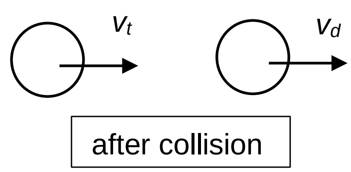
DUNMAN HIGH SCHOOL

2023 H2 PHYSICS (YEAR 6)

<u>Answers to Prelim Exam H2 Physics Paper 3</u>

1	**(a)**	The principle of conservation of momentum states that the total momentum of a system of bodies is constant provided <u>no resultant external</u> force acts on the system.	B1
	(b)	The total momentum of the two-nuclei system is non-zero. Thus, if one of the nuclei is at rest, then the other nucleus must possess a non-zero momentum (i.e. it is moving). Hence the two nuclei cannot be at rest simultaneously.	B1 B1
	(c)	Taking right to be positive,  By conservation of momentum, $3mv - 2mv = 3mv_t + 2mv_d$ $v = 3v_t + 2v_d$ relative speed of approach = relative speed of separation $2v = v_d - v_t$ Solving simultaneously for v_t and v_d, $v_d = 1.4v$ $v_t = -0.6v$ (i.e. tritium nucleus is travelling leftward)	C1 C1 A1 for both correct answers
		Marker's comments: There were answers that did not treat momentum as a vector. Answers should never be left in fraction form.	
	(d)	Let F_{avg} be the average force exerted by the deuterium nucleus on the tritium nucleus, $F_{avg} = \frac{\Delta p_{tritium}}{t}$ $= \frac{3m(-0.6v - v)}{t}$ $= -\frac{4.8mv}{t}$ (negative sign indicates it points to the left) Magnitude of the average force = $\frac{4.8mv}{t}$	C1 A1
		Marker's comments: The magnitude of the average force should be the same for either deuterium or tritium nucleus. There were mistakes in using the wrong mass or wrong change in velocity. The final numerical value should be shown and not left in fraction form.	

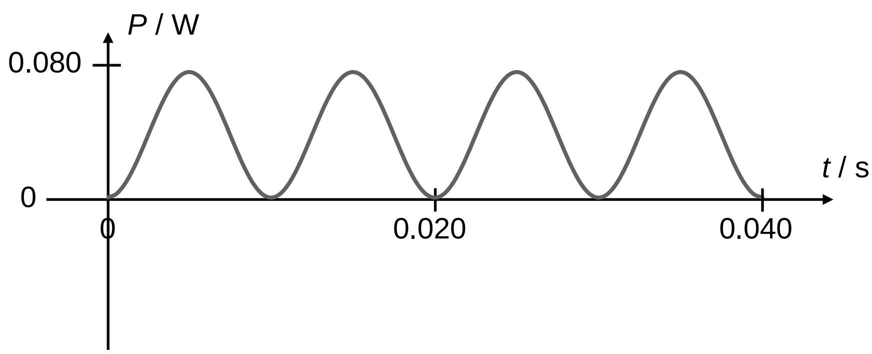
2	**(a)**	Loss in GPE $= mgh$ $= 70.0(9.81)(1.50) = 1030$ J	A1
	(b)	kinetic energy of man $= \frac{1}{2}mv^2$ $= \frac{1}{2}(70.0)(2.00)^2 = 140$ J	A1
	(c)(i)	The perpendicular distance between the line of action of the weight and the pivot is zero.	B1
	(c)(ii)	The man will fall a further distance equal to the extension of the spring, x before coming to a stop. Assuming no loss in energy to the surroundings, By conservation of energy, loss in k.e. + loss in g.p.e. = gain in e.p.e $(1030 + 140) + 70x = \frac{1}{2}kx^2$ $(1030 + 140) + 70x = \frac{1}{2}(10000)x^2$ Solving: $x = 0.556$ m $\sin\theta = \frac{x}{2.40}$ $\theta = \sin^{-1}\left(\frac{0.557}{2.40}\right)$ $= 13.4°$ (to 3 s.f.)	M1 M1 M1 M1 A0
		Marker's comments: The board is NOT in rotational equilibrium, i.e. sum of clockwise moments is NOT equal to sum of anti-clockwise moments.	
	(c)(iii)	$F = kx$ $= (10000)(2.40 \sin 13.4^o)$ $= 5560$ N	A1
	(c)(iv)	The board is in translational equilibrium so net force acting on the diving board is zero. $N = W_{board} + W_{man} + W_{spring}$ $= 300 + 70(9.81) + 5560$ $= 6550$ N (3 s.f.)	C1 A1
		Marker's comments: Students should attempt to provide explanation for their working and not simply show the arithmetic to arrive at the answer.	

3	**(a)**	The gravitational field strength at a point is the gravitational force exerted per unit mass placed at that point.	B1
	(b)	Gravitational force on the satellite provides the centripetal force for the circular motion of the satellite. $\frac{GMm}{r^2} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$	C1
		$r^3 = \frac{GM}{4\pi^2}T^2$ $= \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{4\pi^2}(94\times60)^2$	C1
		$r = 6.9 \times 10^6$ m	A1
	(c)(i)	From $\frac{GMm}{r^2} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$ $r^3\omega^2$ = constant or $\frac{r^3}{T^2}$ = constant $\frac{(6.9 \times 10^6)^3}{(94)^2} = \frac{r^3}{(150)^2}$ $r = 9.42 \times 10^6$ m $v = r\omega$ $= (9.42\times10^6)\left(\frac{2\pi}{150\times60}\right)$ $= 6600$ m s^{-1} (to 2 s.f.)	M1 M1 M1 A0
	(c)(ii)	Gravitational potential energy $U = -\frac{GMm}{r}$ Change in gravitational potential energy $= U_{final} - U_{initial}$ $= -GMm\left(\frac{1}{r_{final}} - \frac{1}{r_{initial}}\right)$ $= -(6.67 \times 10^{-11})(6.0 \times 10^{24})(1200)\left(\frac{1}{9.4 \times 10^6} - \frac{1}{6.9 \times 10^6}\right)$ $= 1.9 \times 10^{10}$ J	C1 A1

4	**(a)**	An ideal gas obeys the equation of state $PV = nRT$ at all temperatures T, volume V, pressure P and number of moles n.	B1
	(b)	(table below)	

	work done on gas / J	heat supplied o gas / J	increase in internal energy of gas / J
A to B	+360	0	**+360** (&)
B to C	0	+670	**+670** (&)
C to D	**−810** (&)	0	−810
D to A	**0** (@)	**−220** (@)	**−220** (#)

		&: first, second and third line correct #: −220 correct in right hand column @: other two figures correct in bottom row	B1 B1 B1
	(c)	the gas molecules bounce off the receding piston at lower speeds there is a decrease in kinetic energy of the molecules	B1 B1
5	**(a)(i)**	out of the page	B1
	(a)(ii)	magnetic force provides centripetal force: $Bev = mv^2/r$ $v = Ber / m$	B1 B1
	(b)(i)	gain in kinetic energy = ½ m v^2 = eV <u>OR</u> work done = eEd = ½ m v^2	B1
	(b)(ii)	[use $v = Ber / m$ and ½ m $v^2 = eV$ to obtain] $r^2 = 2Vm / eB^2$ OR $r = [2Vm / eB^2]^{1/2}$	 C1
		correct substitution for V, m, e and B^2	C1
		$r = 1.6 \times 10^{-2}$ m	A1
	(c)	the force acting on the electron is always perpendicular to its direction of motion no work is done on the electron (thus no change in its kinetic energy or speed)	B1 B1
6	**(a)**	$V_{r.m.s.} = \sqrt{\dfrac{2^2(0.002)+1^2(0.002)}{0.010}} = 1.0$ V Steady voltage of 1.0 V will produce the same heating effect as $V_{r.m.s.}$ of 1.0 V.	M1 A1
		Marker's comments: Common mistakes like without taking the square root value of the mean square voltage was observed.	

	(b)	Transmission of electrical energy at high voltage means that the current is low according to $P = IV$. Power loss through joule heating (I^2R) is hence lowered as less electrical energy is dissipated as heat in the cables of resistance R.	B1 B1
		Marker's comments: no mention of power loss as heat dissipation was very common among the answers given by candidates.	
	(c)(i)	$\frac{V_s}{V_p} = \frac{N_s}{N_p}$ $V_s = 71 \times 6.5 \times 10^{-3} = 0.46$ V	A1
	(c)(ii)	 Correct shape: $0.080\sin^2\left[\left(2\pi f\right)t\right]$. Correct labelling of values: peak power and period.	B1 B1
		Marker's comments: Most answers given was a sine curve instead of sine square curve.	
	(c)(iii)	**1.** In the forward biased direction, the diode has no resistance. Current flows downwards through resistor R. In the reverse biased direction, diode has infinite resistance. There is no current flowing through resistor R.	B1 B1
	(c)(iii)	**2.** In the <u>forward biased direction</u>, there is a <u>half-wave sinusoidal voltage</u> across resistor R, having the same frequency as that of the input voltage. In the reverse biased direction, there is no voltage across resistor R.	B1
		Marker's comments: No mention of why there was a current in one direction and no current in the other direction.	

7	**(a)**	92 protons and 92 electrons 143 neutrons (in the nucleus)	B1 B1
	(b)(i)	α-particle travels short distance in air	B1
		Marker's comments: Majority of candidates did not state the effect of interaction of alpha particles with air.	
	(b)(ii)	very small proportion in backwards direction / large angles majority pass through with no /small deflections either most of mass is in very small volume (nucleus) and is charged or most of atom is empty space	B1 B1 B1
		Marker's comments: Qualitative answers were poorly presented to explain the observations.	
	(c)	$I = Q / t = nq / t$ $n / t = (1.5 \times 10^{-12}) / (2 \times 1.60 \times 10^{-19})$ $n / t = 4.7 \times 10^{6}\ s^{-1}$	 C1 A1
		Marker's comments: Power of ten was wrongly quoted.	
8	**(a)(i)1.**	number of oscillations per unit time (not per second)	B1
	(a)(i)2.	$n\lambda$	A1
	(a)(ii)	v = distance / time = $n\lambda / t$ $n / t = f$, hence $v = f\lambda$	M1 A1
	(b)	1 period, $T = 3 \times 2.0$ ms = 6.0 ms $f = 1 / T = 1 / (6.0 \times 10^{-3})$ = 170 Hz	C1 A1
	(c)(i)	Sources emitting waves with a constant phase difference.	B1
	(c)(ii)	$f = v / \lambda$ $f = (3.00 \times 10^{8}) / (6.0 \times 10^{-2})$ $= 5.0 \times 10^{9}$ Hz	 C1 A1
	(c)(iii)	path difference = 3λ (integer number of wavelengths) hence no phase difference between the waves arriving at X hence constructive interference occurs → maximum intensity	M1 M1 A1
	(c)(iv)	decrease in the distance between adjacent maxima / minima	B1

(d)(i)

order, *n*	**angle for red maximum / º**	**angle for green maximum / º**
0	0	0
1	23.6	19.0
2	53.0	40.5
3	Nil	77.2
4	Nil	Nil

Each correct row 1 mark. (using $d\sin\theta_n = n\lambda$)
(no credit for blank)

B4

(d)(ii)

two overlapping interference patterns as red and green light have different wavelengths:
brightness of each line/band decreases (since less light passes through the two slits) and the pattern of lines/bands are fuzzy instead of sharp/narrow

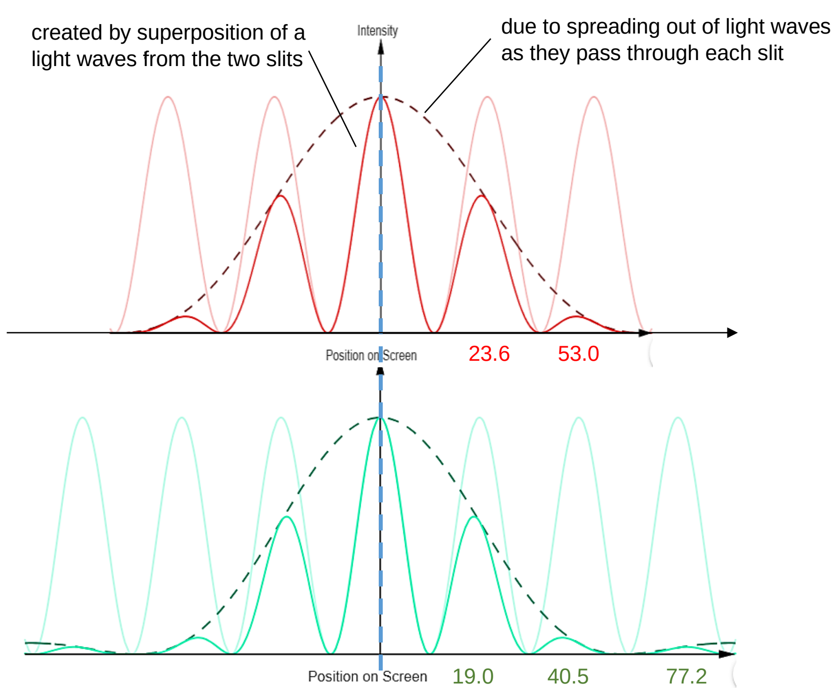
B1

Any two from:

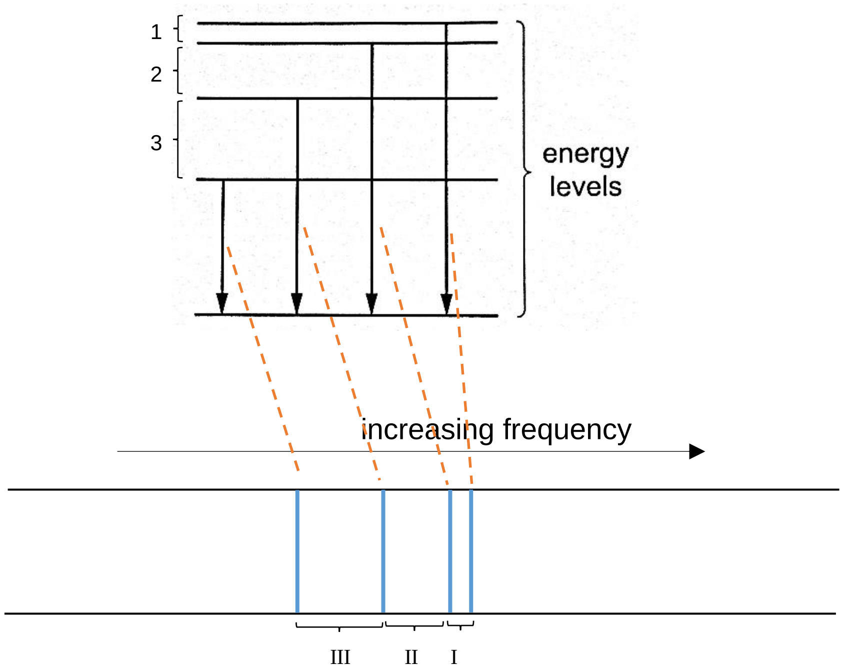
- red bands wider than green bands
- red bands (longer wavelength) wider apart than green bands
- equally spaced fringes within each band
- missing orders as the intensities are reduced by diffraction effects

B2

e.g., individual double slits pattern for red (upper) and green light:



9	**(a)**	discrete quantity / packet / quantum of energy of electromagnetic radiation energy of photon = Planck constant × frequency	B1 B1
	(b)	- existence of threshold frequency for incident light - rate of emission of electrons is proportional to intensity of incident light - max. kinetic energy of electron dependent on frequency of incident light - max. kinetic energy independent of intensity of incident light (any three, 1 each, max 3)	B1 B1 B1 B1
	(c)	either $E = hc/\lambda$ $= hc/(450\text{ nm})$ $= 4.4 \times 10^{-19}$ J or 2.8 eV as 2.8 eV $<$ 3.5 eV, $\Rightarrow$ no emission or $\Phi = hc/\lambda_0$ $\Rightarrow 3.5\text{ eV} = hc/\lambda_0$ $\Rightarrow \lambda_0 = 355$ nm as 355 nm $<$ 450 nm, $\Rightarrow$ no emission	C1 M1 A1
	OR	or $\Phi = hf_0$ $\Rightarrow 3.5\text{ eV} = hf_0$ $\Rightarrow f_0 = 8.45 \times 10^{14}$ Hz 450 nm $\rightarrow 6.67 \times 10^{14}$ Hz as 6.67×10^{14} Hz $< 8.45 \times 10^{14}$ Hz $\Rightarrow$ no emission	C1 M1 A1
	(d)(i)	when electrons/atoms are in their lowest energy/minimum energy/most stable (state)	B1
	(d)(ii)	excitation promotes an electron to a higher energy level. ionization occurs when an electron receives enough energy to leave the atom.	B1 B1
	(e)	electrons occupy discrete energy levels / difference in energy levels are discrete. energy of photon is proportional to frequency ($E = hf$) atom/electron can be excited only when energy of photon exactly matches the difference in energy levels (1 to 1 interaction / all energy of photon absorbed)	B1 B1 B1

	(f)	<u>Four</u> lines drawn. <u>Correct spacings</u>:  (since the energy levels are drawn to scale, the spacings III, II and I should correspond to the spacings 3, 2 and 1, respectively)	M1 A1
	(g)(i)	Δx decreases and Δp increases	B1
	(g)(ii)	link between momentum p and kinetic energy E_K: $\frac{p^2}{2m} = E_K$ increased uncertainty in momentum implies increased uncertainty in kinetic energy	B1 B1
	(g)(iii)	For very small orbits the uncertainty in the kinetic energy becomes large enough (to make the total energy positive) that the electron will escape	B1