MARK SCHEME for the May/June 2012 question paper
for the guidance of teachers

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Section A

1 (a) work done in bringing unit mass from infinity (to the point) B1 [1]

(b) gravitational force is (always) attractive B1

either as r decreases, object/mass/body does work
or work is done by masses as they come together B1 [2]

(c) either force on mass = mg (where g is the acceleration of free fall /gravitational field strength) B1

\[ g = \frac{GM}{r^2} \]
if \( r \gg h \), g is constant B1

\( \Delta E_p = \text{force} \times \text{distance moved} \) M1

= \( mgh \) A0

or \( \Delta E_p = m\Delta \phi \) (C1)

\[ = \frac{GMM(1/r_1 - 1/r_2)}{r_1 r_2} = \frac{GMM(r_2 - r_1)}{r_1 r_2} \] (B1)
if \( r_2 \approx r_1 \), then \( (r_2 - r_1) = h \) and \( r_1 r_2 = r^2 \) (B1)

\[ g = \frac{GM}{r^2} \] (B1)

\( \Delta E_p = mgh \) (A0) [4]

(d) \[ \frac{1}{2}mv^2 = m\Delta \phi \]

\[ v^2 = 2 \times \frac{GM}{r} \] C1

\[ v = \left(2 \times 4.3 \times 10^{13}\right) / (3.4 \times 10^6) \] C1

\[ v = 5.0 \times 10^3 \text{m s}^{-1} \] A1 [3]

(Use of diameter instead of radius to give \( v = 3.6 \times 10^3 \text{m s}^{-1} \) scores 2 marks)

2 (a) (i) either random motion B1 [1]

or constant velocity until hits wall/other molecule

(ii) (total) volume of molecules is negligible compared to volume of containing vessel A1

or radius/diameter of a molecule is negligible compared to the average intermolecular distance (M1) [2]

(b) either molecule has component of velocity in three directions M1

or \[ c^2 = c_x^2 + c_y^2 + c_z^2 \] M1

random motion and averaging, so \( <c_x^2> = <c_y^2> = <c_z^2> \) M1

\( <c^2> = 3 <c_x^2> \) A1

so, \( pV = \frac{1}{2}Nm<c^2> \) A0 [3]

(c) \( <c^2> \propto T \) or \( c_{\text{rms}} \propto \sqrt{T} \) C1

temperatures are 300 K and 373 K C1

\( c_{\text{rms}} = 580 \text{m s}^{-1} \) A1 [3]

(Do not allow any marks for use of temperature in units of °C instead of K)

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3 (a) (numerically equal to) quantity of (thermal) energy required to change
the state of unit mass of a substance
without any change of temperature

(Allow 1 mark for definition of specific latent heat of fusion/vaporisation)

(b) either

energy supplied = \(2400 \times 2 \times 60 = 288000\) J

energy required for evaporation = \(106 \times 2260 = 240000\) J

difference = \(48000\) J

rate of loss = \(48000 / 120 = 400\) W

or

energy required for evaporation = \(106 \times 2260 = 240000\) J

power required for evaporation = \(240000 / (2 \times 60) = 2000\) W

rate of loss = \(2400 – 2000 = 400\) W

4 (a) \(a = (-)\omega^2x\) and \(\omega = 2\pi/T\)

\(T = 0.60\) s

\(a = (4\pi^2 \times 2.0 \times 10^{-3}) / (0.6)^2\)

= \(2.2\) m s\(^{-2}\)

(b) sinusoidal wave with all values positive

all values positive, all peaks at \(E_K\) and energy = 0 at \(t = 0\)

period = \(0.30\) s

5 (a) force per unit positive charge acting on a stationary charge

(b) (i) \(E = Q / 4\pi\varepsilon_0 r^2\)

\(Q = 1.8 \times 10^4 \times 10^2 \times 4\pi \times 8.85 \times 10^{-12} \times (25 \times 10^{-2})^2\)

\(Q = 1.25 \times 10^{-5}\) C = 12.5 \(\mu\)C

(ii) \(V = Q / 4\pi\varepsilon_0 r\)

\(= (1.25 \times 10^{-5}) / (4\pi \times 8.85 \times 10^{-12} \times 25 \times 10^{-2})\)

\(= 4.5 \times 10^{5}\) V

(Do not allow use of \(V = Er\) unless explained)
6 (a) (i) peak voltage = 4.0 V
     
     (ii) r.m.s. voltage \( (\frac{4.0}{\sqrt{2}}) = 2.8 \) V
     
     (iii) period \( T = 20 \) ms
           frequency = \( 1 \div (20 \times 10^{-3}) \)
           frequency = 50 Hz

(b) (i) change \( = 4.0 - 2.4 = 1.6 \) V
     
     (ii) \( \Delta Q = C \Delta V \) or \( Q = CV \)
          \( = 5.0 \times 10^{-6} \times 1.6 = 8.0 \times 10^{-6} \) C

(c) average p.d. = 3.2 V
     resistance \( = \frac{3.2}{1.1 \times 10^{-3}} \)
     \( = 2900 \Omega \) (allow 2800 \( \Omega \))

7 (a) sketch: concentric circles (minimum of 3 circles)
     separation increasing with distance from wire
     correct direction

(b) (i) arrow direction from wire B towards wire A
     
(b) (ii) either reference to Newton’s third law
        or force on each wire proportional to product of the two currents
        so forces are equal

(c) force always towards wire A/always in same direction
    varies from zero (to a maximum value)
    variation is sinusoidal \( / \sin^2 \)
    (at) twice frequency of current
    (any two, one each)

8 (a) packet/quantum/discrete amount of energy
    of electromagnetic radiation
    \( \text{allow 1 mark for ‘packet of electromagnetic radiation’} \)
    energy \( = \text{Planck constant} \times \text{frequency} \) (seen here or in b)

(b) each (coloured) line corresponds to one wavelength/frequency
    energy \( = \text{Planck constant} \times \text{frequency} \)
    implies specific energy change between energy levels
    so discrete levels
9 (a) (i) either probability of decay (of a nucleus) per unit time

\[ \lambda = \frac{-(dN/dt)}{N} \]  

(M1)  

or \( \lambda = \frac{-(dN/dt)}{N} \) and \( N \) explained (A1)

(ii) in time \( t_{\frac{1}{2}} \), number of nuclei changes from \( N_0 \) to \( \frac{1}{2}N_0 \)

\[ \frac{1}{2} = \exp(-\lambda t_{\frac{1}{2}}) \] or \( 2 = \exp(\lambda t_{\frac{1}{2}}) \)  

B1  

\[ \ln \left(\frac{1}{2}\right) = -\lambda t_{\frac{1}{2}} \] and \( \ln \left(\frac{1}{2}\right) = -0.693 \) or \( \ln 2 = \lambda t_{\frac{1}{2}} \) and \( \ln 2 = 0.693 \)  

B1

\[ 0.693 = \lambda t_{\frac{1}{2}} \]  

A0  

[b] 228 = 538 \( \exp(-8\lambda) \)  

C1

\[ \lambda = 0.107 \text{ (hours}^{-1}\text{)} \]  

C1

\( t_{\frac{1}{2}} = 6.5 \text{ hours (do not allow 3 or more SF)} \)  

A1  

[c] e.g. random nature of decay background radiation daughter product is radioactive

(\text{any two sensible suggestions, 1 each})  

B2  

[2]
Section B

10 (a) light-dependent resistor (allow LDR)  B1 [1]

(b) (i) two resistors in series between +5 V line and earth  M1
midpoint connected to inverting input of op-amp  A1 [2]

(ii) relay coil between diode and earth  M1
switch between lamp and earth  A1 [2]

(c) (i) switch on/off mains supply using a low voltage/current output  B1 [1]
(allow ‘isolates circuit from mains supply’)

(ii) relay will switch on for one polarity of output (voltage)  C1
switches on when output (voltage) is negative  A1 [2]

11 (a) (i) e.m. radiation produced whenever charged particle is accelerated  M1
electrons hitting target have distribution of accelerations  A1 [2]

(ii) either  wavelength shorter/shortest for greater/greatest acceleration
or  \( \frac{\lambda_{\text{min}}}{E_{\text{max}}} = \frac{hc}{E_{\text{max}}} \)
or  minimum wavelength for maximum energy  B1
all electron energy given up in one collision/converted to single photon  B1 [2]

(b) (i) hardness measures the penetration of the beam  C1
greater hardness, greater penetration  A1 [2]

(ii) controlled by changing the anode voltage  C1
higher anode voltage, greater penetration/hardness  A1 [2]

(c) (i) long-wavelength radiation more likely to be absorbed in the body/less
likely to penetrate through body  B1 [1]

(ii) (aluminium) filter/metal foil placed in the X-ray beam  B1 [1]

12 (a) strong uniform (magnetic) field  M1
either  aligns nuclei
or  gives rise to Larmor/resonant frequency in r.f. region  A1

non-uniform (magnetic) field  M1
either  enables nuclei to be located
or  changes the Larmor/resonant frequency  A1 [4]

(b) (i) difference in flux density  \( = 2.0 \times 10^{-2} \times 3.0 \times 10^{-3} = 6.0 \times 10^{-5} \) T  A1 [1]

(ii) \( \Delta f = 2 \times c \times \Delta B \)
\( = 2 \times 1.34 \times 10^8 \times 6.0 \times 10^{-5} \)
\( = 1.6 \times 10^4 \) Hz  A1 [2]
13 (a) (i) no interference (between signals) near boundaries (of cells) B1 [1]

(ii) for large area, signal strength would have to be greater and this could be hazardous to health B1 [1]

(b) mobile phone is sending out an (identifying) signal M1
    computer/cellular exchange continuously selects cell/base station with strongest signal A1
    computer/cellular exchange allocates (carrier) frequency (and slot) A1 [3]