th order interference maximum coincides/overlap with (first order) diffraction minimum. B1

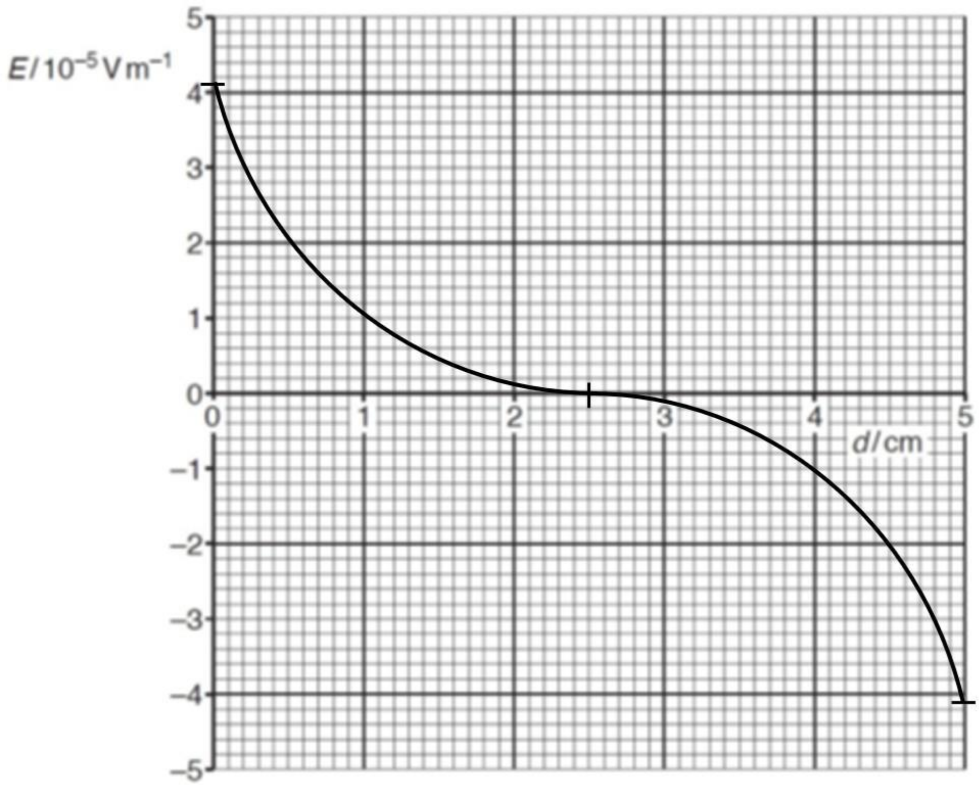
6 **(a)**

$E = Q / 4\pi\varepsilon_0 r^2$ or $E = kQ / r^2$ with k defined / substituted in

$4.1 \times 10^{-5} = [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.025^2)] - [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.075^2)]$ M1

$Q = 3.2 \times 10^{-18}$ C A1

(b)



correct shape (start positive E, gradient trend) B1

through points $(0, 4.1 \times 10^{-5})$ $(2.5, 0)$ & $(5.0, - 4.1 \times 10^{-5})$ B1

(c)

Using the graph, E-field strength on the left of d = 2.5 cm is positive, while on the right is negative. Thus, the graph shows E-field is always directed towards the d = 2.5 cm. B1

Electric Force, F = qE, (or acceleration) on positive charge is always opposite to displacement from d = 2.5 cm B1

7 **(a)** $V = 2.4\ V = V_p$

$N_s / N_p = 50 = V_s / V_p$ M1

$V_s = 2.4 \times 50 = 120V$

Max V_S $= 120 \times \sqrt{2}$

$= 170V$ A1

(b) $P_{ave} = ½ (½) P_0$

$= ¼ V_0^2/R$

$= ¼\ 170^2 / 47$ C1

$= 154$ W A1

(c) $P_{new} = 2\ P_{ave} = 307$ W (allow ecf part b) M1

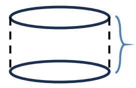
(d) Direct voltage since the voltage shown is always positive (w.r.t. time) B1

(e) Transformers requires an input voltage that varies with time. B1

Section B

8 **(a)** **(i)** Area cut in time $\otimes t$ is the curved surface area of a cylinder traced out by the falling ring. $A = (2\pi r)(v\Delta t)$

Flux cut, $\Delta\Phi = BA = B(2\pi r)(v\Delta t)$ B1



Comments: Some explanation is expected in the working since this is a "show" question. No credit for candidates who just write $\Delta\Phi = B(2\pi r)(v\Delta t)$

(ii) From Faraday's Law, induced e.m.f. $E = \dfrac{\Delta\Phi}{\Delta t}$

$$= \frac{B(2\pi r)(v\Delta t)}{\Delta t} = 2\pi rBv$$ M1

Induced current $I = \dfrac{E}{R}$

$$= \frac{2\pi rBv}{R}$$ M1

(iii) Magnetic force exerted by the radial magnetic field on the induced current in the ring, $F_B = BIL = B(\square)(2\pi r)$ M1

From Newton's 2nd Law: Resultant force on the ring $= mg - F_B = ma$ M1

$$mg - B\left(\frac{2\pi rBv}{R}\right)(2\pi r) = ma$$

$$a = g - \frac{(2\pi rB)^2 v}{mR}$$ A0

(iii) Maximum speed (when a = 0) is

$$v_{max} = \frac{mgR}{(2\pi rB)^2}$$ C1

$$= \frac{(0.0235)(9.81)(2.30\times10^{-4})}{(2\pi\times0.03\times0.800)^2}$$ M1

= 2.33 x 10^{-3} m s^{-1} A1

(iv)

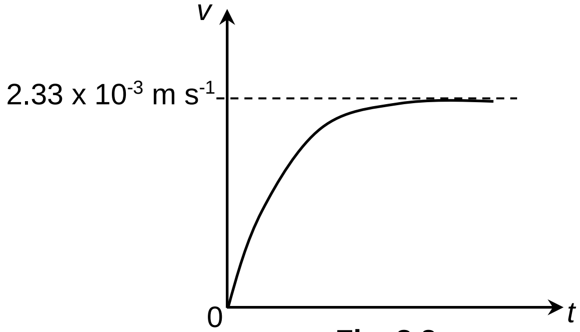


Fig. 8.2a

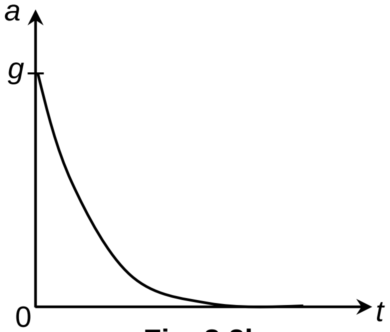


Fig. 8.2b

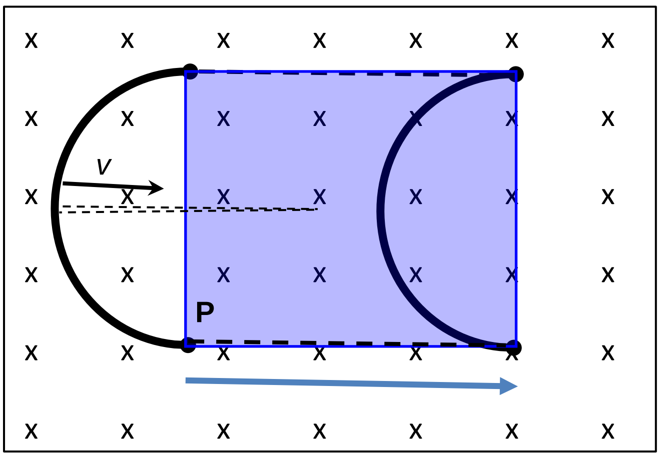
Correct shape B1
label terminal velocity B1
Correct shape for a-t graph B1

(b) **(i)** Induced e.m.f. = Brv = 0.500 x 0.03 x 0.03 M1

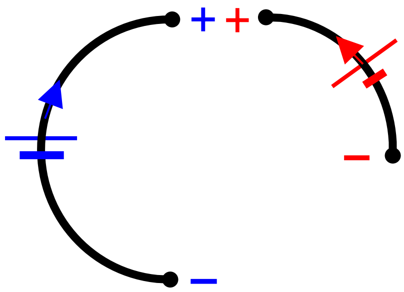
= 4.50×10^{-4} V A1

(ii) Q B1

Explanation for (i) above



Polarity of induced emf (use FRHR)



Area cut/swept in time t is equal to the area of the shaded rectangle.

Induced emf for the semi-circle.

Induced emf for the quarter circle

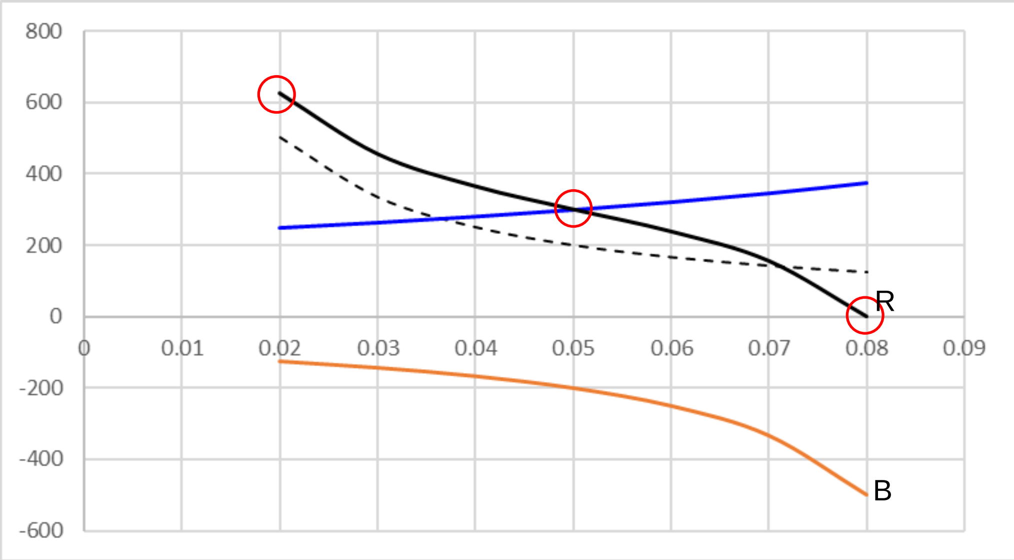
Net induced emf

(c) **(i)** Flux density due to the two conductors carrying 20 A will cancel at X leaving the resultant flux density = $\frac{\mu_0(90)}{2\pi \times 0.15}$ M1

= 1.20×10^{-4} T A1

Out of the page B1

(ii)



Correct shape and negative values for curve B	B1
Correct shape for R	B1
R must pass through 2 out of 3 circled points.	B1

9 **(a)** **(i)** lowest frequency of electromagnetic radiation M1

giving rise to emission of electrons (from the surface) A1

(ii) threshold frequency = $(9.0 \times 10^{-19}) / (6.63 \times 10^{-34})$ M1

$= 1.4 \times 10^{15}$ Hz A1

(iii) *either*

frequency of radiation between 5×10^{14} Hz and 10×10^{14} Hz
or energy of photons between 3.3×10^{-19} J and 6.6×10^{-19} J
or threshold wavelength: zinc = 340 nm, sodium = 520 nm, platinum = 220 nm M1

emission from sodium and zinc A1

(iv) **1.** photon interact with electron below surface M1

energy required to bring electron to surface A1

2. show threshold frequency is 5.8×10^{14} Hz
e.g extrapolate graph to intersect with *x*-axis
e.g chose a point (7.0, 0.5) and substitute into $E_{MAX} = \frac{h}{e}(f - f_0)$ M1

metal is sodium A1

(b) **(i)** **1.** centripetal force of orbiting electron provided by electric force acted by proton and so $\frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2}$ M1

correct manipulation to obtain $\frac{1}{2}mv^2 =$ expression A1

2. $E_T = \frac{e^2}{8\pi\varepsilon_0 r} + \left(-\frac{e^2}{4\pi\varepsilon_0 r}\right)$ M1

$E_T = -\frac{e^2}{8\pi\varepsilon_0 r}$ A0

(ii) $\lambda = \frac{h}{\sqrt{2mE_K}} = \frac{h}{\sqrt{2m \times \frac{e^2}{8\pi\varepsilon_0 r}}}$ M1

$\lambda = \frac{h}{e}\sqrt{\frac{4\pi\varepsilon_0 r}{m}}$ A0

(iii) $E_T = -\frac{e^2}{8\pi\varepsilon_0 \times \frac{n^2h^2\varepsilon_0}{\pi m e^2}} = -\frac{me^4}{8\varepsilon_0{}^2 h^2}\frac{1}{n^2}$ B1

$$k = \frac{me^4}{8\varepsilon_0{}^2h^2} = \frac{\left(9.11\times10^{-31}\right)\left(1.60\times10^{-19}\right)^4}{8\left(8.85\times10^{-12}\right)^2\left(6.63\times10^{-34}\right)^2}$$ M1

$k = 2.17\times10^{-18}\,J$ A1

(iv)

$$\lambda = \frac{hc}{\Delta E}$$

longest wavelength for transition from n = 3 to n = 2 and shortest wavelength from n = ∞ to n = 2 C1

correctly show longest wavelength is 660 nm M1

correct show shortest wavelength is 367 nm M1

so, Balmer series are visible A0