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MARK SCHEME for the October/November 2015 series

9702 PHYSICS
9702/42 Paper 4 (A2 Structured Questions), maximum raw mark 100

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Section A

1 (a) (i) gravitational force provides/is the centripetal force \( B_1 \)

\[ \frac{GMm_S}{x^2} = \frac{m_S v^2}{x} \] \( \text{allow } x \text{ or } r, \text{ allow } m \text{ or } m_S \) \( M_1 \)

\[ E_K = \frac{1}{2} m_S v^2 \] and clear algebra leading to \( E_K = \frac{GMm_S}{2x} \) \( A_1 \) [3]

(ii) \( E_P = - \frac{GMm_S}{x} \) (sign essential) \( B_1 \) [1]

(iii) \( E_T = E_K + E_P \)

\[ = \frac{GMm_S}{2x} - \frac{GMm_S}{x} \]

\[ = - \frac{GMm_S}{2x} \] (allow ECF from (a)(ii)) \( C_1 \) \( A_1 \) [2]

(b) (i) decreases \( B_1 \) [1]

(ii) decreases \( B_1 \) [1]

(iii) decreases \( B_1 \) [1]

(iv) increases \( B_1 \) [1]

(for answers in (b) allow ECF from (a)(iii))

2 (a) obeys the equation \( pV = nRT \) or \( pV/T = \text{constant} \) \( M_1 \)

all symbols explained; \( T \) in kelvin/thermodynamic temperature \( A_1 \) [2]

(b) (i) temperature rise = 48 K \( A_1 \) [1]

(ii) \[ <c^2> \propto T \text{ or equivalent} \]

\[ <c^2> = \frac{353}{305} \times 1.9 \times 10^6 \]

\[ c_{r.m.s.} = 1480 \text{ m/s} \] \( C_1 \) \( C_1 \) \( A_1 \) [3]

3 (a) heat/thermal energy gained by system or energy transferred to system by heating plus work done on the system or minus work done by the system \( B_1 \)

B1 [2]

(b) (i) either volume decreases so work done on the system or small volume change so work done on system negligible (thermal) energy absorbed to break lattice structure internal energy increases \( M_1 \) \( M_1 \) \( A_1 \) [3]

(ii) gas expands so work done by gas (against atmosphere) no time for thermal energy to enter or leave the gas internal energy decreases \( M_1 \) \( M_1 \) \( A_1 \) [3]

4 (a) free: (body oscillates) without any loss of energy/no resistive forces/no external forces applied \( B_1 \)

forced: continuous energy input (required)/body is made to vibrate by an (external) periodic force/driving oscillator \( B_1 \) [2]
(b) (i) idea of resonance
maximum amplitude at natural frequency
frequency = 2.1 Hz (allow 2.08 to 2.12 Hz) B1 [3]

(ii) peak not very sharp/amplitude not infinite so frictional forces are present B1 [1]

(c) \[ v = \omega x_0 \]
\[ = 2\pi \times 2.1 \times 4.7 \times 10^{-2} \text{ (allow ECF from (b)(i))} \] C1
\[ = 0.62 \text{ m s}^{-1} \] A1 [2]

5 (a) (i) force proportional to the product of the two/point charges
and inversely proportional to the square of their separation B1 [2]

(ii) 1. force radially away from sphere/to right/to east B1 [1]
2. (maximum) at/on surface of sphere or \( x = r \) B1 [1]
3. \( F \propto \frac{1}{x^2} \) or \( F = \frac{q_1q_2}{(4\pi\varepsilon_0x^2)} \) C1
    ratio = 16 A1 [2]

(b) \( E = \frac{q}{(4\pi\varepsilon_0x^2)} \) or \( E \propto q \) C1
maximum charge = \( (2.0/1.5) \times 6.0 \times 10^{-7} \) C1
\[ = 8.0 \times 10^{-7} \text{ C} \]
additional charge = \( 2.0 \times 10^{-7} \text{ C} \) A1 [3]

6 (a) (i) force = \( mg \)
along the direction of the field/of the motion M1 A1 [2]

(ii) no force B1 [1]

(b) (i) force due to \( E \)-field downwards so force due to \( B \)-field upwards to right into the plane of the paper B1 [2]

(ii) force due to magnetic field = \( Bqv \) B1
force due to electric field = \( Eq \) B1
(use of \( F_B \) and \( F_E \) not explained, allow 1/2) B1 [3]

forces are equal (and opposite) so \( Bv = E \) or \( Eq = Bqv \) so \( E = Bv \) B1 [3]

(c) sketch: smooth curved path M1
in 'upward' direction A1 [2]

7 (a) minimum frequency of e.m. radiation/a photon (not "light") for emission of electrons from a surface M1 A1 [2]
(reference to light/UV rather than e.m. radiation, allow 1/2)
(b) $E_{\text{MAX}}$ corresponds to electron emitted from surface electron (below surface) requires energy to bring it to surface, so less than $E_{\text{MAX}}$  

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(c) (i) $1/\lambda_0 = 1.85 \times 10^6$ (allow 1.82 to 1.88)  

$$f_0 = c / \lambda_0$$  
$$= 3.00 \times 10^8 \times 1.85 \times 10^6$$  
$$= 5.55 \times 10^{14} \text{Hz}$$  

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(ii) $\Phi = hf_0$  

$$= 6.63 \times 10^{-34} \times 5.55 \times 10^{14} \text{ (allow ECF from (c)(i))}$$  

$= 3.68 \times 10^{-19} \text{J}$  

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(d) sketch: straight line with same gradient intercept between 1.0 and 1.5  

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8 (a) nucleus: small central part/core of an atom nucleon: proton or a neutron particle contained within a nucleus  

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(b) (i) 1. decay constant $= \ln 2 / (3.8 \times 24 \times 3600)$  

$= 2.1 \times 10^{-6} \text{s}^{-1}$  

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2. $A = \lambda N$  

$= 2.1 \times 10^{-6} \times N$  

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$N = 4.6 \times 10^7$  

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A1 [2]  

(ii) $1.0 \text{m}^3$ contains $(6.02 \times 10^{23}) / (2.5 \times 10^{-2})$ air molecules  

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ratio $= (4.6 \times 10^7 \times 2.5 \times 10^{-2}) / (6.02 \times 10^{23})$  

$= 1.9 \times 10^{-18}$  

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A1 [2]
Section B

9 (a) (i) (+) 3.0 V  

(ii) potential  = 6.0 \times \{2.0 / (2.0 + 2.8)\}  
     = 2.5 V  

(iii) potential  = 6.0 \times \{2.0 / (2.0 + 1.8)\}  
      = 3.2 V  

(b) at 10 °C, \(V_A > V_B\)  

\(V_{\text{OUT}}\) is \(-9.0\) V \text{ (allow “negative saturation”)\)  

at 20 °C, \(V_{\text{OUT}}\) is \(+9.0\) V  
\text{ (if 20 °C considered initially, mark as M1,A1,B1)\)  

sudden switch (from \(-9\) V to \(+9\) V) when \(V_A = V_B\)  

10 (a) sharpness: clarity of edges/resolution (of image)  
contrast: difference in degree of blackening (of structures)  

(b) (i) X-rays produced when (high speed) electrons hit target/anode  
\text{ either electrons have been accelerated through 80 kV\)  
or electrons have (kinetic) energy of 80 keV  

(ii) \(I_T/I = e^{-3.0 \times 1.4}\)  
     = 0.015  

(c) for good contrast, \(\mu x\) or \(e^{i\mu x}\) or \(e^{-i\mu x}\) must be very different  
\(\mu x\) or \(e^{i\mu x}\) or \(e^{-i\mu x}\) for bone and muscle will be different than that for muscle  
so good contrast  

11 (a) frequency of carrier wave varies  
in synchrony with the displacement of the signal/information wave  

(b) (i) 5.0 V  

(ii) 720 kHz  

(iii) 780 kHz  

(iv) 7500
12  (a)  (i)  (gradual) loss of power/intensity/amplitude (not “signal”)  B1  [1]

(ii)  e.g. noise can be eliminated (not “there is no noise”)  M1
     because pulses can be regenerated  A1
     e.g. much greater data handling/carrying capacity  M1
     because many messages can be carried at the same time/greater
     bandwidth  A1

     e.g. more secure
     because it can be encrypted  (M1)
     e.g. error checking
     because extra information/parity bit can be added  (M1)  [4]

     (allow any two sensible suggestions with ‘state’ M1 and ‘explain’ A1)

(b)  attenuation = 10 \lg (145/29) (= 7.0)  C1
     attenuation per unit length  = 7.0/36
     = 0.19 dB km\(^{-1}\)  A1  [2]