NJC Preliminary Examination 2024
H2 Physics Paper 2

Solutions and Mark Scheme

1 **(a)** Use $v_y = u_y + a_y t$
At max height, $v_y = 0$
$0 = 30 \sin 60^{o} - (9.81)\, t$ M1

$t = 2.6$ s A0

(b) initial velocity = 26 m s^{-1}, final velocity = –26 m s^{-1} B1

straight line intersects *x*-axis at 2.6 s and ends at 5.2 s (or 5.3 s) B1

(c) **(i)** horizontal line at u_x = 15 m s^{-1} from t = 0 to 5.2 s (or 5.3 s) B1

(ii) downward sloping curve from 15 m s^{-1} and its gradient decreases numerically B1

ending before t = 5.20 s B1

(d) Calculate displacements of first and second object to be 34.4 m and 5.84 m respectively using 2.6 s (or 34.5 m and 5.31 m using 2.65 s) C1

Displacement between objects = 29 m A1

2 **(a)** Force is the <u>rate of change of momentum</u> B1

(b) **(i)** Resultant force = change of momentum / time taken = [0.140 x (5.5 – (– 4.0))]/0.04 M1

= 33 N A1

(ii) resultant force on ball = Δp/Δt = 33.25 N

Taking forces on the ball, (N is force on ball by bar)

33.25 = N – W M1

N = 33.25 + 0.14*9.81 = 34.62 N

By N3L, force on bar by ball is 35 N. A0

(c) **(i)** Taking pivot about support B,
clockwise moments = F_A x (45 – 25) C1

anti clockwise moments = (0.450 x 9.81) (25) + 35 (25 + 50) C1

Clockwise moments = anti clockwise moments
F_A = 136.768 N = 140 N (to 2 sf) A1

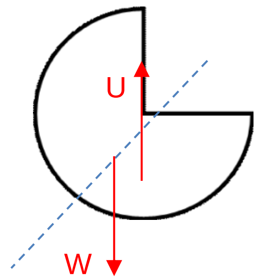
(ii) net force = 0
Upward force = downward force
F_B = 35 + 140 + 0.450 x 9.81 M1

= 180 N (to 2 sf) A1

3 **(a)** Pressure = ρgh = 900 x 9.81 x 6.0/100 M1

= 530 Pa A1

(b) weight and upthrust drawn in correct places (weight starts along the central blue dotted line and upthrust from centre of submerged part, ignore lengths) B1



the object turn anticlockwise (rotating ACW and CW with decreasing angle) until the weight and upthrust are on the same line of action (dotted line is vertical) B1

4 **(a)** The gravitational field strength at a point in a gravitational field is defined as the **gravitational force exerted per unit mass** acting on a small mass placed at that point. B1

(b) **(i)** point X is on the line and closer to Moon B1

(ii) Gravitational field strength at A = $\frac{G(5.97\times10^{24})}{(6.37\times10^{6})^2} - \frac{G(7.34\times10^{22})}{(3.84\times10^{8}-6.37\times10^{6})^2}$ = 9.81 m s^{-2}

Gravitational field strength at B = $\frac{G(7.34\times10^{22})}{(1.74\times10^{6})^2} - \frac{G(5.97\times10^{24})}{(3.84\times10^{8}-1.74\times10^{6})^2}$ = 1.61 m s^{-2}

Marks awarded as follow for both calculations:
- correct equations that include contributions by both Earth and Moon M1

- correct substitutions (e.g. unit conversion, etc) M1

- correct final values A1

(iii) Shape of graph, one positive one negative, cut x-axis closer to B. B1

5	**(a)**	**(i)**	Length of path 1 = 1.000 - 0.300 = 0.700 m Length of path 2 = 1.000 + 0.300 = 1.300 m Path difference = 1.300 – 0.700 = 0.600 m	B1
		(ii)	Phase difference = $\left(\frac{0.600}{1.000} \times 2\pi\right) \pm \pi$	M1
			$= 2.2\pi$ or 6.91 rad or 0.2π or 0.628 rad.	A1
		(iii)	Two segments / loops	M1
			One solid line + one dotted line	A1
		(iv)	Antiphase or π rad / 3.14 rad / 180° out of phase	A1
	(b)	**(i)**	For stationary waves to form, $L = 1.0 = n\left(\frac{\lambda}{2}\right)$ or $\lambda = \frac{2L}{n}$	M1
			From $v = f\lambda$	M1
			$f = \frac{v}{\lambda} = \left(\frac{n}{2L}\right)\sqrt{\frac{mg}{\mu}} = \left(\frac{n}{2}\right)\sqrt{\frac{mg}{\mu}}$ since $L = 1.000$	A0
		(ii)	$m = \frac{4f^2}{n^2}\left(\frac{\mu}{g}\right) = \frac{4(25)^2}{6^2}\left(\frac{7.0\times10^{-3}}{9.81}\right) = 0.050$ kg	A1
		(iii)	Next higher frequency has 8 segments	C1
			Frequency = 33 Hz	A1
6	**(a)**	**(i)**	From $V = IR$, $I = \frac{V}{R}$ hence $I \propto \frac{1}{R}$	C1
			Ratio = 1 : 0.5 : 0.2 or 10 : 5 : 2	A1
		(ii)	**1.** Q = Ne = $1.0 \times 10^{-3} \times 6.02 \times 10^{23} \times 1.6 \times 10^{-19} = 96.32 \approx 96$ C (shown)	A1
			2. Current through the resistor: $I = \frac{Q}{t} = \frac{96}{320} = 0.30$ A	M1
			Energy dissipated = $I^2Rt = (0.30)^2(4.0)(320)$ $= 115.2 \approx 115$ J	M1
			OR	
			p.d. V = IR = 0.30 x 4.0 = 1.2 V	(M1)
			Energy = QV = 96 x 1.2 or Energy = $\frac{V^2}{R}t = \frac{1.2^2}{4.0} \times 320$	(M1)
			3. Let the current through R be I. Current through 4-ohm resistor = 3I Since resistors are in parallel: I x R = 3I x 4	M1
			R = 12 Ω	A1
	(b)	**(i)**	0.2 A	A1
		(ii)	1.0 V	A1

5 ohms A1

7 **(a)** 6, 6 A1

(b) **(i)** Decay constant is the probability of decay per unit time of a nucleus. B1

(ii) Half-life is the time taken for half the (number of radioactive nuclei/count rate/activity) present in any given sample of a given isotope to decay at any given time. B2

(c) Radioactive decay is a random process, in other words we don't know which nuclei will decay next; we only know the probability of decay.

After one half-life, it is not guaranteed that exactly half of the original atoms remain, but that this is just the most likely, and the average outcome.

Marks awarded as follow:
- meaning of random M1
- a reasonable discussion of what that means. A1

(d) **(i)** Original ratio = $\frac{C_{14,initial}}{C_{12,initial}} = \frac{1}{3.3\times10^{10}}$

Over the years, the ratio became $\frac{C_{14,final}}{C_{12,initial}} = \frac{1}{8.6\times10^{10}}$

$\frac{N}{N_o} = \frac{C_{14,final}}{C_{14,initial}} = \frac{C_{14,final}}{C_{12,initial}} \times \frac{C_{12,initial}}{C_{14,initial}} = \frac{1}{8.6\times10^{10}} \times \frac{3.3\times10^{10}}{1}$ C1

$= 0.384$ A0

Assumption: Ratio of C-12 to C-14 for a fresh sample of wood is constant/ C-12 remains the same B1

(ii) $N = N_0 e^{-\lambda t}$

$\lambda = \frac{ln2}{5700} = 1.2160 \times 10^{-4}$ y^{-1}

$0.384 = e^{-1.2160\times10^{-4}(t)}$ M1

$t = 2.49 \times 10^{11} s$ = 7870 years A1

8	**(a)**	<u>larger energy gap</u> between conduction band and lower orbitals than standard silicon			M1
		resulting in a larger energy / higher frequency photons			A1
	(b)	**(i)**	wavelength = 595 nm		C1
			energy = $(6.63 \times 10^{-34})(3.00 \times 10^{8}) / (595 \times 10^{-9})$ (= 3.343×10^{-19} J)		M1
			energy = $3.343 \times 10^{-19} / 1.60 \times 10^{-19}$ = 2.09 eV or 2.1 eV		A1
		(ii)	**1.**	insufficient energy for electron to promote / excite to appropriate energy level	B1
			2.	energy of the photons greater / wider gap between the conduction band and the lower orbitals than red LED so higher energy per unit charge is required	B1
	(c)	**(i)**	point correctly plotted		B1
		(ii)	even distribution of points on either side of the line along the full length		B1
		(iii)	correct method to compute gradient i.e. $\Delta y / \Delta x$ and coordinates are read accurate to half the smallest square		M1
			gradient calculated correctly (most line will give a gradient of about –1.7 to –1.8)		A1
	(d)	**(i)**	*either* obtain lg V_F from graph and $V_F = 10^{\text{value}}$ (e.g. lg (520) = 2.716, lg V_F= 0.435) *or* calculate k from y-intercept and substitute 520 nm into $V_F = k\,\langle\lambda\rangle^n$		M1
			$V_F \approx 2.7$ V (final answer depends on the line of best fit and rounding in the intermediate calculations)		A1
		(ii)	p.d. across resistor = 4.5 – V_F from **(d)(i)** resistance = p.d. / 20 mA		M1
			resistance ≈ 90 Ω		A1
	(e)	**(i)**	$v = c / n = 3.00 \times 10^{8} / 4.24$		M1
			$v = 7.08 \times 10^{7}$ m s^{-1}		A0
		(ii)	$n_1 \sin\sin\theta_1 = n_2 \sin\sin\theta_2 \Rightarrow 4.24 \sin\sin\theta = (1.00) \sin\sin 90°$ $\theta = 13.6°$		C1 A1
		(iii)	coating increase critical angle so more photons emerge / allows photons with larger angles to the normal of the surface of diode (that are otherwise trap in diode) to emerge		M1
			these photons (with those emerging perpendicularly) are then reflected by plastic bulb and concentrated in forward direction		A1
			so, more photons released for given energy input		
	(f)	ratio = (900 / 9) / (840 / 60)			M1
		= 7.1			A1