
PHYSICS

9702/41

Paper 4 A Level Structured Questions

October/November 2016

MARK SCHEME

Maximum Mark: 100

Published

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- 1 (a) gravitational force provides/is the centripetal force B1
- $$GMm/r^2 = mv^2/r \quad \text{or} \quad GMm/r^2 = mr\omega^2$$
- $$\text{and } v = 2\pi r/T \quad \text{or} \quad \omega = 2\pi/T \quad \text{M1}$$
- with algebra to $T^2 = 4\pi^2 r^3 / GM$ A1 [3]
- or
- acceleration due to gravity is the centripetal acceleration (B1)
- $$GM/r^2 = v^2/r \quad \text{or} \quad GM/r^2 = r\omega^2$$
- $$\text{and } v = 2\pi r/T \quad \text{or} \quad \omega = 2\pi/T \quad \text{(M1)}$$
- with algebra to $T^2 = 4\pi^2 r^3 / GM$ (A1)
- (b) (i) equatorial orbit/orbits (directly) above the equator B1
- from west to east B1 [2]
- (ii) $(24 \times 3600)^2 = 4\pi^2 r^3 / (6.67 \times 10^{-11} \times 6.0 \times 10^{24})$ C1
- $$r^3 = 7.57 \times 10^{22}$$
- $$r = 4.2 \times 10^7 \text{ m} \quad \text{A1 [2]}$$
- (c) $(T/24)^2 = \{(2.64 \times 10^7) / (4.23 \times 10^7)\}^3$ B1
- $$= 0.243$$
- $T = 12 \text{ hours}$ A1 [2]
- or
- $$k (= T^2/r^3) = 24^2 / (4.23 \times 10^7)^3 \quad \text{(B1)}$$
- $$= 7.61 \times 10^{-21}$$
- $$T^2 (= kr^3) = 7.61 \times 10^{-21} \times (2.64 \times 10^7)^3$$
- $$= 140$$
- $T = 12 \text{ hours}$ (A1)
- 2 (a) (i) $p \propto T$ or $pV/T = \text{constant}$ or $pV = nRT$ C1
- $T (= 5 \times 300 =) 1500 \text{ K}$ A1 [2]
- (ii) $pV = nRT$
- $$1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300$$
- or
- $$5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500 \quad \text{C1}$$
- $n = 0.016 \text{ mol}$ A1 [2]

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- (b) (i) 1. heating/thermal energy supplied B1
2. work done on/to system B1 [2]
- (ii) 1. 240 J A1
2. same value as given in 1. (= 240 J) **and** zero given for 3. A1
3. zero A1 [3]
- 3 (a) $2k/m = \omega^2$ M1
- $\omega = 2\pi f$ M1
- $(2 \times 64 / 0.810) = (2\pi \times f)^2$ leading to $f = 2.0$ Hz A1 [3]
- (b) $v_0 = \omega x_0$ or $v_0 = 2\pi f x_0$
- or
- $v = \omega(x_0^2 - x^2)^{1/2}$ and $x = 0$ C1
- $v_0 = 2\pi \times 2.0 \times 1.6 \times 10^{-2}$
- $= 0.20 \text{ ms}^{-1}$ A1 [2]
- (c) frequency: reduced/decreased B1
- maximum speed: reduced/decreased B1 [2]
- 4 (a) (i) noise/distortion is removed (from the signal) B1
- the (original) signal is reformed/reproduced/recovered/restored B1 [2]
- or
- signal detected above/below a threshold creates new signal (B1)
- of 1s and 0s (B1)
- (ii) noise is superposed on the (displacement of the) signal/cannot be distinguished
- or
- analogue/signal is continuous (so cannot be regenerated)
- or
- analogue/signal is not discrete (so cannot be regenerated) B1
- noise is amplified with the signal B1 [2]

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(b) (i) $\text{gain/dB} = 10 \lg(P_2/P_1)$

$$32 = 10 \lg[P_{\text{MIN}}/(0.38 \times 10^{-6})]$$

or

$$-32 = 10 \lg(0.38 \times 10^{-6}/P_{\text{MIN}})$$

C1

$$P_{\text{MIN}} = 6.0 \times 10^{-4} \text{ W}$$

A1 [2]

(ii) $\text{attenuation} = 10 \lg[(9.5 \times 10^{-3})/(6.02 \times 10^{-4})]$

C1

$$= 12 \text{ dB}$$

$$\text{attenuation per unit length} (= 12/58) = 0.21 \text{ dB km}^{-1}$$

A1 [2]

5 (a) in an electric field, charges (in a conductor) would move

B1

no movement of charge so zero field strength

or

charge moves until $F = 0$ / $E = 0$

B1 [2]

or

charges in metal do not move

(B1)

no (resultant) force on charges so no (electric) field

(B1)

(b) at P, $E_A = (3.0 \times 10^{-12})/[4\pi\epsilon_0(5.0 \times 10^{-2})^2] (= 10.79 \text{ NC}^{-1})$

M1

at P, $E_B = (12 \times 10^{-12})/[4\pi\epsilon_0(10 \times 10^{-2})^2] (= 10.79 \text{ NC}^{-1})$

M1

or

$$(3.0 \times 10^{-12})/[4\pi\epsilon_0(5.0 \times 10^{-2})^2] - (12 \times 10^{-12})/[4\pi\epsilon_0(10 \times 10^{-2})^2] = 0$$

or

$$(3.0 \times 10^{-12})/[4\pi\epsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12})/[4\pi\epsilon_0(10 \times 10^{-2})^2]$$

(M2)

fields due to charged spheres are (equal and) opposite in direction, so $E = 0$

A1 [3]

(c) $\text{potential} = 8.99 \times 10^9 \{(3.0 \times 10^{-12})/(5.0 \times 10^{-2}) + (12 \times 10^{-12})/(10 \times 10^{-2})\}$

C1

$$= 1.62 \text{ V}$$

A1 [2]

(d) $\frac{1}{2}mv^2 = qV$

$$E_K = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2$$

C1

$$qV = 47 \times 1.60 \times 10^{-19} \times 1.62$$

C1

$$v^2 = 1.37 \times 10^8$$

$$v = 1.2 \times 10^4 \text{ ms}^{-1}$$

A1 [3]

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- 6 (a) reference to input (voltage) and output (voltage) B1
there is no time delay between change in input and change in output B1 [2]
- or
- reference to rate at which output voltage changes (B1)
infinite rate of change (of output voltage) (B1)
- (b) (i) $2.00/3.00 = 1.50/R$ C1
- or
- $V_+ = (3.00 \times 4.5)/(2.00 + 3.00) = 2.7$
 $2.7 = 4.5 \times R/(R + 1.50)$ (C1)
- resistance = $2.25 \text{ k}\Omega$ A1 [2]
- (ii) 1. correct symbol for LED M1
two LEDs connected with opposite polarities between V_{OUT} and earth A1 [2]
2. below 24°C , $R_T > 1.5 \text{ k}\Omega$ or resistance of thermistor increases/high B1
- $V_- < V_+$ or V_- decreases/low (must not contradict initial statement) M1
- V_{OUT} is positive/+5 (V) and LED labelled as 'pointing' from V_{OUT} to earth A1 [3]
- 7 (a) region (of space) where a force is experienced by a particle B1 [1]
- (b) (i) gravitational B1
- (ii) gravitational and electric B1
- (iii) gravitational, electric and magnetic B1 [3]
- (c) (i) force (always) normal to direction of motion M1
- (magnitude of) force constant
or
speed is constant/kinetic energy is constant M1
- magnetic force provides/is the centripetal force A1 [3]
- (ii) $mv^2/r = Bqv$ B1
- momentum or p or $mv = Bqr$ B1 [2]

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- 8 strong uniform magnetic field B1
- nuclei precess/rotate about field (direction) (1)
- radio-frequency pulse (applied) B1
- R.F. or pulse is at Larmor frequency/frequency of precession (1)
- causes resonance/excitation (of nuclei)/nuclei absorb energy B1
- on relaxation/de-excitation, nuclei emit r.f./pulse B1
- (emitted) r.f./pulse detected and processed (1)
- non-uniform magnetic field B1
- allows position of nuclei to be located B1
- allows for location of detection to be changed/different slices to be studied (1)
- any two of the points marked (1)* B2 [8]
- 9 (a) (induced) e.m.f. proportional to rate of change of (magnetic) flux (linkage) M1
A1 [2]
- (b) flux linkage = BAN
- $$= \pi \times 10^{-3} \times 2.8 \times \pi \times (1.6 \times 10^{-2})^2 \times 85 = 6.0 \times 10^{-4} \text{ Wb}$$
- B1 [1]
- (c) e.m.f. = $\Delta N\Phi / \Delta t$
- $$= (6.0 \times 10^{-4} \times 2) / 0.30$$
- C1
- $$= 4.0 \text{ mV}$$
- A1 [2]
- (d) sketch: $E = 0$ for $t = 0 \rightarrow 0.3 \text{ s}$, $0.6 \text{ s} \rightarrow 1.0 \text{ s}$, $1.6 \text{ s} \rightarrow 2.0 \text{ s}$ B1
- $E = 4 \text{ mV}$ for $t = 0.3 \text{ s} \rightarrow 0.6 \text{ s}$ (either polarity) B1
- $E = 2 \text{ mV}$ for $t = 1.0 \text{ s} \rightarrow 1.6 \text{ s}$ B1
- with opposite polarity B1 [4]

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- 10 (a)** electromagnetic radiation/photons incident on a surface B1
causes emission of electrons (from the surface) B1 [2]
- (b)** $E = hc / \lambda$
 $= (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (436 \times 10^{-9})$ C1
 $= 4.56 \times 10^{-19} \text{ J } (4.6 \times 10^{-19} \text{ J})$ A1 [2]
- (c) (i)** $\Phi = hc / \lambda_0$
 $\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (1.4 \times 1.60 \times 10^{-19})$ C1
 $= 890 \text{ nm}$ A1 [2]
- (ii)** $\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (4.5 \times 1.60 \times 10^{-19})$
 $= 280 \text{ nm}$ A1 [1]
- (d)** caesium:
wavelength of photon less than threshold wavelength (or v.v.)
or
 $\lambda_0 = 890 \text{ nm} > 436 \text{ nm}$
so yes A1
- tungsten:
wavelength of photon greater than threshold wavelength (or v.v.)
or
 $\lambda_0 = 280 \text{ nm} < 436 \text{ nm}$
so no A1 [2]
- 11** in metal, conduction band overlaps valence band/no forbidden band/no band gap B1
as temperature rises, no increase in number of free electrons/charge carriers B1
as temperature rises, lattice vibrations increase M1
(lattice) vibrations restrict movement of electrons/charge carriers M1
(current decreases) so resistance increases A1 [5]

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- 12 (a) (i)** time for number of atoms/nuclei or activity to be reduced to one half M1
- reference to (number of...) original nuclide/single isotope
or
 reference to half of original value/initial activity A1 [2]
- (ii)** $A = A_0 \exp(-\lambda t)$ and either $t = t_{1/2}$, $A = \frac{1}{2}A_0$ or $\frac{1}{2}A_0 = A_0 \exp(-\lambda t_{1/2})$ M1
- so $\ln 2 = \lambda t_{1/2}$ (and $\ln 2 = 0.693$), hence $0.693 = \lambda t_{1/2}$ A1 [2]
- (b)** $A = \lambda N$
- $N = 200 / (2.1 \times 10^{-6})$ C1
- $= 9.52 \times 10^7$ C1
- mass = $(9.52 \times 10^7 \times 222 \times 10^{-3}) / (6.02 \times 10^{23})$
- or*
- mass = $9.52 \times 10^7 \times 222 \times 1.66 \times 10^{-27}$ C1
- $= 3.5 \times 10^{-17} \text{ kg}$ A1 [4]