This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners’ meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge will not enter into discussions about these mark schemes.

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1 (a) 1. \( F = \frac{Gm_1m_2}{x^2} \)
\[ = (6.67 \times 10^{-11} \times 2.50 \times 5.98 \times 10^{24})/(6.37 \times 10^6)^2 \]
\[ = 24.6 \text{ N (accept 2 s.f. or more)} \]

2. \( F = mx\omega^2 \) or \( F = \frac{mv^2}{x} \) and \( v = \omega x \) (accept \( x \) or \( r \) for distance)
\[ = 2.50 \times 6.37 \times 10^6 \times \left(\frac{2\pi}{24 \times 3600}\right)^2 \]
\[ = 0.0842 \text{ N (accept 2 s.f. or more)} \]

(ii) reading \( = 24.575 - 0.0842 \)
\[ = 24.5 \text{ N (accept only 3 s.f.)} \]

(b) gravitational force provides the centripetal force
gravitational force is 'equal' to the centripetal force
(accept \( Gm_1m_2/x^2 = mx\omega^2 \) or \( F_C = F_G \))
'weight/sensation of weight/contact force/reaction force is difference between \( F_G \)
and \( F_C \) which is zero

2 (a) mean speed \( = 1.44 \times 10^3 \text{ m s}^{-1} \)

(b) evidence of summing of individual squared speeds
mean square speed \( = 2.09 \times 10^6 \text{ m}^2 \text{ s}^{-2} \)

(c) root-mean-square speed \( = 1.45 \times 10^3 \text{ m s}^{-1} \)
(allow ECF from (b) but only if arithmetic error)

3 (a) (numerically equal to) quantity of heat/(thermal) energy to change state/phase of unit mass
at constant temperature
(allow 1/2 for definition restricted to fusion or vaporisation)

(b) (i) constant gradient/straight line (allow linear/constant slope)

(ii) \( Pt = mL \) or power = gradient \( \times L \)

use of gradient of graph
(or two points separated by at least 3.5 minutes)
\[ 110 \times 60 = L \times (372 - 325) \times 10^{-3}/7.0 \]
\[ L = 9.80 \times 10^5 \text{ J kg}^{-1} \) (accept 2 s.f.) (allow 9.8 to 9.9 rounded to 2 s.f.)

(iii) some energy/heat is lost to the surroundings or vapour condenses on sides
so value is an overestimate

4 (a) displacement (directly) proportional to acceleration/force
either displacement and acceleration in opposite directions
or acceleration (always) towards a (fixed) point
(b) (i) $\frac{1}{3}\pi$ rad or 1.05 rad (allow 60° if unit clear)  
A1 [1]

(ii) $a_0 = -\omega^2 x_0$

$= (-) (2\pi / 1.2)^2 \times 0.030$

$= (-) 0.82 \text{ m/s}^2$  
C1

(special case: using oscillator $P$ gives $x_0 = 1.7 \text{ cm}$ and $a_0 = 0.47 \text{ m/s}^{-1}$ for 1/2)  
A1 [2]

(iii) max. energy $\propto x_0^2$

ratio $= 3.0^2 / 1.7^2$

$= 3.1$ (at least 2 s.f.)  
C1

(if has inverse ratio but has stated max. energy $\propto x_0^2$ then allow 1/2)  
A1 [2]

(c) graph: straight line through (0,0) with negative gradient  
M1

correct end-points (−3.0, +0.82) and (+3.0, −0.82)  
A1 [2]

5 (a) work done bringing/moving per unit positive charge  
from infinity (to the point)  
M1

(b) (i) slope/gradient (of the line/graph/tangent)  
B1 [1]

(allow $dV/dx$, but not $\Delta V/\Delta x$ or $V/x$)  
(allow potential gradient)  
(negative sign not required)

(ii) maximum at surface of sphere A or at $x = 0$ (cm)  
zero at $x = 6$ (cm)  
then increases but in opposite direction  
(any mention of attraction max. 2/3)  
B1

(c) (i) M shown between $x = 5.5 \text{ cm}$ and $x = 6.5 \text{ cm}$  
B1 [1]

(ii) 1. $\Delta V = (570 - 230) = 340 \text{ V}$ (allow 330 V to 340 V)  
A1 [1]

2. $q(\Delta)V = \frac{1}{2}mv^2$ or change/loss in PE = change/gain in KE or $\Delta E_K = \Delta E_P$  
B1

$4.8 \times 10^7 \times 340 = \frac{1}{2}v^2$

$v^2 = 3.26 \times 10^{10}$

$v = 1.8 \times 10^5 \text{ m/s}^{-1}$ (not 1 s.f.)  
C1

6 (a) packet/quantum/discrete amount of energy  
of electromagnetic energy/radiation/waves  
M1

(b) (i) arrow below axis and pointing to right  
B1 [1]
(ii) 1. \[ E = \frac{hc}{\lambda} \]
\[ = (6.63 \times 10^{-34} \times 3.0 \times 10^8)/(6.80 \times 10^{-12}) \]
\[ = 2.93 \times 10^{-14} \text{J} \text{ (accept 2 s.f.)} \]
\[ C1 \]
\[ A1 \quad [2] \]

2. energy of electron = \((3.06 - 2.93) \times 10^{-14}\)
\[ = 1.3 \times 10^{-15} \text{J} \]
\[ C1 \]
\[ \text{speed} = \sqrt{2E/m} \]
\[ = 5.4 \times 10^7 \text{m/s}^{-1} \]
\[ C1 \]
\[ A1 \quad [3] \]

(c) momentum is a vector quantity
\[ \text{either} \quad \text{must consider momentum in two directions} \]
\[ \text{or} \quad \text{direction changes so cannot just consider magnitude} \]
\[ B1 \]
\[ A1 \quad [2] \]

7 (a) moving magnet gives rise to-causes/induces e.m.f./current in solenoid/coil
\[ \text{(induced current) creates field/flux in solenoid that opposes (motion of) magnet} \]
\[ \text{work is done/energy is needed to move magnet (into solenoid)} \]
\[ \text{(induced) current gives heating effect (in resistor) which comes from the work done} \]
\[ B1 \]
\[ A1 \quad [4] \]

(b) current in primary coil give rise to (magnetic) flux/field
\[ \text{(magnetic) flux/field (in core) is in phase with current (in primary coil)} \]
\[ \text{(magnetic) flux threads/links/cuts secondary coil inducing e.m.f. in secondary coil} \]
\[ \text{(there must be a mention of secondary coil)} \]
\[ \text{e.m.f. induced proportional to rate of change/cutting of flux/field so not in phase} \]
\[ B1 \]
\[ A1 \quad [4] \]

8 (a) (i) energy = \(5.75 \times 1.6 \times 10^{-13}\)
\[ = 9.2 \times 10^{-13} \text{J} \]
\[ A1 \quad [1] \]

(ii) number = \(1900/(9.2 \times 10^{-13} \times 0.24)\)
\[ = 8.6 \times 10^{15} \text{s}^{-1} \]
\[ C1 \]
\[ A1 \quad [2] \]

(b) (i) decay constant = \(0.693/(2.8 \times 365 \times 24 \times 3600)\)
\[ = 7.85 \times 10^{-9} \text{s}^{-1} \text{ (allow 7.8 or 7.9 to 2 s.f.)} \]
\[ C1 \]
\[ A1 \quad [2] \]

(ii) \[ A = \lambda N \]
\[ 8.6 \times 10^{15} = 7.85 \times 10^{-9} \times N \]
\[ N = 1.096 \times 10^{24} \]
\[ C1 \]
\[ C1 \]
\[ \text{mass} = (1.096 \times 10^{24} \times 236)/(6.02 \times 10^{23}) \]
\[ = 430 \text{g} \]
\[ M1 \]
\[ A1 \quad [4] \]

(c) \[ 0.84 = 1.9 \exp(-7.85 \times 10^{-9} t) \]
\[ t = 1.04 \times 10^8 \text{s} \]
\[ = 3.3 \text{ years} \]
\[ C1 \]
\[ A1 \quad [2] \]
Section B

9 (a) \( V_B = 1000 \text{ mV} \) when strained, \( V_A = 2000 \times \frac{121.5}{(121.5 + 120.0)} \) = 1006.2 mV \( \) change = 6.2 mV \( (allow \ 6 \text{ mV}) \) \( \)

M1  [3]

(b) (i) 1. resistor between \( V_{IN} \) and \( V^- \) and \( V^+ \) connected to earth \( \) resistor between \( V^- \) and \( V_{OUT} \)

B1  [2]

2. P/+ sign shown on earth side of voltmeter

B1  [1]

(ii) ratio of \( R_F / R_{IN} = 40 \)

M1  [2]

\( R_{IN} \) between 100 \( \Omega \) and 10 k\( \Omega \)

A1  [2]

\( (any \ values \ must \ link \ to \ the \ correct \ resistors \ on \ the \ diagram) \)

10 (a) product of density (of medium) and speed (of ultrasound)

in the medium

M1  [2]

A1  [2]

(b) (i) \( 7.0 \times 10^6 = 1.7 \times 10^3 \times \text{speed} \)

speed = \( 4.12 \times 10^3 \text{ m s}^{-1} \)

wavelength = \( \frac{(4.12 \times 10^3)}{(9.0 \times 10^5)} \text{m} \)

= 4.6 mm \( (2 \text{ s.f. minimum}) \)

A1  [3]

(ii) for air/tissue boundary, \( I_R / I \approx 1 \)

for air/tissue boundary, (almost) complete reflection/no transmission

for gel/tissue boundary, \( I_R / I = 0.1^2 / 3.1^2 \)

\( = 1.04 \times 10^{-3} (accept \ 1 \text{ s.f.}) \)

M1  [4]

gel enables (almost) complete transmission (into the tissue)


11 (a) (i) metal \( (allow \ specific \ example \ of \ a \ metal) \)

B1  [1]

(ii) e.g. provides ‘return’ for the signal

shields inner core from interference/reduces cross-talk/reduces noise

increased security

\( (any \ two \ sensible \ suggestions, \ 1 \ each) \)

B2  [2]

(b) (i) (gradual) loss of power/intensity/amplitude

B1  [1]

(ii) dB is a log scale

\( either \ large \ (range \ of) \ numbers \ are \ easier \ to \ handle \ (on \ a \ log \ scale) \)

\( or \) compounding attenuations/amplifications is easier

B1  [2]

(c) attenuation = \( 190 \times 11 \times 10^{-3} = 2.09 \text{ dB} \)

\( -2.09 = 10 \log(P_{OUT} / P_{IN}) \)

C1  [3]

ratio = 0.62

A1  [3]
12  handset transmits (identification) signal to number of base stations  
    base stations transfers (signal) to cellular exchange  
    (idea of stations needed at least once in first two marking points)  

computer at cellular exchange selects base station with strongest signal  
computer at cellular exchange selects a carrier frequency for mobile phone  
(idea of computer needed at least once in these two marking points)