**1.** (a) (i) E = (Pt =) 36 × 3600

*__allow__ I = 3 A and E = VIt, etc.*

**C1**

= $1.3 \times 10^5$ (J)

*__accept__ 129600 (J)*

**A1**

(ii) Q = E/V = $1.3 \times 10^5$/12 **or** Q = It =3 × 3600

*__ecf__ (a)(i)*

**C1**

= $1.1 \times 10^4$

*__accept__ $1.08 \times 10^4$*

**A1**

unit: C

*__allow__ A s __not__ J $V^{-1}$*

**B1**

(iii) Q/e = $1.1 \times 10^4/1.6 \times 10^{-19}$

***ecf (a)(ii)***

**C1**

= $6.9 \times 10^{22}$

*__accept__ 6.75 or $6.8 \times 10^{22}$ using 10800*

**A1**

(b) (i) *no mark for quoting formula*

the average displacement/distance travelled of the electrons <u>along the wire</u> per second;

*__allow__ in one second*

**B1**

(over time/on average) they move slowly in one direction through the metal/Cu lattice (when there is a p.d. across the wire);

**B1**

(because) they collide constantly/in a short distance with the lattice/AW

***max 2 marks** from 3 marking points*

**B1**

(ii) select I = nAev (= 3.0 A)

*1 mark for correct formula* **C1**

$v = 3.0/8.0 \times 10^{28} \times 1.1 \times 10^{-7} \times 1.6 \times 10^{-19}$

*1 mark for correct substitutions into formula* **C1**

$= 2.1 \times 10^{-3}$ (m $s^{-1}$)

*1 mark for correct answer to 2 or more SF* **A1**

**[12]**

***2.*** $\rho$ = RA/l

*full word definition gains both marks* **M1**

with terms defined

***allow** A is area as adequate; no unit cubes* **A1**

**[2]**

**3.** (a) (i) **either** the cable consists of (38) strands <u>in parallel;</u>
or the area of the cable is 38 times the area of a strand or vice versa;

*max 1 mark for 38 × 0.052 = 1.98 with no further explanation*
***allow** with **either** and **or*** **B1**

so the resistance of 1 strand is 38 times bigger, (i.e. 1.98 Ω $km^{-1}$)
**or** the resistance is inversely proportional to the area

***allow** only with **or*** **B1**

(ii) $A = \rho\, l/R = 2.6 \times 10^{-8} \times 1000/2.0$

***allow** 1 mark max. for R = 0.052 giving*
*$A = 5.0 \times 10^{-4}$ ($m^2$)* **C1**

$= 1.3 \times 10^{-5}$ ($m^2$)

***give** 1 mark max. for $1.3 \times 10^{-8}$ ($m^2$)* **A1**

(b) (i) $P = VI = 400 \times 10^3 \times 440$

*P = VI* ***not*** *adequate for first mark*

**C1**

$= 1.8 \times 10^8$ (W) or 180 M(W)

***expect*** *176*

**A1**

(ii) 2000/176 = 11.4 so 12 required

***ecf(b)(i)****; using 180 gives 11.1*

**B1**

(iii) $P = I^2R$

***accept*** *power/cable = 2000/12 = 167 MW*

**C1**

$= 440^2 \times 0.052$

*I = 167M/400k = 417 A*

**C1**

$= 1.0 \times 10^4$ W ($km^{-1}$) or 10 kW ($km^{-1}$)

$P = 417^2 \times 0.052 = 9.0(3)$ kW ($km^{-1}$)

**A1**

***N.B****. answer mark includes consistent unit*

(iv) power lost per cable = 10 k × 100 × 12 = 12.0 MW

***ecf(b)(ii)(iii)***

**C1**

fraction remaining = (2000 – 12)/2000 = 0.994 × 100 = 0.994 so 99.4%
or power lost per strand = 10 k ×100 = 1.0 MW
fraction remaining = (176 – 1)/176 = 0.994 so 99.4%

***allow*** *second mark for 'correct' answer as fraction not percentage with BOD sign*
***allow*** *1 mark max. if give correct % lost given rather than % remaining*
***allow*** *1 mark max. for 100 × (2000 – 1)/2000 = 99.95%*

**A1**

**[12]**

**4.** (a) resistors in series add to 20 Ω and current is 0.60 A

***accept*** *potential divider stated* ***or*** *formula*

**B1**

so p.d. across XY is 0.60 × 12 (= 7.2 V)

*gives (12 /20) × 12 V (= 7.2 )V*

**B1**

(b) (i) the resistance <u>of the LDR</u> decreases **M1**

(so total resistance in circuit decreases) and current increases **A1**

(ii) resistance of LDR and 12 Ω (in parallel)/across **XY** decreases **B1**

so has smaller share of supply p.d. (and p.d. across XY falls)
***alternative*** *I increases so p.d. across 8.0 Ω increases; so p.d. across **XY** falls* **B1**

**[6]**

**5.** (i) no current/no light/does not conduct until V is greater than 1.5 V
***allow*** *1.4 to 1.6 V (QWC mark)* **B1**

brightness/intensity of LED increases with current/voltage above 1.5 V
*(alternative QWC mark)* **B1**

above 1.8 V current rises almost linearly with increase in p.d./AW **B1**

the LED does not obey Ohm's law **M1**

as I is not proportional to V/AW **A1**

below 1.5 V, LED acts as an infinite R/ very high R/acts as open switch **B1**

above 1.5 V, LED resistance decreases (with increasing current/voltage) **B1**

***max 5 marks*** *which must include at least one of the first 2 marking points*

(ii) **1** infinite resistance **B1**

**2** 1 = 23.0 ± 1.0 (mA) **C1**

$R = 1.9 \times 10^3/(23 \pm 1) = 83 \pm 4\ \Omega$
***apply*** *POT error for 0.083 Ω* **A1**

**[8]**

**6.** (a) LED symbol with correct orientation

*diode symbol + circle + at least one arrow pointing away*

**B1**

resistor (need not be labelled) and ammeter in series with it

**B1**

voltmeter in parallel across LED only

**B1**

(b) in fig 2 the voltage range is from zero to maximum possible

***allow*** *6.0 V*

**B1**

in fig. 1 the resistance variation is small/AW

***accept*** *the LED is part of a potential divider*

**B1**

(so) in fig. 1 voltage variation across LED is small

***accept*** *only at the top end of the range/AW*

**B1**

**[6]**

**7.** the resistor limits the current in the circuit (when the LED conducts)

**B1**

otherwise it could overheat/burn out/be damaged/AW

**B1**

**[2]**

**8.** (i) λ distance between (neighbouring) identical points/points with same phase (on the wave)

***accept*** *peak/crest to peak/crest, etc.*

**B1**

f number of waves passing a point /cycles/vibrations (at a point) per unit time/second

***accept*** *number of waves produced by the wave source per unit time/second*

**B1**

v distance travelled by the wave (energy) per unit time/second

***not*** *$v = f\lambda$ and not 'in one second'*

**B1**

(ii) in 1 second f waves are produced each of one wavelength $\lambda$

*__accept__ time for one $\lambda$ to pass is 1/f so $v = \lambda/(1/f) = f\lambda$*

**M1**

distance travelled by first wave in one second is $f\lambda = v$

*__give__ max 1 mark for plausible derivations purely in terms of algebra (no words)*

**A1**

**[5]**

**9.** (i) infra red is part of the e-m spectrum

**B1**

lower f **or** longer $\lambda$ than the visible region/light **or** suitable value or range of $\lambda$

*__accept__ any single $\lambda$ in range $10^{-5}$ m to $7.5 \times 10^{-7}$ m or any reasonable wider range*

**B1**

(ii) **1** $\lambda = c/f = 3.0 \times 10^8 / 6.7 \times 10^{13}$

**C1**

$4.5 \times 10^{-6}$ (m)

*__accept__ $4.48 \times 10^{-6}$ or more s.f.*

**A1**

**2** $T = 1/f = 1/6.7 \times 10^{13}$

**C1**

$T = 1.5 \times 10^{-14}$ (s)

*__accept__ $1.49 \times 10^{-14}$*

**A1**

(iii) at least one cycle of a sine or cosine curve as judged by eye

***ecf (ii)2***

**B1**

amplitude $8.0 \times 10^{-12}$ m

**B1**

period = $1.5 \times 10^{-14}$ s

**B1**

**[9]**

**10.** (i) when (two) waves meet/combine/interact/superpose, etc. (at a point)

**M1**

there is a change in overall intensity/displacement

*__allow__ for A1 mark: (vector) sum/resultant displacement(s)/AW*

**A1**

(ii) constant phase difference/relationship (between the waves)

*just stating same frequency not sufficient*

**B1**

**[3]**

**11.** (i) path difference of n$\lambda$ for constructive interference

***allow*** *waves arrive in phase*

**M1**

producing **either** maximum amplitude/intensity **or** a maximum

**A1**

path difference of $(2n + 1)\lambda/2$ for destructive interference

***allow*** *waves arrive in anti-/out of phase*

**M1**

producing **either** minimum amplitude/intensity **or** a minimum

**A1**

***max*** *3 marks; max 1 mark for two correct marking points but with n omitted*

(ii) $x = \lambda D/a = 0.030 \times 5.0/0.20$

**C1**

= 0.75 (m)

***give*** *1 mark max for 0.75 mm but zero for 750 m*

**A1**

(iii) **1** intensity increases by factor of 4

**B1**

position unchanged

**B1**

**2** intensity unchanged

**B1**

distance apart of maxima is doubled

**B1**

**3** intensity unchanged

**B1**

maxima move to positions of minima (and vice versa)

**B1**

**[11]**

**12.** (a) (i) $E = hc/\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 6.3 \times 10^{-7}$

*mark is for correct substitution into formula*

**M1**

$= 3.16 \times 10^{-19}$ (J)

*min of 2 sig figs;* ***allow*** *3.1 for* $h = 6.6 \times 10^{-34}$

**A1**

(ii) $1.0 \times 10^{-3}/3(.2) \times 10^{-19}$ ($= 3.1 \times 10^{15}$)

***accept*** $3 \times 10^{15}$*; the mark is for the expression*

**B1**

(iii) energy levels explanation: electrons have discrete energies in atom/AW

*QWC mark*

**B1**

each photon produced by electron moving between levels

*good diagram can score marks*

**B1**

photon energy equal to energy difference between levels

***allow*** $E_1 - E_2 = hf$ *or similar*

**B1**

electron loses energy/making transition in correct direction

**B1**

(iv) blue light has a higher frequency/shorter wavelength than red light

**B1**

energy per photon is higher (so fewer needed to produce one mW)

**B1**

(b) (i) vertical arrow up approximately through **X**

***allow*** *tolerance e.g.* $\pm 10°$

**B1**

(ii) $I = 0.2\,ne$; $= 0.2 \times 3.2 \times 10^{15} \times 1.6 \times 10^{-19}$

***max*** *2 marks if forget 0.2 factor*

**C2**

$= 1.0(24) \times 10^{-4}$ (A) or 0.10 mA ($9.6 \times 10^{-5}$ if using $3 \times 10^{15}$)

*0.51 mA (0.48) if forget 0.2 factor*

**A1**

(iii) reflection/absorption at top layer; light/some photons reach bottom layer; photons below threshold energy/photons absorbed by electrons without release; recombination of ion pairs in insulating layer; scattering of light/photons out of insulating layer

***award*** *mark for any sensible comment; see examples given*

**B1**

**[14]**

**13.** (a) (i) paths spread out after passing through a gap or around an obstacle/AW

**B1**

(ii) wavelength of electrons

***allow*** *electrons behave as waves/AW*

**M1**

must be comparable/of the order of magnitude of the atomic spacing

***allow*** *must be about* $10^{-10}$ *m*

**A1**

(b) $\lambda = h/mv$

*mark for selecting formula*

**C1**

$v = 6.6(3) \times 10^{-34} / 9.1(1) \times 10^{-31} \times 1.2 \times 10^{-10}$

*correct manipulation and subs. shown*

**M1**

$= 6.0$ or $6.1 \times 10^{6}$ (m s$^{-1}$)

***give*** *all 3 marks for answers to 3 figs or more: i.e. 6.04, 6.06 or 6.07*

**A1**

(c) (i) $eV = ½mv^2$

*mark for algebraic equation*

**C1**

$V = mv^2/2e = 9.1 \times 10^{-31} \times (6.0 \times 10^{6})^2/2 \times 1.6 \times 10^{-19}$

*mark for correct substitution*

**C1**

$= 1.0(2) \times 10^{2}$ (V)

***give*** *1 mark max for k.e. =* $1.6(4) \times 10^{-17}$ *J*
*using 6.1 gives 104 (V)*

**A1**

(ii) electrons should be repelled by cathode and/or attracted by anode **or** they will be attracted back to the cathode/slowed down if cathode positive

*__award__ mark if answer indicates this idea*

**B1**

**[10]**

**14.** (a) resistance = p.d./current

*__accept__ voltage instead of p.d.; ratio of voltage to current; voltage per (unit) current*
*__not__ R = V/I or p.d. = current x resistance or p.d. per amp or answer in units or voltage over current*

**B1**

(b) (i) 6 V

**B1**

(ii) R = V/I = 6/0.25
= 24 (Ω)

*__ecf (b)(i)__ 240 V gives 960 Ω*
*__award__ 0.024 Ω 1 mark only (POT error)*

**C1**
**A1**

(c) (i) 6 V supply with potential divider 'input' across it and lamp across p.d. 'output'
ammeter in series with lamp
voltmeter across lamp

*__accept__ 0 – 6 V variable supply with lamp across it*
*__not__ variable R in series with supply*
*circuit with no battery present can only score voltmeter mark*

**B1**
**B1**
**B1**

(ii) non-zero intercept
line indicating increasing value of R with current

*curve must reach y-axis*
***accept** straight line or upward curve*

**B1**
**B1**

(iii) resistivity/resistance of filament wire increases with temperature
the temperature of the lamp increases with current/voltage increase
more frequent electron-ion/atom collisions/AW
increased ion vibrations

***accept** any two of the four statements*
***accept** AW, e.g the lamp heats up because of the current*

**B1**
**B1**

(d) (i) lamps do not light

***ignore** reasons unless too contrary*

**B1**

remaining lamps are lit with qualification

*qualification could be more dimly or sensible explanation*

**B1**

(ii) using resistors in parallel formula to obtain a value of R per unit
R per unit = 19.4 Ω or R total = 774 Ω
I = 6/19.4 or 240/774 = 0.31 A

*eg takes R of bulb = 10 Ω giving R per unit = 9.1 Ω gains first mark only*
***ecf (b)(i)(ii)***
***accept** R of resistors = 4000 Ω; current in chain = 0.06 A; total current = 0.06 + 0.25 = 0.31 A*
*0.3 A is SF error so gains 2 marks only*
*apply **SF error only once** in paper*

**C1**
**C1**
**A1**

**[16]**

**15.** (a) E = I(R + r) **B1**

(b) (i) 1 0.80 Ω **B1**

2 6.4 V **B1**

(ii) (sum of) e.m.f.s = sum /total of p.d.s/sum of voltages (in a loop) **B1**

(iii) 6.4 = 0.80I
I = 8.0 A

***can be 2 ecf*** *from* ***(b)(i)****, eg 21.6/0.8*
*= 27 A (1 ecf) or 21.8/0.68 = 31.8 A (2 ecf)*

**C1**
**A1**

(c) (i) Q = It = 2.5 × 6 × 60 × 60
= 54000 (C)

***allow*** *1 mark if forgets one or two 60's giving 900 C or 15 C*

**C1**
**A1**

(ii) energy = QE = 54000 × 14
= 756000 (J)

***allow*** *(use of 12 V gives) 648000 J for 1 mark*

**C1**
**A1**

(iii) energy loss = I2Rt = VIt = 2 × 2.5 × 6.0 × 60 × 60 = 108000 J
percentage = (108000/756000) × 100 = 14%

***accept*** *QΔV = 54000 × 2.0 = 108000 J*
***accept*** *QΔV/QE = 2.0/14.0 = 14%*
***not*** *756000/54000 = 14%*

**C1**
**A1**

**[12]**

**16.** (a) (i) I = V/R = 8.0/200
I = 0.040 (A)

**C1**
**A1**

(ii) V = 24 – 8 = 16 (V)

**B1**

(iii) R = 16/0.04 giving
R = 400 (Ω)

***accept*** *ratio of p.d.s to ratio of Rs*
***ecf*** *from* ***(i)*** *&* ***(ii)*** *ie* ***(a)(ii)/(a)(i)***

**C1**
**A1**

(iv) $P = VI = I^2R = V^2/R$
P = 0.640 (W)

***ecf*** *from* ***(i)*** *&* ***(ii)***
***accept*** *640 mW*

**C1**
**A1**

(b) (i) the thermistor has heated up/ its temperature has increased
so its resistance has dropped
so the ratio of the voltages across the potential divider changes/AW

***accept*** *so the current increases*
***accept*** *so IR of fixed resistor increases*

**B1**
**M1**
**A1**

(ii) voltages are equal so resistances are equal

**B1**

(c) (i) straight line through origin labelled R
passing through 0.06,12

***allow*** *correct lines with no labels*

**B1**
**B1**

(ii) upward curve below straight line through origin labelled T
passing through 0.06,12

**B1**
**B1**

**[15]**

**17.** (i) diffraction or refraction or superposition or interference

*__accept__ any two from the four listed*

**B2**

(ii) only transverse waves can be polarised

*__accept__ sound is a longitudinal wave or e-m waves are transverse*

**B1**

(iii) place transmitter and receiver facing each other

**B1**

rotate either transmitter or receiver through 90° about axis joining aerials
**or** use two polarising filters and rotate from parallel to crossed

**B1**

observe signal fall to zero/minimum from initial high value on meter monitoring output of receiver
explanation of observations/link between observations and polarisation

*__accept__ from diagram*
*__allow__ (metal) grille/polarising filter to polarise microwaves*
*__accept__ place (metal) grille/polarising filter [__not__ Polaroid] between transmitter and receiver and rotate through 90°*

*QWC mark*

**B1**
**B1**

**[7]**

**18.** (i) 1 0.3 (mm)

*tolerance ±0.02 mm ie 0.28 – 0.32 (mm)*

**B1**

2 T = 4.0 ms
F = 1/T = 250 (Hz)

***allow*** *0.25 Hz or any other POT error for 1 mark*

**C1**
**A1**

(ii) realisation that intensity is proportional to $(\text{amplitude})^2$
giving amplitude increase by $\sqrt{2}$, ie4(.2) mm
sine wave of same frequency with any increased amplitude

**B1**
**B1**
**B1**

(iii) microphone (to transfer mechanical motion to electrical signal/voltage)
oscilloscope to display oscillation/wave for measurement (of period)/AW

***accept*** *computer/datalogger/frequency meter with qualification as for oscilloscope*

**B1**
**B1**

**[8]**

**19.** (i) node occurs where the amplitude/displacement is (always) zero

***accept*** *displacement for amplitude for (i) only*

**B1**

(ii) antinode occurs where the amplitude (of the standing wave) takes the maximum (possible) value

**B1**

**[2]**

**20.** (a) (i) wave travels to end and is reflected
reflected wave <u>interferes/superposes</u> with incident wave

**B1**
**B1**

always destructively at certain points to produce nodes
**or** always constructively at certain points to produce antinodes

***accept*** *2 waves of same f travelling in opposite directions* *<u>interfere</u> with no reference to reflection*

**B1**

(ii) A and N points labelled correctly

**B1**

(iii) 3

**B1**

(iv) 30 cm = $\lambda/2$ or $\lambda$ = 60 cm
v = f $\lambda$ = 120 × 0.6
v = 72 (m $s^{-1}$)

***allow*** *1 mark for correct calculation using* *$v = f\lambda$ with wrong wavelength if* *method/reasoning clear*

**C1**
**C1**
**A1**

(b) v = 2k becomes v = 3k (k = 36)
wavelength increases by 3/2 (as frequency unchanged)
2 half wavelengths fit on the string so standing wave is set up/AW

***accept*** *v increases by 3/2 or v = 108 m $s^{-1}$*
***accept*** *wavelength becomes 90 cm*
***allow ecf*** *correct conclusion with wrong $\lambda$*

**B1**
**B1**
**B1**

**[11]**

**21.** (a) (i) line spacing d = 1/(300 × 1000) (= $3.3 \times 10^{-6}$ (m))

*look for clear reasoning to award mark*

**B1**

(ii) $\sin\theta = \lambda/d$

$= 6.3 \times 10^{-7}/3.3 \times 10^{-6} = 0.19$

$\theta$ = 11 degrees

*rounding error of 0.2 here gives 11.9°*
*11.9° gets 2 marks*

**C1**
**C1**
**A1**

(iii) spots can be seen where $n = d \sin\theta/\lambda$
maximum n when $\sin\theta = 1$ (giving n = 5.3) so n = 5 can be seen
thus 5 spots on either side of straight through + straight through = 11

***accept*** *basic idea of orders for first mark*
*N.B. calculation not necessary*

**B1**
**B1**
**B1**

(b) (i) $\varepsilon = hc/\lambda = 6.6 \times 10^{-34} \times 3.0 \times 10^{8}/6.3 \times 10^{-7}$

$= 3.14 \times 10^{-19}$ (J)

**C1**
**A1**

(ii) $5.0 \times 10^{-4}/3.14 \times 10^{-19}$

$= 1.6 \times 10^{15}$

***accept*** *$3.2 \times 10^{-19}$ (J)*
***ecf*** *from* ***b(i)1***

**C1**
**A1**

**[11]**

**22.** (i) Electrons behave as waves/have a wavelength

**B1**

diffraction observable because gaps/atoms are similar to wavelength of electrons
regular pattern of atoms acts as a grating
allowing constructive interference to produce pattern on screen/AW
rings occur because atomic 'crystals' at all possible orientations to beam/AW

*max 2 out of next 4 marking points*
***can*** *gain first 'waves' mark here as well as second mark if first line not written explicitly*

**B1**
**B1**

(ii) 1 $\lambda = h/mv = 6.63 \times 10^{-34}/9.1 \times 10^{-31}v$
$v = 6.63 \times 10^{-34}/9.1 \times 10^{-31} \times 5.0 \times 10^{-11}$
$v = 1.5 \times 10^7$ (m $s^{-1}$)

**C1**
**A1**

2 $½mv^2 = eV$
$½ \times 9.1 \times 10^{-31} \times 2.25 \times 10^{14} = 1.6 \times 10^{-19}V$
$V = 6.4 \times 10^2$ (V)

*using 6.6 instead of 6.63 gives 1.45 × $10^7$*

*using v =1.45 × $10^7$ gives 600 V*

**C1**
**C1**
**A1**

**[8]**

**23.** (a) A (clean) zinc plate mounted on the cap of a gold-leaf electroscope.
Plate initially charged negatively
A u-v lamp shining on plate
The gold leaf collapses as the charge leaks away from the plate (when ultra-violet light is incident on the zinc plate)
so experiment indicates the emission of negative charge/electrons

*first 3 marks can be awarded from diagram or description*

*QWC mark*

**B1**
**B1**
**B1**
**B1**
**B1**

**Or** A simple photocell, eg two plates in a vacuum envelope
A (12 V) dc supply is connected to the photocell and (nano)ammeter.
A suitable frequency/u-v lamp shining on one plate

**B1**
**B1**
**B1**

The presence of u-v /blue light causes a current in the circuit.
so experiment indicates the emission of negative charge/electrons

***accept*** *photocell made of clean magnesium ribbon surrounded by fine copper gauze*
*first 3 marks can be awarded from diagram or description*
***ignore*** *polarity of supply*
*QWC mark*

**B1**
**B1**

**Or** A (potassium) photocell connected across a (high impedance) voltmeter.
Incident light of different frequencies;
produced either by white light source and colour filters of known spectral range or by using a diffraction grating or prism to produce a first order spectrum.
Different p.d.s are set up across the electrodes of the photocell (when the photocathode is illuminated with light of different frequencies).
so experiment indicates the emission of negative charge

*first 3 marks can be awarded from diagram or description*

*QWC mark*

**B1**
**B1**
**B1**
**B1**
**B1**

(b) Individual photons are absorbed by individual electrons in the metal surface.
These electrons must have absorbed sufficient energy to overcome the work function energy of the metal/to reach the minimum energy to release an electron from the surface **or** only photons with energies above the work function energy will cause photoelectron emission
Concept of instantaneous emission
Number of electrons emitted also depends on light intensity
Einstein's photoelectric energy equation in symbols
with symbols explained, ie (energy of photon) = (work function of metal) + (maximum possible kinetic energy of emitted electron)

***stop marking after the first five marking points, ie ticks and crosses***
***not** photons are absorbed by electrons; 1 to 1 relationship must be implied*
***accept** definition of work function energy*

*accept shorter λ/higher f photon causes higher (kinetic) energy electron*

***accept** full word equation without symbols for 2 marks*
*maximum 5 marks*

**B1**
**B1**
**B1**
**B1**
**B1**

**[10]**

**24.** (a) (i) Electrons in a metal B1

(ii) Ion in an electrolyte B1

| | | | | |
|---|---|---|---|---|
| (b) | **1.** $I = Q/t$ / $I = 650/5$ | | | C1 |
| | $I = 130$ (A) | | | A1 |
| | **2.** $n = I/e = 130/1.6 \times 10^{-19}$ | | | C1 |
| | $n = 8.1 \times 1020$ | | | A1 |

**[6]**

| | | | | |
|---|---|---|---|---|
| **25.** | (a) | (i) | Correctly selected and re-arranged: $\rho = RA/L$; | M1 |
| | | | symbols defined: $A$ = <u>cross-sectional</u> area, $R$ = resistance, $L$ = length | A1 |
| | | (ii) | $\rho$ is independent of dimensions of the specimen of the material/AW | B1 |
| | (b) | | $R = 1.7 \times 10^{-8} \times 0.08/3.0 \times 10^{-4}$ | C1 |
| | | | $R = 4.5(3)\ 10^{-6}$ (Ω) | A1 |

**[5]**

| | | | |
|---|---|---|---|
| **26.** | (i) | p.d.: energy transferred per unit charge from electrical form (into other forms, e.g. light/heat) | B1 |
| | | e.m.f.: energy transferred per unit charge into electrical form (from other forms, e.g. chemical/mechanical) | B1 |
| | (ii) | J $C^{-1}$ | B1 |

**[3]**

| | | |
|---|---|---|
| **27.** | (Sum of) e.m.f.s = sum /total of p.d.s/sum of voltages (in a loop) | B1 |
| | energy is conserved | B1 |

**[2]**

| | | | | | |
|---|---|---|---|---|---|
| **28.** | (a) | (i) | | any straight line of best fit judged by eye | B1 |
| | | (ii) | **1** | 6.0 ± 0.2 (V) /consistent with the y-intercept of their graph | B1 |
| | | | **2** | r = gradient / (ε – V)/ I / $V_{lost}$/ I | B1 |
| | | | | e.g. r = (6.0 – 0)/2.0 | M1 |
| | | | | r = 3.0 Ω | A1 |
| | (b) | (i) | | $I$ = 0.6 A and V = 4.2 V | B1 |
| | | | | $R = V/I = 7.0$ (Ω) | C1 |
| | | (ii) | | $R = 7.0$ (Ω) | A1 |
| | | | | $P = IV = 4.2 \times 0.6$ | C1 |
| | | | | $P = 2.5$ W | A1 |

**[10]**

| | | | | |
|---|---|---|---|---|
| **29.** | (a) | (i) | resistance decreases/falls/drops (with increase in temperature) | B1 |
| | | (ii) | $100 \pm 10\ \Omega$ | B1 |
| | | (iii) | for low temps $\Delta R$ is large for $\Delta\theta$ and at high temps $\Delta R$ is small for same $\Delta\theta$; so sensitivity decreases (continuously)from low to high temperatures | B1<br>B1 |
| | (b) | (i) | correct circuit symbol | B1 |
| | | (ii) | connections in parallel with fixed resistor B1 | B1 |
| | | (iii) | $R_{th} = 100$ to $105\ \Omega$<br>$R_{tot} = 200 + R_{th}$<br>$I = V/R_{tot} = 6/R_{tot}$ (= 0.02 A) | B1<br>M1<br>A1 |
| | | (iv) | (V = IR = 0.02 × 200) = 4.0 (V) | A1 |

**[10]**

| | | | |
|---|---|---|---|
| **30.** | (i) | basic potential divider argument<br>detail, e.g.with Rth about 100 Ω at 70°C then R must be 1000 Ω to achieve 0.5 V to 5.5 V ratio/AW | B1<br>B1 |
| | (ii) | advantage: (approx.) constant sensitivity/ linear (output)<br>disadvantage: less sensitive (over most of range)/range of voltages is small/battery lasts for less time | B1<br>B1 |

**[4]**

| | | | |
|---|---|---|---|
| **31.** | A: | gamma / γ (ray/radiation/wave)<br>$\lambda = 10^{-16}$ to $10^{-10}$ (m) | B1<br>B1 |
| | B: | infrared / IR / i.r.<br>$\lambda = 7 \times 10^{-7}$ to $10^{-3}$ (m) | B1<br>B1 |

**[4]**

**32.** Any **two** from:

travel at the speed of light/$3 \times 10^8$ (m $s^{-1}$) (in a vacuum)
can travel in a vacuum
consists of oscillating E- and B-fields
transverse waves/can be polarised
can be diffracted/reflected/refracted — B1 × 2

**[2]**

| | | | | | |
|---|---|---|---|---|---|
| **33.** | (i) | | plane polarised light vibrates (travels) <u>in one plane only</u> (look for reference to one plane of oscillation) | B1 | |
| | (ii) | | only transverse waves can be polarised/AW | B1 | |
| | | | sound waves are longitudinal/not transverse/AW | B1 | |
| | | | | | **[3]** |
| **34.** | (i) | | evidence of knowledge of: full/max transmission when the (transmission axis of) polarising sheet is parallel to the light's plane of polarisation/vibrations | B1 | |
| | | | no transmission when the (transmission axis of) polarising sheet is at right angles to light's plane of polarisation/vibrations | B1 | |
| | (ii) | | reflected light from surface is partially plane polarised | B1 | |
| | | | polarising sheet is placed at right angles to reflected light's polarisation plane/AW | B1 | |
| | | | | | **[4]** |
| **35.** | any valid example: e.g. radio waves, microwaves | | | M1 | |
| | valid method of detection: e.g. aerial (allow microwave detector) | | | A1 | |
| | | | | | **[2]** |
| **36.** | possible differences in amplitude/wavelength/phase/waveform/energy: | | | | |
| | As described for progressive wave | | | A1 | |
| | As described for standing wave | | | A1 | |
| | | | | | **[2]** |
| **37.** | (a) | (i) | correct standing wave drawn to top of end correction | B1 | |
| | | (ii) | all A and N labelled correctly | B1 | |
| | | (iii) | clear method showing $L_1 - L_2 = \lambda/2$ | B1 | |
| | | (iv) | $0.506 - 0.170 = \lambda/2$ ; $\lambda = 0.67(2)$ (m) | C1 | |
| | | | $v = 500 \times 0.672$ | C1 | |
| | | | $v = 336$ (m $s^{-1}$) (only accept 340 m s-1 if working shown) | A1 | |
| | (b) | | smaller wavelength | C1 | |
| | | | means smaller distances to measure | M1 | |
| | | | so less accuracy <u>in the measurements</u> /AW | A1 | |
| | | | Candidate's response shows steps in a logical order as above. | 1 | |
| | | | | | **[10]** |

**38.** when two waves meet/interfere (at a point)
the resultant displacement is the <u>sum</u> of individual <u>displacements</u>
(allow the resultant amplitude is the vector/phasor sum of the individual amplitudes) B1 B1

**[2]**

**39.** (a) (i) constant phase difference
(allow 1 mark for same phase difference or same frequency/wavelength) B2

(ii) path difference = $\lambda/2$ B1

(b) (i) evidence shown that fringe width $x$ = 8.0 mm B1
$a = \lambda D/x = 6.4 \times 10^{-7} \times 1.5/8.0 \times 10^{-3} = 1.2 \times 10^{-4}$ m C1
(give 2 marks for using $x$ = 4.0 mm giving $a = 2.4 \times 10^{-4}$ m) A1

(ii) maximum intensity when $y$ = 0 AND minima at +4 and –4 B1
correct repeat distance, i.e. 8.0 mm with at least 2 full cycles drawn B1

**[8]**

**40.** (a) quantum of energy / radiation / packet of energy B1

(b) (i) $f = E/h = 5.60 \times 10^{-19} / 6.63 \times 10^{-34}$ C1
$f = 8.45 \times 10^{14}$ (Hz) A1

(ii) **1** minimum energy to release an electron from the surface (of the metal) B1

**2** $5.60 \times 10^{-19} - 4.80 \times 10^{-19}$ (= $8.0 \times 10^{-20}$ J) B1

(iii) $8.0 \times 10^{-20} = ½(9.1 \times 10^{-31})v^2$ M1
giving $v = 4.2 \times 10^5$ (m s$^{-1}$) A1

(c) (i) Correct selection of: $\lambda = h/p$ or $\lambda = h/mv$ M1
where all symbols are defined A1

(ii) $\lambda = 6.6 \times 10^{-34} / (9.1 \times 10^{-31} \times 4.2 \times 10^5)$ C1
$\lambda = 1.7 \times 10^{-9}$ (m) A1

**[11]**

**41.** Any **Eleven** from:

| | |
|---|---|
| 1 kW h is the energy (transformed by) 1 kW (device) in a time of 1 hour | B1 |
| reference to E = Pt/1 kW h = 1000 × 3600 | B1 |
| 1 kW h = $3.6 \times 10^{6}$ (J) | B1 |
| 1 eV is the energy (transformed by an) electron travelling through a p.d. of 1 V | B1 |
| reference to E = VQ | B1 |
| 1 eV = $1.6 \times 10^{-19}$ (J) | B1 |
| kilowatt hour is useful when considering large amounts of energy/AW | B1 |
| electronvolt is useful when considering small amounts of energy/AW | B1 |
| eV for photons/in atomic physics/in nuclear physics | B1 |
| kW h for domestic use/electrical bills | B1 |
| energy of electron **or** lamp in joules ($1.6 \times 10^{-13}$ J and $4.3 \times 10^{6}$ J) (mark to be awarded only if E = Pt or E = VQ not credited) | B1 |
| filament lamp: 1.2 kW h | B1 |
| electron: 1.0 MeV | B1 |
| # Candidate must make specific links to how the size of these answers compare with the Joule. | 1 |

**[12]**

**42.** Any **two** from: B2

Travel through vacuum (allow 'free space')
Travel at the speed of light \ c \ 3 × 108 m s-1 (in vacuum)
Consist of oscillating electric and magnetic fields
They are all transverse waves \ can be polarised
Can be diffracted \ reflected \ refracted
Consist of photons

**[2]**

**43.** radio (waves); Infra-red \ ir; gamma \ γ (rays\waves\radiation) B3

**[3]**

**44.** Quantum of energy \ (electromagnetic) radiation \ light \ packet of energy B1
(Do not allow 'particle of light' – since in the stem of the question)

**[1]**

**45.** (a) $Q = It$ (Allow any subject) C1

$Q = 0.040 \times 5.0 \times 60 \times 60$ \ $Q = 0.040 \times 1.8 \times 10^4$

charge = 720 A1

($40 \times 5 = 200$ or $0.040 \times 5 = 0.02$ or $40 \times 1.8 \times 10^4 = 7.2 \times 10^5$ scores 1/2)

coulomb \ C \ As B1

(b) It is less because the average current is less \ area (under graph) is less \ current 'drops' after 3 hours. B1

**[4]**

**46.** Current is (directly) proportional to potential difference (for a metal conductor) M1

provided the temperature \ (all) physical condition(s) remains constant A1

**[2]**

**47.** (i) **M** marked at the end of the graph B1

(ii) current is 5 (A) and p.d is 6 (V) C1

$P = VI$ \ $p = 6.0 \times 5.0$

(Allow $p = I^2 R$ or $p = V^2$ \ $R$) C1

power = 30 (W) A1

(iii) **1.** $V_L = 1.0$ (V) (From the $I/V$ graph) \ $R_L = 1.0/2.0$ or 0.5 (Ω) M1

$V_R = 1.2 \times 2.0$ \ $R_T = 1.2 + 0.5$ M1

$V = 1.0 + 2.4$ \ $V = 1.7 \times 2.0$ A1

voltmeter reading = 3.4 (V) A0

**2.** Vr = 4.5 − 3.4 (= 1.1 V) \ 4.5 = 2.0r + 3.4 (Possible ecf) C1

$$r = \frac{1.1}{2.0}$$

r = 0.55 (Ω) (1.05 Ω scores 0/2 since the lamp is ignored) A1

**[9]**

**48.** (a) Ammeter in series B1

Voltmeter in parallel (across the ends of the wire) B1

(b) $\rho = \frac{RA}{L}$ (Allow any subject) M1

$R$ = resistance, $L$ = length and $A$ = (cross-sectional) area A1

($\rho$ = resistivity is given in the question)

Any **four** from:

Measure the length of the wire using a ruler B1

Measure the diameter of the wire B1

using a micrometer \ vernier (calliper) B1

Calculate the (cross-sectional) area using A = πr2 \ A = πd2/4 B1

Calculate the resistance (of the wire) using $R = \frac{V}{I}$ B1

Repeat experiment for different lengths \ current \ voltage \ diameter (to get an average) B1

Plot a graph of R against L. The gradient = ρ/A. B1

(Or Plot V against I. The gradient is ρL/A)

Structure and organisation. B1

Spelling and grammar. B1

**[10]**

**QWC**

The answer must involve physics, which attempts to answer the question.

**Structure and organisation**

Award this mark if the whole answer is well structured.

**Spelling and Grammar mark**

More than two spelling mistakes or more than two grammatical errors means the SPAG mark is lost.

**49.** (i) light-dependent resistor \ LDR B1

(ii) Resistance of **X** decreases (as light intensity is increased) B1
The current (in the circuit) increases B1

(iii) The current is halved. B1

**[4]**

**50.** total resistance of three in series = 6.0 (kΩ) C1

$\frac{1}{R} = \frac{1}{2} + \frac{1}{6}$ \ $R = \frac{2 \times 6}{2 + 6}$ C1

resistance = 1.5 (kΩ) A1

**[3]**

**51.** (i) p.d across 1.5 k Ω resistor = 5.0 – 1.2 = 3.8 (V) B1

(ii) $V = \frac{R_2}{R_1 + R_2} \times V_0$ \ $\frac{V_1}{R_1} = \frac{V_2}{R_2}$ \ current = 3.8/1.5 (= 2.53 mA) C1

$1.2 = \frac{R}{R + 1.5} \times 5.0$ \ $\frac{1.2}{R} = \frac{3.8}{1.5}$ \ $R = 1.2/2.53$ C1

R = 474 (Ω) ≈ 470 (Ω) A1

(Using 3.8 V instead of 1.2 V gives 4.75 kΩ - allow 2/3)

**[4]**

**52.** $\lambda = \frac{h}{mv}$ \ $\lambda = \frac{h}{p}$ M1

λ = wavelength, *m* = (particle) mass, *v* = speed \ velocity or *p* = momentum A1

The wavelength \ λ is a wave property B1

The mass \ *m* (or momentum \ *p*) is a particle property B1

**[4]**

**53.** (i) **1**. The <u>minimum frequency</u> (of radiation \ waves) needed for electrons to be released (from the metal surface) \ for photoelectric effect B1

**2**. Its temperature increases \ gets warm \ 'heats up' B1

(ii) *E* = 2.2 + 1.9 (= 4.1) C1

$E = 4.1 \times 1.6 \times 10^{-19} = 6.56 \times 10^{-19}$(J) C1

(Allow this mark for correct conversion of either 1.9 eV or 2.2 eV to joules)

$f = (\frac{6.56 \times 10^{14}}{6.63 \times 10^{-34}} =) 9.89 \times 10^{14} \approx 9.9 \times 10^{14}$ \ $\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{6.56 \times 10^{-19}}$ C1

$\lambda = 3.03 \times 10^{-7} \approx 3.0 \times 10^{-7}$(m)

(Allow 1 sf answer) A1

(Allow 3/4 marks for $\lambda = 4.85 \times 10^{-26}$ m when eV is not converted to joules)

**[6]**

**54.** (a) (i) amplitude = 3.75 cm {allow 3.7 to 3.8) B1

(ii) when t = 1.8 ms displacement = ANY negative value B1
(–)3.35 cm (ALLOW 3.3 TO 3.4) B1

(iii) period = 2.64 ms (allow 2.64 to 2.68) B1

(iv) frequency = 1/period C1
= 1/(2.64 × 10 – 3) = 379 Hz (379 to 373 or 380) {ecf for T} A1

(b) recall of v = fλ C1
λ = v/f = 300/379 = 0.79 m (or 0.8 m) {allow ecf from (iv)} A1

**[8]**

**55.** (i) ANY 3 correct phenomena from REFLECTION, REFRACTION, INTERFERENCE, SUPERPOSITION, DIFFRACTION, (allow transfer energy) B2

3 correct scores 2 marks, 2 correct scores 1 mark otherwise zero

(ii) POLARISATION B1

**[3]**

**56.** (i) it consists of nodes and antinodes / it does not transfer energy (WTTE) B1
formed by two identical waves travelling in opposite directions (WTTE) B1
(microwaves leaving transmitter) interfere (with reflected waves) (WTTE) B1
{allow superimpose/interact/cancel out/reinforce for interfere}

(ii) 1.wavelength of the microwaves = 2 × 1.4 = 2.8 cm B1

2. speed of microwaves in air = 3 × 108 m/s OR c M1
frequency = 3 × 108 /2.8 × 10 – 2 (allow ecf) = 1.07 × 1010 Hz A1

(iii) Place a metal grid {allow "Polaroid"} (between T and D) and rotate (or place at 900) OR rotate grid/transmitter/detector B1
this causes minm/zero signal (WTTE) B1

**[8]**

**57.** (a) (i) R = V / I = 6.0 / 8.2 × 10-6 = 7.32 × 105 Ω (1)
σ = 1 / ρ stated or implied (1)
= L / RA (1)
= 0.018 / (7.32 × 105 × 0.0075 × 0.0075) = 4.37 × $10^{-4}$ $\Omega^{-1}m^{-1}$ (1) 4

(ii) v = I / nAe = 8.2 × $10^{-6}$ / (2.1 × $10^{16}$ × 0.0075 × 0.0075 × 1.6 × $10^{-19}$) (1)
= 43.4 m $s^{-1}$ (1) 2

(b) (i) Charge carriers / electrons in the valence band are given more thermal energy; (1)
so more are able to cross the energy gap (into the conduction band). (1) 2

(ii) $\ln \dfrac{n^2}{2.1\times10^{16}} = 1.28\times10^4\left(\dfrac{1}{298}-\dfrac{1}{303}\right)$ (= 0.709) (1)

$\dfrac{n2}{2.1\times10^{16}}$ = 2.03 (1)

$n^2 = 4.27 \times 10^{16}\ m^{-1}$ (1) 3

(iii) (From I = nAve), with no change in drift velocity current would be 4.27 / 2.1
= 2.03 times bigger; (1)
For same current p.d. needs to be 6 / 2.03 = 2.95 V. (1) 2

**[13]**

**58.** (a) p.d. across electromagnet = 0.2 × 48 (1)
= 9.6 V (1) < 1% of 1200 V 2

(b) Cable resistance ≈ 1200 / 0.2 (1)
≈ 6000 Ω 1

(more precisely R = [1200 – 9.6] / 0.2 = 5952 Ω)

(c) Area of copper = ρ L / R (1)
$= 1.7 \times 10^{-8} \times 3000 \times 10^3 / 6000$ (1)
$= 8.5 \times 10^{-6}\ m^2$ (1)

Diameter = $\sqrt{(4 \times 8.5 \times 10^{-6} / \pi)}$ (1)
= 3.3 mm 4

(d) Mass of copper = $8930 \times 3000 \times 10^3 \times 8.5 \times 10^{-6}$ (1)
$= 2.28 \times 10^5$ kg (1) 2

(allow ecf using dia.. 3.5mm)

**[9]**

**59.** (a) (i) Q = It with knowledge of what the symbols mean (1)
= 0.050 × 4.0 × 3600 (1)
= 720 (C) (1) 3

(ii) E = QV with knowledge of what the symbols mean (1)
= 720 × 6.0 = 4320 (J) (1) 2

(b) chemical (potential) (energy) (1) 1

(c) (i) I = 4.0/48 = 0.5/r (ie by proportion or by finding current) (1)
r = 24/4 = 6 (Ω) (1) 2

(ii) E = V2t/R with knowledge of what the symbols mean (1)
= 4.02 × 2700 / 48 (1)
= 900 (J) (1) 3

(iii) 900/4320 = 5/24 = (0.208) (1) 1

(d) because the p.d. across it (4.5 – 4.0) is known only to 1 sig.fig. 1

**[13]**

**60.** diagram does not show the movement of particles (in direction across tube) (1)
distance across tube is a measure of the displacement of particles along tube (1)

**[2]**

**61.** on open circuit (infinite resistance so) current zero so V × I = 0 (1)
when shorted, resistance is zero so $I^2R$ is zero (1) 2

**[2]**

**62.** (a) speed = $3.00 \times 10^8$ (m $s^{-1}$) (1) 1

(b) (i) wavelength = eg 0.124(±0.002)/3 = 0.041 (m) (1) 1

(ii) frequency = c/λ = $3.00 \times 10^8$ / 0.041 (1)
= $7.3(2) \times 10^9$ Hertz or Hz (1) 2

(iii) allow microwaves or radio waves (1) 1

(c) (i) both 49 cm (1) 1

(ii) phase difference will be zero (1)
so amplitude of resultant wave will be a maximum (1) 2

(iii) DABC = 80 cm, DC = 18 cm (1) 1

(iv) path difference = 62 cm, which is 15½ wavelengths (1)
so waves arrive (π radians) out of phase (1)
so cancellation (may) take(s) place (1) 3

(v) large signal from transmitter would swamp (reflected) weak signals (1)
unless they arrived at different times (1)
this cancels out the strong signal (1)
but allows the weak signal through (1)
strong signal could damage the receiver (1) 3
*MAXIMUM 3*

**[15]**

**63.** Finite resistance at 0° C B1
Resistance increases B1

**[2]**

**64.** (i) Any <u>four</u> from:

1. The resistance of the <u>thermistor</u> decreases (as temperature is increased) B1
2. The <u>total</u> resistance (of circuit) decreases B1
3. The voltmeter reading increases B1
4. Explanation of 3. above in terms of 'sharing voltage' / $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ / $V = \frac{R_2}{R_1 + R_2} \times V_0$ B1
5. The current increases / ammeter reading increases B1
6. Explanation of current increase in terms of $I = \frac{V}{R_{total}}$ B1

(Allow ecf for statements 3. and 5. if statement 1. is incorrect – maximum score of 2/4)

(ii) $I = \frac{3.6}{1200} (= 3.0 x 10^{-3})$ / $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ / $V = \frac{R_2}{R_1 + R_2} \times V_0$ C1

$R = \frac{1.4}{3.0 \times 10^{-3}}$ / $\frac{R}{1200} = \frac{1.4}{3.6}$ / $1.4 = \frac{R}{R + 1200} \times 5.0$ C1

R = 467 (Ω) ≈ 470 (Ω) A1

(When 1.4 V and 3.6 V are interchanged, then $R = 3.1 \times 10^3$ (Ω) can score2/3)

(Calculation of total circuit resistance of $1.67 \times 10^3$ (Ω) can score 2/3)

(Use of $I = \frac{5.0}{1200}$ scores 0/3)

**[7]**

**65.** (a) (Semiconductor) diode B1

(b) The diode symbol circled (No ecf allowed) B1

(c) $R = \frac{V}{I}$ C1

At 0.20 V, R = infinite / <u>very</u> large A1

At 0.70 V, $R = (\frac{0.70}{0.020} =) 35 (\Omega)$ (Allow answers in the range: {31.82 to 38.89}) A1

(d) p.d across diode = 0.75 (V) / $(R_t = \frac{4.5}{0.060} =)\ 75\ (\Omega)$ C1

p.d across resistor = 4.5 – 0.75 = 3.75 (V) / $(R_d = \frac{0.75}{0.060} =) 12.5 (\Omega)$ C1

$R = (\frac{3.75}{0.060} = 62.5 \approx) 63 (\Omega)$ / $R$ = (75 – 12.5 = 62.5≈) 63 (Ω) A1

(Use of 0.70 V across the diode gives $R$ = 63.3Ω - This can score 2/3)

(e) Straight line through the origin M1
Line of correct gradient (with line passing through 0.63 V, 0.01 A)
[Possible ecf] A1

**[10]**

**66.** Electromotive force /e.m.f. B1

**[1]**

**67.** ohm / (1) Ω B1

**[1]**

**68.** Coulomb / C B1

**[1]**

**69.** The sum of the currents entering a point / junction is equal to the sum of the currents leaving (the same point) Or 'Algebraic sum of currents at a point = 0' B2
(–1 for the omission of 'sum' and -1 for omission of 'point'/ 'junction')
(Do not allow $I_1 + I_2 = I_3 + I_4$ unless fully explained)

**[2]**

**70.** (i) $S_2$ closed and $S_1$ open. B1

(ii) $R = \dfrac{\rho L}{A}$ (Allow any subject) C1

$\rho = \dfrac{RA}{L} = \dfrac{4.0 \times 2.3 \times 10^{-8}}{0.15}$ C1

$\rho = 6.133 \times 10^{-7} \approx 6.1 \times 10^{-7}$ (Answer of $6.1 \times 10^{-9}$ can score 2/3) A1

unit: Ω m B1

(iii) **1** $\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$ / $R = \dfrac{R_1 R_2}{R_1 + R_2}$ C1

resistance of parallel combination $= \dfrac{12 \times 4.0}{12 + 4.0} = 3.0$ (Allow 1 SF) C1

total resistance = 8.0 + 3.0 = 11 (Ω) A1

**2** $P = \dfrac{V^2}{R}$ / $I = 4.5/11\ (= 0.4091A)$ C1

$P = \dfrac{4.5^2}{11}$ / $P = 0.4091^2 \times 11$ or $P = 4.5 \times 0.4091$ C1

P = 1.84 ≈ 1.8(W) (Possible ecf from (iii)1.) A1

**3** $\text{ratio} = (\dfrac{V/12}{V/4.0} = \dfrac{4.0}{12} =)0.33$ / $\text{ratio} = \dfrac{1}{3}/1:3$ B1

**[12]**

**71.** (i) particle / particulate / quantum / photon B1

(ii) wave B1

**[2]**

**72.** Any three from points 1 to 6:

1. Photon mentioned B1
2. Surface electrons are involved B1
3. A single photon interacts with a single electron B1
4. Energy is conserved in the interaction between photon and electron B1
5. $hf = \phi + KE_{(\max)}$ M1
6. $hf$ is the energy of the photon, $\phi$ is the work function (energy) and $KE_{(\max)}$ is the (maximum) kinetic energy of the electron. A1

The frequency of blue light is greater than the red light / the wavelength of blue light is shorter than the red light (ora) B1

The photon of blue light has energy greater than the work function energy / the frequency of blue light is greater than the threshold frequency (ora) B1

Intensity does not change the energy of a photon B1

**QWC**

The answer must involve physics, which attempts to answer the question.

**Structure and organisation -**

Award this mark if the whole answer is well structured. B1

**Spelling and Grammar mark -**

More than two spelling mistakes or more than two grammatical errors means the SPAG mark is lost. B1

**[8]**

**73.** (i) $E = 2.0 \times 1.6 \times 10^{-19}$ (= $3.2 \times 10^{-19}$ J) C1

$E = hf$ / $E = \dfrac{hc}{\lambda}$ / $f = \dfrac{3.2\times10^{-19}}{6.63\times10^{-34}} (= 4.83\times10^{14}\ Hz))$

$\lambda = \dfrac{6.63\times10^{-34}\times3.0\,x10^{8}}{3.2\times10^{-19}}$ / $\lambda = \dfrac{3.0\times10^{8}}{4.83\times10^{14}}$ C1

$\lambda = 6.22 \times 10^{-7}$ (m) $\approx 6.2 \times 10^{-7}$ (m) A0

(ii) visible / 'red' (Allow: 'light') (No ecf allowed) B1

**[3]**

**74.** gradient = $5.6(7) \times 10^{-8}$ (Allow range: $5.5 \times 10^{-8}$ to $5.9 \times 10^{-8}$) B1

$gradient = \frac{h}{m}$ / $m = \frac{6.63\times10^{-34}}{(\text{value of }\lambda)\times(value\ of\ v^{-1})^{-1}}$ C1

$m = \frac{6.63\times10^{-34}}{5.67\times10^{-8}} = 1.1(7)\times10^{-26}\,(Kg)$ / $m$ in the range: $1.1 \times 10^{-26}$ to $1.2 \times 10^{-26}$ (Kg) A1

(Possible ecf for the last two marks)

(The $10^{-4}$ factor is not very clear on the $v^{-1}$ axis; therefore allow **full credit** for using $10^{4}$. This gives a gradient of $5.7 \times 10^{-16}$ and mass $m$ of $1.17 \times 10^{-18}$ kg)

**[3]**

**75.** (a) (i) (***f***) vibrations/waves/wavelengths/cycles per second/unit time B1

(ii) (ii) (**$\lambda$**) distance between neighbouring crests/troughs/pts in phase (WTTE) B1

{idea of **minimum** distance is essential i.e. look <u>next</u> or equivalent word; <u>allow diagrams</u> but <u>do not allow</u> "length of a wave"}

(b) $\boldsymbol{v = f\lambda}$ B1

ANY VALID AND CONVINCING justification B1

e.g. <u>distance travelled in one second</u> (v) = ***f*** (waves) × $\lambda$ (length of each wave)
{**most** will probably **not score** this additional mark}

**[4]**

**76.** Any 2 differences, e.g.: light is transverse (sound is longitudinal) B2
light travels in vacuum (sound cannot) OR light can be polarised (sound cannot);
$\lambda$ is bigger for sound than light OR f is smaller for sound than light
{N.B. maximum of 1 mark if <u>anything</u> is incorrect}

**[2]**

**77.** (i) (wave sources have) **<u>constant phase difference</u>** (WTTE) B1
{do not allow "in phase" but accept "same phase difference"}

(ii) difference in length between detector and each wave source (WTTE) B1

**[2]**

**78.** (i) **1.** path diff. = $n\lambda$ (where n = 0,1,2 etc) {allow 0, OR $\lambda$, OR $2\lambda$ etc} B1

**2.** path diff = $(n + ½)\lambda$ (where n = 0,1,etc) {allow = $0.5\lambda$ OR,$1.5\lambda$, etc} B1

{do not allow answers purely about phase diff. e.g. with degrees or $\pi$ used and no ref to $\lambda$}

(ii) recall of formula $\lambda$ **= ax/D** C1

correct substitution for a, $\lambda$ and D: e.g. $x = (4.86 \times 10^{-7} \times 2)/0.5 \times 10^{-3}$ C1

$\mathbf{x = 1.94 \times 10^{-3}}$ **m** (1.9 or 1.944) A1

(iii) <u>**central white**</u> fringe B1

other fringes are <u>**coloured**</u> (WTTE: e.g. allow spectrum formed) B1

**[7]**

**79.** (a) ANY **2 points** made from the following: B2

- reference to nodes AND antinodes OR constructive AND destructive interference
- correct link for either antinodes with constructive OR nodes with destructive
- (meeting/superposing) waves must be COHERENT (allow "in phase" )

(b) <u>**two**</u> antinodes labelled (with **A**) at centres of hot zones (<u>please look closely</u>!) B1

{N.B. two or more correct scores 1, any incorrect scores zero),

(c) recall of speed of microwaves = $\mathbf{3 \times 10^8}$ (m/s) B1

correct substitution: e.g. $\lambda = v/f = 3 \times 10^8 / 2.45 \times 10^9$ C1

$\lambda = 1.22 \times 10^{-1}$ m = **0.122 m** A1

**[6]**

**80.** (i)

- $10 \times 3 \times 5000$ (= 150000) (1)
- $(150000) \times 100 / 85$ (1)
- $= 1.8 \times 10^5$ (1) 3

(ii)

- $E = h c / \lambda$ (1)
- $E = 6.6 \times 10^{-34} \times 3 \times 10^8 / 4.0 \times 10^{-7} = 4.95 \times 10^{-19}$ J (1)
  $1.8 \times 10^5 \times 4.95 \times 10^{-19}$
- $= 8.9 \times 10^{-14}$ W (1) ecf (i) 3

**[6]**

**81.** Electrons have high speed random motion; (1)
r.m.s. speed defined / linked to random motion; (1)
Electrons make (random) collisions with atoms; (1)
Slower speed motion in opposite direction to current / towards + terminal; (1)
This motion superimposed on the random motion; (1)
Drift velocity is the <u>mean / average</u> (resultant) velocity (of the free electrons)(1) max 4

**[4]**

**82.** (a) DO NOT allow answers which answer the question "Why are power stations near coal mines"
e.g. infra structure in place
cost of re-location 2

(b) e.g pollution – dirty atmosphere
smell – cleaning gases still leads to an acidic smell
noise – running day and night
(1) for each fact × 2 + (1) for valid comment 4

(c) plenty of cooling water available 1

(d) (i) knowledgeable use of P = V × I (1)
= 11 000 V × 800 A
= 8 800 000 (W) (1) 2

(ii) knowledgeable use of V = I × R (1)
= 800 × 5 = 4000 (V) (1) 2

(iii) 11 000 – 4000 = 7000 (V) 1

(iv) 7000 V × 800 A (1)
= 5 600 000 (W) (1) 2

(v) 5.6 MW / 8.8 MW OR 7000 V / 11 000 V (1)
= 0.64 = 64% (1) 2

(e) working from power lost in the cables (1)
power of 2 MW lost in 5 Ω (1)
$2 \times 10^6 = I^2 \times 5$  $I = \sqrt{400\,000} = 632$ A (1)
Allow the following (2) marks as e.c.f from incorrect current
$1.0 \times 10^8 = V \times 632$ (1)
$V = 1.0 \times 10^8 / 632 = 158\,000$ V (1) — 5

**[21]**

**83.** (a) one (or more) electrons removed (or added) to an atom — 1

(b) $E = hf = hc/\lambda$ together with knowledge of symbol meaning (1)
$= \dfrac{6.63\times10^{-34} \times 3.00\times10^{8}}{238\times10^{-9}}$ (1)
$= 8.36 \times 10^{-19}$ (J) (1) — 3

(c) frequency of UV is greater than frequency of light
OR alternative statement in terms of wavelength.
so photon energy of visible light is less than photon energy of UV (1)
PLUS one of the idea of conservation of energy
it is not possible for a low energy photon to give a high energy photon
this is a one to one process (1) — 2

(d) $E = V/d$ and power of 10 correct for d (1)
= 30/0.00020 = 150 000 (1)
V $m^{-1}$ (1) — 3

**[9]**

**84.** (a) Voltmeter connected in parallel with **X** — B1
(b) Same reading / no effect / no change — B1
(c) (i) LDR / light-dependent resistor — B1
(ii) The resistance decreases (as the intensity of light increases) — B1
(iii) $3.5 - 4.0 \times 10^{-7}$ (m) (to) $6.5 - 7.5 \times 10^{-7}$ (m) — B1

(d) (i) $R = \frac{V}{I}$ / $R = \frac{1.8}{4.8(\times 10^{-3})}$ C1

resistance = 375 ≈ 380 (Ω) A1

(ii) 1 $Q = It$ (Allow with or without the Δ notation) C1

$Q = 4.8 \times 10^{-3} \times 30$ C1

charge = 0.144 ≈ 0.14 (C) A1

2 $W = VQ$ / $W = VIt$ C1

$W = 1.8 \times 0.144$ / $W = 1.8 \times 4.8 \times 10^{-3} \times 30$

energy = 0.259 ≈ 0.26 (Possible ecf) A1

unit: joule / J / VC /VAs B1

(Allow 1/3 if power is 0.0086 (W))

**[13]**

**85.** (a) Kirchhoff's second B1

(b) Ohm's B1

(c) Resistance B1

(d) Electronvolt (Allow eV) B1

**[4]**

**86.** (a) (i) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ / $R = \frac{R_1 R_2}{R_1 + R_2}$ C1

$\frac{1}{R} = \frac{1}{20} + \frac{1}{30}$ / $R = \frac{20 \times 30}{20 + 30}$

resistance = 12 (Ω) A1

(ii) $R = 10 + 12$

resistance = 22 (Ω) (Possible ecf) B1

(b) $R = 10$ (Ω) / Resistance between B and C = 0 M1

$I = \frac{5.0}{10}$

reading = 0.5 (A) A1

**[5]**

**87.** Any <u>four</u> from: B1 × 4

1. (As temperature increases) the resistance of the thermistor / **T** decreases
2. The total resistance decreases (Possible ecf)
3. The current increases (in the circuit) (Possible ecf)
4. The (voltmeter) reading increases / voltage across **R** increases (Possible ecf)
5. The voltage across the thermistor / **T** decreases (Possible ecf)
6. Correct use of the potential divider equation / comment on the 'sharing' of voltage / correct use of $V = IR$

**[4]**

**88.** (a) $R = \frac{pL}{A}$ (Allow any subject) B1

(b) The resistance decreases M1

by a factor of four (because resistance is inversely proportional to radius$^2$) A1

**[3]**

**89.** (i) $2200 = \frac{3.5\times10^{-5} \times 1.3\times10^{-2}}{A}$ / $A = \frac{\rho L}{R}$ C1

$(A =)\ \frac{3.5\times10^{-5} \times 1.3\times10^{-2}}{2200}$ C1

($A$ = ) $2.07 \times 10^{-10}$ (m2) ≈ $2 \times 10^{-10}$ (m$^2$) A0

(ii) $P = I^2R$ / $P = VI$ <u>and</u> $V = IR$ C1

$0.50 = I^2 \times 2200$ C1

current = 0.015 (A) A1

($2.23 \times 10^{-4}$ scores 2/3 – answer not square rooted)

**[5]**

**90.** *Electromagnetic waves - Any two from:* B1 × 2

1. EM wave / light behave like 'particle'/ photon / quantum of energy
2. $E = hf$ / $E = hc/\lambda$
3. $E$ is the energy of photon and $f$ is the frequency (of EM waves) / $\lambda$ is the wavelength

*Moving electrons - Any four from:* B1 × 4

4. Moving / travelling particle / electron behaves like a wave
5. Mention of the de Broglie (equation)
6. $\lambda = \dfrac{h}{mv}$
7. $\lambda$ is the wavelength of particle/electron, $m$ is the mass (of particle) and v is speed
8. Electrons can be diffracted (Can score on diagram)
9. Electrons travelling through matter /graphite (show diffraction effects) (Can score on diagram if not scored in 8 above)
10. Electrons diffract because their wavelength is comparable to the size of atoms /gap between atoms (Do not allow 'particles in place of atoms)

**QWC** Spelling, punctuation and grammar B1
Organisation B1

**[8]**

**91.** (i) The minimum frequency needed to free an electron (from the surface of a metal) B1

(ii)1 Line extended intersects (the $f$ axis at) this value / At this frequency, $E_k = 0$ B1

(ii)2 ($\phi =$ ) $h \times 5.0 \times 10^{14}$ / ($\phi =$ ) $6.63 \times 10^{-34} \times 5.0 \times 10^{14}$ C1

work function energy = $3.3 \times 10^{-19}$ J A1

(iii)1 1 The gradient / slope of the line is the same B1

The gradient is equal to $h$ / independent of the metal B1

(iii)2 The line is shifted to the right B1

The threshold frequency is greater (AW) B1

**[8]**

**92.** (i) wave sources that have a constant phase difference (WTTE) B2
{max of 1 mark for sources have same frequency/wavelength/in phase C1}

(ii) sum of displacements (= resultant displacement) (WTTE) B1
(no marks for reference to amplitude)

**[3]**

**93.** (i) constructive interference/waves in phase for maxima
OR destructive interference/waves 'out of phase' — C1
maxima produced when path difference is 0 OR n$\lambda$ (WTTE) — A1
minima produced when path difference is (n+1/2) $\lambda$ (WTTE) — A1

NB answers that do not account for SERIES of both maxima and minima can score maximum of 2 marks only)

(ii) recall of $x = \lambda D/a$ — C1
{expressed in any form; allow unusual symbols if correctly identified}
correct substitution: $x = (3.0 \times 50)/6$ — A1
$x = 25$ cm — A1

(iii) microwaves vibrate/oscillate/displaced in one plane (WTTE) — B1
{do not allow travel/propagate in one plane)
signal decreases to zero (WTTE) — B1

**[8]**

**94.** (a) waves (travel out from centre and) are reflected (WTTE) — B1
interference/superpositioning occurs (WTTE) — B1

(b) correct shape drawn — M1
N labelled at both ends and A in the middle — A1

(c) wavelength = 0.5 × 2 = 1.0m {allow ecf from (b)} — B1

**[5]**

**95.** the spreading out (WTTE) of waves — B1
(reject bending/change in direction)
when they pass through a gap OR pass a barrier edge — B1

**[2]**

**96.** (i) semicircular wavefronts leaving the gap — B1
no change in wavelength stated OR
clearly shown (at least 3 waves needed) – judged by eye — B1

(ii) LESS diffraction would occur – shown or stated — B1
wavefronts mainly plane (by eye) (allow curved at edges) — B1

(iii) MORE diffraction for SOUND — B1
Wavelength of sound > wavelength of light (WTTE) — B1
Valid comparison of wavelength of light or sound with doorway e.g.
doorway of similar size to wavelength of sound OR
wavelength of light is very small compared to door (WTTE) — B1

**[7]**

**97.** (a) 29; 34 — 2

(b) $\lambda = 0.693/T = 0.693/(120 \times 3.2 \times 10^7) = (1.8 \times 10^{-10}\ s^{-1})$ *accept ln 2* 1

(c) (i) $Q = CV = 1.2 \times 10^{-12} \times 90$; evidence of calculation $(= 1.1 \times 10^{-10}\ C)$ 2

(ii) $n = Q/e = 1.1 \times 10^{-10}/1.6 \times 10^{-19}$; $= 6.9 \times 10^8$ *allow sig. fig. variations* 2

(iii) $A = \lambda N$; $N = 6.9 \times 10^8/1.8 \times 10^{-10}$; $= 3.8 \times 10^{18}$ *using 7.0 gives 3.9* 3

(iv) 1 y is less than 1% of 120 y so expect to be within 1%/
using $e^{-\lambda t}$ gives exactly 1% fall/ problem of random emission
or other relevant statement 1

**[11]**

**98.** (a) *either* (If in parallel) when one bulb fails, other bulbs stay on
*or* (If in parallel) can identify which bulb has failed; (1) 1

(b) (i) $P = VI$ (1)
$0.5 = 240\ I$
$I = 2.1 \times 10^{-3}$ A *1 s.f. in answer (–1) once only* (1) 2

(ii) $R = V/I$ (1)
$= 240/(2.1 \times 10^{-3})$
$= 1.14 \times 10^5\ \Omega$ or $1.15 \times 10^5\ \Omega$ *ans*
*accept (1.1 to 1.2)* $\times 10^5\ \Omega$. (1) 2

(iii) $A = \rho\ l\ /\ R$ (1)
$= 1.1 \times 10^{-6} \times 6.0 \times 10^{-3} / (1.14 \times 10^5)$ $(= 5.79 \times 10^{-14}\ m^2)$
$A = \pi r^2$ (1)
$5.79 \times 10^{-14} = \pi r^2$ so $r = 1.4 \times 10^{-7}$ m (1) 3

(iv) filament too thin / fragile to be manufactured / used without damage;
allow ecf from (iii). (1) 1

(c) **P**: 0 V **Q**: 0 V; (1)
**R**: 240 V **S**: 240 V (1)

current is zero (1)
p.d. across (any intact) bulb becomes zero (1)
so all 240 V across Y (1) *any 2* 4

(d) (i) *either* set B bulb(s) have less resistance (than set A bulbs)
*or* adding (each) set B bulb lowers circuit resistance; (1)

*either* so current increases (when set B bulb inserted)
*or* p.d. across (each) bulb increases
*or* any valid argument using $V^2 / R$; (1)

so power dissipation (in any bulb) increases; (1) 3

(ii) set A bulbs fail first; (1)

Then
*either* Failure current for set A bulb $I_f = \sqrt{P/R} = \sqrt{0.75/200} = 0.0612$ A; (1)
When failure occurs total resistance of set = 240 / 0.0612 (= 3920); (1)
Let X be number of 50 Ω bulbs substituted
3920 = 50X + 200(24 – X); (1)
so X = 5.87 bulbs, so 5 or 6 bulbs;

*or* Total initial resistance = 24 × 200 = 4800 Ω
After substituting X set B bulbs, resistance = 4800 – 150 X (1)
Current = 240/(4800 – 150 X) (1)
So power in a set A bulb,
$P = I^2 R = [240/(4800 - 150 X)]^2 \times 200 = 0.75$ for failure (1)
This gives X = 5.87 i.e. 5 or 6 bulbs (1) 4

**[20]**

**99.** (a) In the dark few electrons in the conduction band; (1)
In daylight light photons provide energy; (1)
to promote (many) more electrons from valence band to conduction band; (1)
High / low resistance related to few / many conduction band electrons. (1) 4

(b) (i) Circuit with battery connected to LDR; (1)
Ammeter and voltmeter correctly connected. (1) 2

(ii) Control and measurement of light intensity:
Arrangement to shield LDR from light from unwanted sources /
Carry out experiment in darkened room; (1)
Use constant light source placed at variable distance from LDR /
Use light source of variable power at fixed distance from LDR; (1)
with light meter to record light intensity at position of LDR. (1)

Ranges of meters:
Voltmeter with range applicable to battery voltage / say 0 - 10 V scale; (1)
For maximum light conditions use milliammeter; (1)
and for minimum light conditions use microammeter. (1)
OR
Reference to multimeter to read current (1) with appropriate
change of scale.
Readings and calculations:
For each position of light source / power value of light source, measure
(and record) readings from light meter; (1)
Read (and record) readings from voltmeter and ammeter and calculate
resistance using R = V/I. (1) 8

**[14]**

**100.** (i) Correct direction shown (anticlockwise) B1

(ii) Direction in which positive charges / ions move / Direction / flow / current / from positive to negative / Flow of (positive) charge from positive to negative / Direction / flow opposite to electron flow B1

(iii) $Q = It$ (Allow any subject with or without delta notation) C1

$I = \dfrac{0.76}{5.0 \times 60}$ C1

current = $2.53 \times 10^{-3}$ (A) $\approx 2.5 \times 10^{-3}$ (A) A1
(0.152 / 0.15 (A) scores 1/3)

**[5]**

**101.** Any <u>three</u> properties from: (–1 for each error or contradiction) B1 × 3

1. Travel at the speed of light / $c$ / $3 \times 10^8$ <u>m s$^{-1}$</u> (NOT 'same speed')
2. Travel through vacuum / 'free space'
3. Have oscillating electric <u>and</u> magnetic fields
4. They are (all) transverse waves / can be polarised
5. Allow: 'They show diffraction / reflection / refraction / interference'
6. Allow: 'Consist of photons'

Any <u>three</u> regions from the list below: B1 × 3

Gamma (rays / radiation) / $\gamma$ (rays) ; X-rays ; u.v ; ir ; microwaves ; radio waves (NOT 'radio')

<u>One</u> suitable application for the opted region. B1

(E.g.: Gamma rays for radiotherapy / sterilisation;
X-rays for taking pictures of skeleton / bones; u.v for tanning; ir for TV remote control; microwaves for cooking / mobile phones; radio waves for communication)

(Note: Reference to alpha, beta and gamma can only score the last marking point)

**[7]**

**102.** (a) current $\propto$ p.d / voltage (for a metallic conductor) M1
as long as temperature is constant / physical conditions remain constant A1

(b) (i) $(R =)\ \dfrac{0.15}{4.3}$ (= 0.0349) B1

(ii) $R = \dfrac{\rho L}{A}$ (Allow any subject) C1

$\rho = \dfrac{RA}{L} = \dfrac{0.035\times(0.012\times0.012)}{0.09}$ C1

resistivity = $5.6 \times 10^{-5}$ A1

unit: ohm metre / Ω m (Allow V m A$^{-1}$) A1

($5.6 \times 10^{-n}$ without unit or incorrect unit and n ≠ 5 or 3 – can score 2/4)
($5.6 \times 10^{-3}$ Ω m – can score 3/4)
($5.6 \times 10^{-3}$ Ω cm – can score 4/4)

**[7]**

**103.** (a) Parallel B1

(b) (i) $I = \frac{12}{8.0}$ C1

current = 1.5 (A) A1

(ii) $P = \frac{V^2}{R}$ / $P = IV$ $P = I^2 R$ C1

$P = \frac{12^2}{8}$ / $P = 1.5 \times 12$ $P\ 1.5^2 \times 8.0$ (Possible ecf) C1

power = 18 (W) A1

(iii) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + (\frac{1}{R_3})$ / $\frac{1}{R} = \frac{1}{8} + \frac{1}{8} + \frac{1}{8}$ C1

$\frac{1}{R} = 3 \times \frac{1}{8}$ C1

resistance = 2.67 ≈ 2.7 (Ω) (Allow answer expressed as 8/3) A1
(0.375 or 3/8 scores 2/3)

(iv) energy = 0.018 × 12 × 3 C1
energy = 0.648 ≈ 0.65 (kW h) (Possible ecf) A1
(0.22 (kW h) scores 1/2)
(648 (kW h) scores 1/2)
($2.3 \times 10^6$ (J) scores 1/2)

(c) It will be brighter B1
The current is larger / correct reference to: $P \propto 1 / R$ B1

**[13]**

**104.** current <u>and</u> current B1

**[1]**

**105.** energy B1

**[1]**

**106.** (i) (NTC) thermistor — B1

(ii) Resistance decreases when temperature is increased. (ora) — B1
(Allow correct credit for a PTC thermistor)

(iii) 1 $I$ = (0.032-0.006 =) 0.026 (A) — B1

2 ($V_{200}$ = 0.026 × 200 =) 5.2 (V) / ($V_{720}$ = 0.006 × 700 =) 4.2 (V) — C1
$E$ = 5.2 – 4.2 (Allow $E$ = 4.2 – 5.2) — C1
$E$ = 1.0 (V) (Allow 1 sf answer) — A1
(9.4 (V) scores 1/3)

**[6]**

**107.** Maximum of <u>three</u> from points 1 to 6: — B1 × 3

1. Photon mentioned (e.g.: photons interact with the surface electrons)
2. Energy is conserved (between the photon and the electron / in the interaction)
3. $hf = \phi + KE_{(max)}$
4. A single photon interacts with a single electron / It is a one-to-one interaction
5. Electron is removed when photon energy is greater than / equal to the work function (energy) / $\phi$ (Allow ora)
6. Electron removed when frequency is greater than / equal to the threshold frequency (Allow ora)
7. (Visible) <u>light</u> has lower frequency than the threshold frequency / Energy of (visible) <u>light</u> photon is less than the work function (energy) (ora with <u>uv</u>) — B1
8. Greater intensity of (visible) <u>light</u> means more photons (per unit time) / energy of a photon remains the same — B1

QWC Spelling, punctuation and grammar — B1
Organisation — B1

**[7]**

**108.** (i) kinetic energy = 1.5 × 1.6 × $10^{-19}$ — C1
kinetic energy = 2.4 × $10^{-19}$ (J) — A1

(ii) $E = hf$ / $E = \frac{hc}{\lambda}$ / $f$ = 7.69 × $10^{14}$ (Hz) / ($E$ =) 5.1 × $10^{-19}$ (J) — C1

$\phi$ = 5.1 × $10^{-19}$ – 2.4 × $10^{-19}$ (Possible ecf) — C1

work function energy = 2.7 × $10^{-19}$ (J) — A1

**[5]**

**109.** ✓

✓

✗

✗

(Four correct: 3 marks, three correct: 2 marks, two correct: 1 mark) B3

**[3]**

**110.** $\lambda = \frac{h}{mv}$ / $\lambda = \frac{h}{p}$ (Any subject) C1

$v = \frac{6.63\times10^{-34}}{6.8\times10^{-11}\times2.0\times10^{-26}}$ C1

speed = 490 (m $s^{-1}$) A1

**[3]**

**111.** Maximum of 2 marks for correctly identifying the 4 errors OR stating the 2 correct notes:
i.e. errors in notes 1, 2, 3, and 6 (shown anywhere) B2
{5 or 6 or 2 or 1 notes nominated scores ZERO, 4 correct scores 2, 3 correct scores 1}

Valid corrections score 1 mark each: do not allow "NOT" corrections apart from note 3

Note 1: In longitudinal waves vibrations are parallel to wave direction (WTTE) B1
{OR in transverse waves vibrations are perpendicular to wave direction (WTTE}

Note 2 light (or any of the em waves) can travel through a vacuum (WTTE) B1
{allow sound/longitudinal waves cannot travel thro' a vacuum}

Note 3: waves carry energy/disturbance (not displacement or info) from…. (WTTE) B1
{allow "waves do not carry the medium" and "the medium carries the waves from……."}

Note 6: wavelength = distance from crest to crest/trough to trough/max to max (WTTE) B1

**[6]**

**112.** diagram showing
laser/light source placed directly behind double slit AND screen placed in front of slits B1
{single slit NOT required; no labelling required}
(i) *D*: allow any value between 30cm and 10m B1
(ii) a: allow any value between 0.1mm and 2mm B1

**[3]**

**113.** (a) (i) evidence of good practice: i.e distance for nx measured e.g.
5x = 18mm C1
x = 3.6 mm (OR 3.5 OR 3.7) A1
{x = 3.4, 3.8, 3.9, 4.0, or 4 mm, implying × is directly measured, and score 1 mark)
(ii) for O path difference = 0 B1
for A path difference = 3(λ) B1
for B path difference = 1.5(λ) B1

(b) recall of λ= ax/D OR × =λD/a OR × ∝ λ B1
λ is smaller for blue light (than red light) hence × is SMALLER (WTTE) B1

**[7]**

**114.** ANY valid differences: e.g.
Sound is longitudinal (light is not) OR light is transverse (sound is not) B1 + B1
OR sound waves have longer wavelengths' OR sound travels much slower
Light can be polarised (sound cannot)
Light can travel though a vacuum, (sound cannot)

**[2]**

**115.** circular arcs (penalise anything flat) B1
same constant wavelength before and after gap – judged by eye or labelled B1
this means at least <u>3 wavefronts need to be drawn</u>

**[2]**

**116.** for noticeable diffraction λ≈ gap size (WTTE) B1
λ for sound much bigger than for light (WTTE) B1

**[2]**

**117.** (a) Positive as E-field is downwards/top plate is positive/like charges repel/AW (1) 1

(b) (i) k.e. = QV; = $300 \times 1.6 \times 10^{-19}$ = ($4.8 \times 10^{-17}$ J) (2) 2

(ii) $1/2mv^2 = 4.8 \times 10^{-17}$; = $0.5 \times 2.3 \times 10^{-26} \times v^2$ so $v^2 = 4.17 \times 10^9$;
(giving $v = 6.46 \times 10^4$ m $s^{-1}$) (2) 2

(c) E = V/d; so d = V/E = $600/4 \times 10^4$ = 0.015 m (2) 2

(d) (i) semicircle to right of hole (1) *ecf(a); (a) and d(i) to be consistent* 1

(ii) $mv^2/r$; = BQv; (2)
giving r = mv/BQ = $2.3 \times 10^{-26} \times 6.5 \times 10^4/(0.17 \times 1.6 \times 10^{-19})$; (1)
r = 55 mm;so distance = 2r = 0.11 m (2) 5

**[13]**

**118.** (a) Light energy is <u>reflected</u> or
Light energy is absorbed and converted to <u>heat</u> or thermal energy 1

(b) (i) Minimum surface area = 360 / 1500 × 100/16 (1)
= 1.5 $m^2$ (1) 2

(ii) The satellite will sometimes be in the shadow cast by Earth -
so no sunlight (or not in direct sunlight)
The electrical circuits or battery are not themselves 100% efficient -
energy wasted as heat
Satellite requires extra power for position control or other stated
function
Panels may not be perpendicular to sunlight
Radiation damage (from cosmic rays) reduces number of useful cells
(ignore any reference to any variation in solar output) 2
*Any two*

**[5]**

**119.** (a) The intensity of sunlight is too small (inverse square law) or
The area of panel required would be too large/massive to launch 1

(b) (i) Energy required = V I t
= 12 × 5 × 120 × 60 (1)
= $4.32 \times 10^5$ J (1) 2

(ii) Steady power required = $(4.32 \times 10^5 \times 100/25) \div 24 \times 3600$ (2)
= 20 W (18.5W if 0.40 MJ used) 2
(or P = VI = 12 × 5 = 60W for 2h so only 5W for 24h if 100% efficient but = 5 / 0.25 = 20W)

(iii) Energy carried by alpha = $5 \times 10^6 \times 1.6 \times 10^{-19} = 8.0 \times 10^{-13}$ J (1)
Activity required = $20 \div (8 \times 10^{-13})$
= $2.5 \times 10^{13}$ Bq (1) 2
(or 0.432MJ / $8 \times 10^{-13}$ J alphas per day = 0.432 MJ / $8 \times 10^{-13}$ / 24 × 3600 alphas per sec)

(c) Decay constant of Pu 238 = $0.69 / T_{½}$
= 0.69 / 88 × 365 × 24 × 3600
= $2.5 \times 10^{-10}$ $\text{sec}^{-1}$ (2)
(allow mark for conversion of 88 years to $2.78 \times 10^9$ seconds)

Number of nuclei required = $A / \lambda = 2.5 \times 10^{13} / 2.5 \times 10^{-10}$ (1)
= $1.0 \times 10^{23}$ (1)
(allow mark for formula $A = \lambda N$)
Mass required = $1.0 \times 10^{23} \times 238 / 6.02 \times 10^{23}$ (1)
= 40 gms = 0.040 kg (1) 6

(d) On launch, the rocket gives the spacecraft a huge kinetic energy (in order to escape)
Failure at this point could cause spacecraft and contents to "burn up" in atmosphere
But plutonium would still be radioactive and being vaporised it could be ingested.
Sensible comment on danger periods of launch (or re-entry)
Sensible comment on mechanism of ingesting Plutonium
Allow one sensible comment on no risks in the isolation of deep space 2

**[15]**

**120.** 3.9 eV = $3.9 \times 1.6 \times 10^{-19}$ J (= $6.24 \times 10^{-19}$ J) (1)
$\lambda = hc/E = 6.63 \times 10^{-34} \times 3.0 \times 10^8 / 3.9 \times 1.6 \times 10^{-19}$ (= $320 \times 10^{-9}$ m) (1) 2

**[2]**

**121.** With no current in the wire:
r.m.s.speed is square root of mean of squares of the speed of free electrons; (1)
r.m.s. speed depends on / increases with increasing temperature; (1)
free electrons move (fast) in random directions; (1)
colliding with atoms (in the lattice); (1)

With current in the wire:
free electrons move in opposite direction to current / electric field; (1)
free electrons accelerate between collisions with atoms; (1)
this motion is superimposed on the random motion; (1)
Drift velocity is the mean value of electrons' velocities due to this motion; (1)
value depending on current, cross-section of wire, free electron concentration and electron charge / I, A, n and e. (1) max 7

**[7]**

**122.** (i) n = I/Aev (1)
$= 0.75 / (4.0 \times 10^{-7} \times 1.6 \times 10^{-19} \times 1.4 \times 10^{-4}) = 8.4 \times 10^{28}$ (1) 2

(ii) 1 drift velocity = $4.7 \times 10^{-5}$ m s$^{-1}$ (1)

2 drift velocity = $3.5 \times 10^{-5}$ m s$^{-1}$ (1) 2

**[4]**

**123.** (a) (i) use of area beneath graphs (1)
acceleration section 125 m and deceleration section 50 m (1)
constant velocity sections and total
50 m + 200 m + 125 m + 50 m = 425 m (1) 3

(ii) 2 straight line sections correct (1)
2 acceleration / deceleration sections correct (1)
smooth transition between sections OR zero speed at end (1) 3

(b) (i) at least three points correctly calculated and drawn (1)
straight line towards origin (1) 2

(ii) 240 (V) (1) 1

(iii) gradient is reciprocal of the e.m.f. (1) 1

(c) (i) e.g. $\frac{0.18 - 1.16}{7.2 - 6.7} = -\frac{0.98}{0.5} = -1.98$ correct approach for gradient (1)
1.96, 1.97, 1.98 as values for accuracy mark (1)
– sign scores 1 (1) 3

(ii) $g \alpha 1/r^2$ OR $g$ inversely proportional to the square of the distance from the centre of the Earth (1) 1

**[14]**

**124.** Electron flow is in opposite direction (to conventional current) B1

**[1]**

**125.** Correct symbol for the LDR B1

(Resistance of LDR) decreases with increased intensity / brightness / light (AW) B1

**[2]**

**126.** current ∝ p.d. (Allow 'voltage' instead of p.d.) B1

(provided the) temperature (of metallic conductor) remains constant B1

(voltage = current × resistance scores 0/2)

($V = IR$ and $R$ = constant scores 0/2)

**[2]**

**127.** (i) 1. *R*-*V* graph for metallic conductor:

shows $R$ = constant / 'horizontal line' B1

2. *R*-*V* graph for thermistor:

shows $R$ has a finite value at $V = 0$ B1

shows $R$ decreases as $V$ increases (Allow a 'curve' or 'straight line') B1

(ii) 1. Any two from:

The resistances larger / line (graph) higher (and horizontal)

(Can score on Fig.1.2a)

The electrons collide more often / frequently (with vibrating atoms)

The atoms / ions vibrate 'more' (Do not allow '*particles*' vibrate) B1 × 2

2. The resistance increases / doubles (Can be scored on Fig.1.2a) M1

Mention of: $R \propto L$ or $R = \frac{\rho l}{A}$ A1

**[7]**

**128.** The energy transformed by a 1 kW device in a time of 1 hour B1

**[1]**

**129.** (i) 1. time = 4.0 × 7 = 28 (hours) / power = 0.11 (kW) C1

number of kW h = 0.110 × 28

number of kW h = 3.08 ≈ 3.1 (If 4 hours used, them 0.44 scores 1/2) A1

2. cost = 3.08 × 7.5 (Possible ecf)

cost = 23 (p) B1

(ii) $Q = It$ (With or without Δ notation) C1

Q = 0.48 × 28 × 3600 / $Q = 0.48 \times (1.008 \times 10^5)$ (Allow $t = 1 \times 10^5$ (s)) C1

$Q = 4.84 \times 10^4 \approx 4.8 \times 10^4$ (C) A1

(If $t$ = 28 used, then $Q$ = 13.4 allow 2/3)

(If $t$ = 4 used, then $Q$ = 1.92 allow 1/3)

(If $1.44 \times 10^4$ s used, then $6.91 \times 10^3$ scores 2/3)

(iii) 1. $E = hf$ / $E = \frac{hc}{\lambda}$ / $f \approx 5.4 \times 10^{14}$ (Hz) C1

$E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{5.5 \times 10^{-7}}$ / $E = 6.63 \times 10^{-34} \times 5.455 \times 10^{14}$ C1

$E = 3.62 \times 10^{-19} \approx 3.6 \times 10^{-19}$ (J) A1

2. number = $\frac{8.0}{3.62 \times 10^{-19}}$ C1

number = $2.21 \times 10^{19} \approx 2.2 \times 10^{19}$ ($s^{-1}$) (Possible ecf) A1

**[11]**

**130.** (a) **Maximum** of **five** marks

Up to <u>four</u> from:

| | |
|---|---|
| $\lambda = \frac{h}{mv}$ / $\lambda = \frac{h}{p}$ | M1 |
| All symbols ($\lambda$, $h$, m and $v$ or $p$) defined | A1 |
| Electrons travel / move / propagate (through space) as a wave | B1 |
| Electrons are diffracted / 'spread out' | M1 |
| by the atoms / spacing between the atoms | A1 |
| The electrons are diffracted when their wavelength is less than or comparable or same as size of atoms / gap between the atoms | B1 |

Up to <u>two</u> from:

| | |
|---|---|
| When the speed of electrons is increased) the rings 'get smaller' | B1 |
| (At greater speed of electrons) the wavelength is shorter | B1 |
| (At greater speed of electrons) there is less diffraction | B1 |
| **QWC** Organisation | B1 |
| Spelling, punctuation & grammar | B1 |

(b) Electrons have mass / momentum / charge / can be 'accelerated' B1

**[8]**

**131.** For e.m.f. the energy transfer to electrical / from other forms or 'charges gain energy'

Or

For p.d. the transfer is from electrical / to heat / to other forms or 'charges lose energy' B1

**[1]**

**132.** The sum of currents entering point / junction is equal to the sum of currents out of that point / junction B2

(The algebraic sum of current at a point = 0 scores 2/2)

(–1 if sum is not mentioned and –1 if point / junction is not mentioned)

**[2]**

**133.** (i) current = 0.80 − 0.20

current = 0.60 (A) B1

(ii) $V = IR$ / $V = 0.60 \times 18$ (Possible ecf) C1

$V = 10.8 \approx 11$ (V) A1

(iii) $R_T = \frac{10.8}{0.20} = 54\ \Omega$ (Possible ecf) C1

$R_{diode} = 54 - 46$ C1

$R_{diode} = 8.0\ (\Omega)$ A1

(Alternatively: $V_{46\Omega} = 46 \times 0.20 = 9.2$ (V) C1

$V_{diode} = 10.8 - 9.2$ (= 1.6) C1

$R_{diode} = \frac{1.6}{0.20} = 8.0\ (\Omega)$ A1

(iv) $P = \frac{V^2}{R}$ / $P = I^2R$ / $P = VI$ C1

$P = 0.20^2 \times 8.0$ (Possible ecf)

$P = 0.32$ (W) A1

**[8]**

**134.** (i) Photoelectric (effect) B1

(ii) $10^{-9}$ (m) ≤ wavelength ≤ $4 \times 10^{-7}$ (m) B1

**[2]**

**135.** (i) (Minimum ) energy needed to free an electron /an electron to escape (from the metal surface) B1

(ii) speed of light / $3 \times 10^8$ (m $s^{-1}$) / $c$ B1

(iii) 1. $hf = \phi + KE_{(max)}$ (Allow any subject) C1

$KE_{max} = 2.8 - 1.1 = 1.7$ (eV) C1

$KE_{max} = 1.7 \times 1.6 \times 10^{-19}$

$KE_{max} = 2.7 \times 10^{-19}$ (J) A1

2. $\frac{1}{2} mv^2 = 2.7 \times 10^{-19}$ (Possible ecf) C1

$$v = \sqrt{\frac{2 \times 2.7 \times 10^{-19}}{9.1 \times 10^{-31}}}$$

$v = 7.7 \times 10^5$ (m $s^{-1}$) A1

(iv) No change (because the energy of the photon remains the same) B1

**[8]**

**136.** (i) any valid example - e.g. LIGHT, MICROWAVES (any em waves) B1
(allow "water" /"sea" but reject 'slinky' unless explained/shown)

(ii) any valid example: e.g. SOUND B1
(allow 'pressure wave'; reject "water" and 'slinky' unless explained/shown)

**[2]**

**137.** (i) *transverse* = vibrations perpendicular to wave (direction) (WTTE) B1
(allow "motion is perpendicular to wave", reject vague answers: e.g. "vibrate up + down")

(ii) *longitudinal* = vibrations parallel to wave direction (WTTE) B1
(allow "motion is perpendicular to wave" reject vague answers: e.g. "vibrate back and for)

**[2]**

| | | | | |
|---|---|---|---|---|
| **138.** | (a) | (i) | amplitude correctly labelled (by **A** or in words )<br>(reject "A" as a point i.e. with no arrows) | B1 |
| | | (ii) | wavelength correctly labelled (by **λ** or in words) | B1 |
| | (b) | (i) | same shape<br>moved slightly to the right consistently drawn for both waves<br>(do not allow shift of more than ¼ wavelength) | B1<br>B1 |
| | | (ii) | movement is VERTICAL<br>Q moves UP ↑ <u>AND</u> S moves DOWN ↓ shown | M1<br>A1 |
| | (c) | | phase difference = 180° (degrees) OR π<br>{allow "in antiphase" do not allow "out of phase"} | B1 |
| | (d) | (i) | recall of T = 1/f | C1 |
| | | | T = 1/25 = 0.04 s | A1 |
| | | (ii) | recall of v= fλ<br>valid substitution: e.g. v = 25 × .036<br>v = 0.90 $ms^{-1}$ | C1<br>C1<br>A1 |
| | | | (there are 2 possible errors – incorrect wavelength and wrong units, so v = 90 m/s scores 2 marks<br>v = 0.45 m/s scores 2 marks but allow 3 marks for ecf from cand's λ in (a) (ii)<br>v = 45 m/s scores 1 mark but allow 2 marks for ecf from cand's λ in (a) (ii) | |
| | (e) | (i) | any valid suggestion: e.g. change <u>depth of water</u> | B1 |
| | | (ii) | wavelength will reduce<br>halved<br>{OR new wavelength = 1.8cm OR half cand's value shown in (d) ii} | C1<br><br>A1 |

**[15]**

| | | |
|---|---|---|
| **139.** | <u>COHERENT</u> (allow coherence) | B1 |

**[1]**

**140.** ***constructive interference***: valid diagram and/or explanation: e.g.

when waves (from coherent sources) meet in phase (or nλ path diff.) B1
waves reinforce: resultant has increased displacement/amplitude B1
correctly shown on diagram or stated

***destructive interference***: valid diagram and/or explanation: e.g.

when waves meet in antiphase/180° phase diff. {or (n + 1/2) λ path diff.} B1
waves cancel: resultant has reduced displacement/amplitude B1
correctly shown on diagram or stated

**[4]**

**141.** ***diagram:***

laser OR light source and single-slit in front of double slit B1
screen (WTTE) (or travelling microscope) behind double-slit B1
(if 'screen' is not labelled mark can be obtained by reference to 'screen' in text)

***measurements:***

measure distance between double-slit and screen B1
measure distance between neighbouring dark/bright images B1
(allow 'fringe spacing' or measure distance for n fringes)

***formula:***

recall of **λ = ax/D** B1

***ALL symbols correctly defined***

a = distance between slits }
x = fringe separation (WTTE) } B1
D = distance between slits and screen }

(If candidate uses their own symbols they must be used correctly to score the formula recall mark)
(do not penalise careless use of d and D: i.e. being interposed)

**[6]**

**142.** Diagram showing or description of incident beam scattered by or diffracted through crystal at only certain angles; 1
moveable detector to measure angles; 1
electrons are scattered from crystal planes like a diffraction grating/because of the regular array of atoms; 1
constructive interference only occurs at certain angles; depending on λ 1
and d; 1
pattern of maximum signals can be very complex depending on structure/AW; 1
must achieve λ of the order of d for significant scattering; 1
size of pattern depends on ratio of λ/d **or** maxima occur at angles of about nλ/d; 1
de Broglie's relation p = h/λ for electrons shows why different energies are needed *with this detail worth 2 marks*; 2
further detail, e.g. electrons accelerated to MeV for nuclei or a few keV for atomic spacing 1
as λ is known d can be found *max 5* 1
Quality of Written Communication 2

**[7]**

**143.** (a) v = dist. / time (or implied by answer) 1
= $54 \times 10^3 / 3600$ 1

(b) (i) $v^2 = u^2 + 2\,as$ 1
$a = 15^2 / 2 \times 1.25 = 90\ \text{m s}^{-2}$ (ignore any -ve sign) 1

(ii) v = u + at or s = ½ (u + v) × t 1
(any other equation used must show correct substitution to gain mark)
t = 15 / 90 = 0.167 s = 167 m s 1

(c) (i) F = k × 1
= 30 × 0.036 = 1.08 N 1

(ii) deceleration $a = F / m = 1.08 / 0.120 = 9.0\ \text{m s}^{-2}$ 1

(d) $P_1V_1 = P_2V_2$ or PV / T = constant (or implied by answer) 1
Pressure = $250 \times 10^3 \times (0.06 + 0.0003) / 0.0003$
= 50 MPa 1

(e) PV = nRT    n $= 50 \times 10^6 \times 0.0003 / 8.3 \times (273 + 17)$ 1
$= 6.23$ moles
number of molecules $= 3.75 \times 10^{24}$ molecules 1
Loss $= 20\% \times 3.75 \times 10^{24} / 4 \times 7 \times 24 \times 3600$ 1
$= 3.1 \times 10^{17}$ molecules $\text{sec}^{-1}$ 1

*For incorrect answer, allow*
*correct process to calculate the number of moles* *1*
*correct conversion of moles to molecules* *1*
*correct use of the 20%* *1*
*correct use of 241920 seconds* *1*

(f) (i) Resistance of filament $= \rho L / A$ 1
$= 1.5 \times 10^{-6} \times 0.022 / 2.75 \times 10^{-8}$ 1
$= 1.2\ \Omega$

(ii) Current in filament $= 12\text{V} / 1.2\ \Omega$ $= 10$ A
Power $= 12\text{V} \times 10\text{A}$ $= 120$ W 1
Time for detonation = energy / power $= 0.96 / 120$ 1
$= 8$ m s 1

**[20]**

**144.** (i) $v = I / nAe = 0.0025 / (8.5 \times 10^{28} \times 1.1 \times 10^{-7} \times 1.6 \times 10^{-19})$ (1)
$= 1.67 \times 10^{-6}$ m $\text{s}^{-1}$ (1) 2

(ii) Free electron concentration (or wtte) is much smaller in the thermistor than in the wire. 1

**[3]**

**145.** (a) Kirchhoff's (first) law OR conservation of charge (1)
for electric current into house must equal current out of house (1)
need for difference in potential for a current (1)
gas supply is used in the house (chemically) (1)
waste gas (combustion products) go up the chimney (1) 3
*MAXIMUM 3*

(b) (i) unit of $Q/t$ is J $\text{s}^{-1}$
unit of $A$ is $\text{m}^2$
unit of $(\theta_2 - \theta_2) / d$ is K $\text{m}^{-1}$ (allow °C $\text{m}^{-1}$) (1)
reorganise to unit of $k$ is J $\text{s}^{-1}$ / $\text{m}^2$ K $\text{m}^{-1}$ (1)
unit of k = J $\text{s}^{-1}$ $\text{m}^{-1}$ $\text{K}^{-1}$ OR W $\text{m}^{-1}$ $\text{K}^{-1}$ OR kg m $\text{s}^{-3}$ $\text{K}^{1}$ (1) 3

(ii) $Q/t = 0.35 \times 12 \times (22 - 8)/ 0.10$ (1)
$= 588$ J $s^{-1}$ or 588 (W) (1) 2

(c) (i) $Q/t = I = V/R$ $R = \rho l/A$ (1)
$Q/t = AV/\rho l$ (1) 2

(ii) 1. $(\theta_2 - \theta_2)$ OR temperature difference (1)
2. $1/k$ (1) 2

(d) (i) $V/t = Ap/cl$ OR $m/t = Ap/cl$ (1)
where $V/t$ is volume of gas per unit time
$m/t$ is mass of gas per unit time
$c$ is a constant and (1)
$p$ is the pressure (difference) (1) 3

(ii) $V_1 /160 = 22^2/15^2$ (1)
$V_1 = 160 \times 484 /225 = 344$ ($cm^3$ $s^{-1}$) (1) 2

**[17]**

**146.** (i) shortest: gamma (1)
allow any wavelength between $10^{-12}$ and $10^{-16}$ (m) (1)
longest: radio (1)
allow any wavelength between $10^2$ and $10^5$ (m) (1) 4

(ii) candidates ratio e.g. $10^4 / 10^{-14} = 10^{18}$ (1) 1

(iii) e.g. $10^{18} = 2^x$ (1)
$x = 18/\lg 2 = 60$ (1) 2

(iv) knowing equation and what each term means (1)
e.g. $E = hc/\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^8 / 10^{-14}$
$E = 2 \times 10^{-11}$ (1) 2

**[9]**

**147.** e.g. all are transverse waves (1)
so all can be polarised (under suitable conditions) (1)
all can travel in a vacuum (1)
at the same speed (1)

MAXIMUM 2 for first part 2

Discussion of other wave phenomena and how they change as wavelength changes
e.g. diffraction
refraction
or such things as
the sensitivity of the eye to certain wavelengths
photographic film for certain wavelengths
heating effect, particularly of infra-red
radio and its effect on electrons
quantum effects – minimal for radio, predominant for gamma

4 marks can be given as 2,2 or 2,1,1 4

i.e. 2 topics dealt with fully or (1) topic dealt with fully and 2 topics outlined

**[6]**

**148.** $3 \times 10^8$ ($ms^{-1}$) (Do not allow 'speed of light' / *c*) B1

**[1]**

**149.** (i) $v = f\lambda$ C1

$3.0 \times 10^8 = f\lambda$ / $3.0 \times 10^8 = f \times 8.8 \times 10^{-7}$
frequency = $3.41 \times 10^{14}$ (Hz) $\approx 3.4 \times 10^{14}$ (Hz) A1

(ii) (e.m.f =) $\frac{W}{Q}$, with $W$ = energy (transformed to electrical) and
$Q$ = charge (B1)

Or

Energy transformed by / per unit charge / 1C (from chemical to electrical) B1
(Allow: 'energy gained by / per unit charge / 1C / one coulomb')

(iii) $I = \frac{\Delta Q}{\Delta t}$ Allow any subject, with or without Δ notation B1

(iv) $Q = 1.4 \times 10^{-3} \times 0.20$ C1
charge = $2.8 \times 10^{-4}$ (C) A1

(v) $W = VQ$ / energy = $VQ$ C1
$W = 3.0 \times 2.8 \times 10^{-4}$
energy = $8.4 \times 10^{-4}$ (J) (Possible ecf) A1

**[8]**

**150.** length B1

(cross-sectional) area (Allow: radius / diameter / thickness / width) B1

**[2]**

**151.** (i) $R = \frac{\rho L}{A}$ (Allow any subject)

$\rho = \frac{0.54 \times [\pi \times (0.135 x 10^{-3})^2]}{1.8}$ C1

$\rho = 1.72 \times 10^{-8} \approx 1.7 \times 10^{-8}$ (Deduct one mark for $10^n$ error) A1

($\rho = 6.87 \times 10^{-8}$ scores 2/3 if 'diameter' is used)

($\rho = 1.72 \times 10^{-5}$ Ω mm scores 4/4)

unit: Ω m B1

(ii) Any <u>four</u> from: (Allow AW)

1. Resistance of the wire increases (as the temperature is increased) B1
2. The current decreases / the ammeter reading falls B1
3. The decrease in current justified in terms of '$I = V/R$' B1
4. The voltage remains the same / the voltmeter reading remains the same B1
5. The electrons (within the wire) collide <u>more</u> (often with the atoms) / the atoms vibrate <u>more</u> (Do not allow 'particles' vibrate more) B1

QWC for 'spelling and grammar' B1

**[9]**

**152.** $E = I(R + r)$ or $E = V + Ir$ / $R_T = \frac{1.5}{0.60} = (2.5)$ / $V_R = 1.8 \times 0.6$ C1

$1.5 = 0.60\ (r + 1.8)$ / $r = 2.5 - 1.8$ / $r = \frac{1.5 - 1.08}{0.6}$ C1

$r = 0.70$ (Ω) (Allow 1sf answer ) A1

**[3]**

**153.** (i) $P = \frac{V^2}{R}$ / $P = VI$ <u>and</u> $V = IR$ C1

$36 = \frac{12^2}{R}$ / $I = 3.0$ (A) hence $R = \frac{12}{3.0}$

resistance = 4.0 (Ω) (Allow 1 sf answer) A1

(ii) $R_{series} = 30$ (Ω) C1

$R = \frac{30 \times 4.0}{30 + 4.0}$ / $\frac{1}{R} = \frac{1}{30} + \frac{1}{4}$ / $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ C1

resistance = 3.53 ≈ 3.5 (Ω) (Possible ecf ) A1

(iii) $l_{lamp} = \frac{36}{12}$ or $3.0$ (A) / $l_{20\Omega} = \frac{12}{30}$ or $0.40$ (A) C1

ratio = 7.5 / ratio $= \frac{30}{4}$ A1

**[7]**

**154.** (a) No current (in circuit) / 'open' circuit / p.d. between **X** and **Y** is 5.0 V B1

(b) $V = \frac{R_2}{R_1 + R_2} \times V_0$ / $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ / $I = \frac{3.4}{168} (= 2.02) \times 10^{-2}$ mA C1

$3.4 = \frac{168}{168 + R} \times 5.0$ / $\frac{1.6}{3.4} = \frac{R}{168}$ / $R = \frac{1.6}{2.02 x 10^{-2}}$ C1

resistance ≈ 79 (kΩ) (Total resistance of 250 kΩ scores 2/3) A1

**[4]**

**155.** ✘ ✓ ✓ ✘ B2

All correct 2 marks; Three correct 1 mark; Two (or less) correct 0 mark

**[2]**

**156.** Any <u>six</u> from: (Allow AW)

1. <u>Photoelectric</u> <u>effect</u> is the removal of electrons (from metals) when exposed to light / u.v. /e.m. radiation / photons — B1
2. <u>Surface</u> electrons are involved / electrons released from the <u>surface</u> — B1
3. A single photon interacts with a single electron — B1
4. Energy is <u>conserved</u> (in the interaction) — B1
5. Energy of photon = $hf$ or $\dfrac{hc}{\lambda}$ — B1
6. Reference to Einstein's photoelectric equation: $hf = \phi + KE_{(max)}$ — C1
7. photon energy = work function (energy) + (maximum) KE (of electron) — A1
8. PE effect takes place / electron(s) released when $hf > \phi$ / $hf = \phi$ / frequency is greater / equal to threshold frequency — B1
9. The (maximum) KE of electron is independent of intensity when electrons are emitted — B1
10. Intensity increases the rate / number of electrons when emission occurs — B1
11. PE effect does not take place / no electrons emitted when $hf < \phi$ / frequency < threshold frequency — B1
12. Intensity has 'no effect' when there is no emission of electrons — B1

QWC for 'organisation' — B1

**[7]**

**157.** (i) 1. $E = hf$ / $E = \dfrac{hc}{\lambda}$ / $f = 7.5 \times 10^{17}$ (Hz) — C1

('$E = hf$' can be secured in (i))

$E = \dfrac{6.63\times10^{-34} \times 3.0\times10^{8}}{4.0\times10^{-10}}$ / $E = 6.63 \times 10^{-34} \times 7.5 \times 10^{17}$ — C1

energy = $4.97 \times 10^{-16}$ (J) ≈ $5.0 \times 10^{-16}$ (J) (Allow 1 sf answer here) — A1

2. $E = \dfrac{4.97\times10^{-16}}{1.6\times10^{-19}}$ (Possible ecf)

energy = $3.1 \times 10^{3}$ (eV) — B1

(ii) The answer to **(c)(i)1**. and 1.4 (W) are used to determine the rate of photons — C1

$\text{number} = \dfrac{1.4}{4.97\times10^{-16}}$ (Possible ecf) — C1

number = $2.8 \times 10^{15}$ ($s^{-1}$) (If 3100 eV is used, then allow 2/3 for $4.5 \times 10^{-4}$) — A1

**[7]**

**158.** any **two** valid points: e.g
in longitudinal waves the vibrations are parallel to wave direction (WTTE) }
in transverse waves the vibrations are perpendicular to wave direction (WTTE) }
transverse waves <u>can</u> be polarised (OR longitudinal waves are not be polarised) }
(all) longitudinal waves need a medium } B1 + B2

**[2]**

**159.** (a) (i) vibrations "V" correctly labelled OR (NOT) B1
(ii) compression "C" correctly shown anywhere on the spring B1
(iii) wavelength "λ" correctly shown: e.g. between neighbouring compressions B1
(generously judged: i.e. somewhere between 28 and 34 mm)

(b) wavelength REDUCES B1
because $v = f\lambda$ AND v remains constant (WTTE) B1

**[5]**

**160.** (a) DIFFRACTION B1

(b) a constant phase difference/relation (WTTE) B1
(allow "zero phase difference" and "in phase")

(c) constructive interference produces bright lines <u>AND</u> destructive for dark lines B1
in phase for bright AND antiphase (allow 'out of phase') for dark B1
(ALLOW diagrams showing crests/troughs meeting crests/troughs for this mark)
path difference = whole number of wavelengths {allow $n\lambda$} for bright B1
(ALLOW path difference = λ but NOT path difference = ZERO)
path difference = odd number of half wavelengths {allow $(n + 1/2)\lambda$} for dark B1
(ALLOW path difference = ½λ)

(d) recall of $\boldsymbol{\lambda = ax/D}$ (in any valid form) C1
valid substitution: e.g. $x = (6.5 \times 10^{-7} \times 1.5)/0.25 \times 10^{-3}$ C1
$x = \mathbf{3.9 \times 10^{-3}}$ m A1
($3.9 \times 10^{-6}$ scores 2 marks)

**[9]**

**161.** (i) node: point of ZERO amplitude/displacement/movement/disruption etc. B1
(ii) antinode: a point of MAXIMUM <u>**AMPLITUDE**</u> B1

**[2]**

**162.** (i) node **N** labelled at the bottom AND antinode **A** labelled at the top — M1
evidence of 'fundamental' i.e only <u>one</u> **A** at top and <u>one</u> **N** at bottom — A1
{allow ecf from (a) i.e. if A and N are defined oppositely}

(ii) (length of air column = $\frac{1}{4}\lambda$ ) $\Rightarrow \lambda = 4 \times 0.32 = \mathbf{1.28}$ m — B1
{NO ecf from incorrect wave in (i)}

(iii) recall of $v = f\lambda$ OR frequency of tuning fork = frequency of standing wave — C1
valid substitution: e.g $f = 330/1.28$ — C1
$f = \mathbf{258}$ Hz — A1
{allow ecf from(ii) e.g if $\lambda = 0.32$ is used f = 1030Hz scores 3 marks}

**[6]**

**163.** (a) (i) energy = 30 + 10 × 50 = 530 keV (1) — 1

(ii) $\frac{1}{2} m v^2 = V e$ (1)
$\frac{1}{2} \times 1.67 \times 10^{-27} v^2 = 530 \times 10^3 \times 1.6 \times 10^{-19}$ (1)
$v = 1.01 \times 10^7$ m s$^{-1}$ allow 1.0 or $1 \times 10^7$ m s$^{-1}$ (1) — 3

omits $10^3$ and gets $3.2 \times 10^5$ 2/3
omits $1.6 \times 10^{-19}$ and gets $2.5 \times 10^{16}$ 1/3
omits $1.67 \times 10^{-27}$ and gets $4.1 \times 10^{-7}$ 1/3
ecf from (i): 500 keV to give $9.8 \times 10^6$
300 keV to give $7.6 \times 10^6$
40 keV to give $2.8 \times 10^6$ all can get 3/3

(b) rest energy + kinetic energy = 2 $h f$ (2)
omits rest energy or ke 1/2

$2 \times (9.11 \times 10^{-31}) (3 \times 10^8)^2 + 650 \times 10^3 \times 1.6 \times 10^{-19} = 2 \times 6.63 \times 10^{-34} f$ (1)

$(1.64 \times 10^{-13} + 1.04 \times 10^{-13} = 13.3 \times 10^{-34} f)$ (1) — 4
$f = 2.02 \times 10^{20}$ Hz

omits rest energy and gets $7.82 \times 10^{19}$ Hz 2/4
omits kinetic energy and gets $1.23 \times 10^{20}$ Hz 2/4
any further error (–1) each, to zero

**[8]**

**164.** X-rays have a very small wavelength (compared with 0.1 mm) (1)
angle of diffraction increases as size of opening decreases (1)
little diffraction when size of opening is much greater than the wavelength (1)
quantitative values - e.g. gap is $10^6$ wavelengths (1) — 3
*MAXIMUM 3*

**[3]**

**165.** sound waves are longitudinal waves (1)
longitudinal waves cannot be polarised (1) 2

**[2]**

**166.** (a) (a lower resistance will) take a larger current from the supply (1)
(power = $V \times I$) so power to/ brightness of headlamps is greater (1) 2

(b) (first position) has no lights on at all (1)
(second position just) lights the sidelights (1)
(third position turns off the sidelights and) just illuminates the headlamps (1) 3

(c) 4 $V$ across the internal resistance of the generator (1)
so current = 4 V / 0.50 Ω = 8.0 A (1) 2

(d) (i) 12 V across headlamp (1)
so current = 12 V / 4.0 Ω = 3.0 A (1) 2

(ii) power = $V \times I$, total current = 6.0 A (1)
power supplied = 12 V × 6.0 A = 72 (1)
watt (1) 3

(e) 8 A from generator but only 6 A to headlamps (1)
therefore current to battery is 2 A (allow –2 A) (1)
battery is being charged (1) 3

(f) (i) constant voltage maintained across bulbs (and other components) (1)
so brightness of bulbs does not vary (when other components
are being used (1)
less energy wastage (1)
can give high current (for starter motor) (1) 2
*MAXIMUM 2*

(ii) If the emf of the generator is (equal to or) less than the emf of
the battery it is impossible to have it supply more current than
the circuit uses (1)
Charging the battery is then impossible (1)
battery would become discharged (1)
or other valid response (1) 2
*MAXIMUM 2*

**[19]**

**167.** (a) Flow / movement of charge / charged particle(s) AW B1
(Allow current = rate of flow of charge / current = rate of change of charge)

(b) The charge (flowing past a point) in 1 s when current is 1 A B1
(Allow 1C = 1A × 1s)

(c) (i) $I = \frac{\Delta Q}{\Delta t}$ / $I = \frac{340}{50}$ (Allow any subject - with or without Δ) C1
6.8 (A) A1

(ii) 1. There is magnetic field (around the current-carrying strip(s) and hence a force) AW B1

2. (Fleming's) left-hand rule B1

3. Towards A / To the left (Allow direction given on diag.) B1

**[7]**

**168.** current ∝ voltage / p.d. (for a metal conductor) [Allow $I \propto V$] M1
as long as temperature remains constant / all physical conditions remain the same A1
($V = IR$ and $R$ = constant scores 1/2)
($V = IR$ scores 0/2)

**[2]**

**169.** (i) (Semiconductor) diode B1

(ii) Any five from: B1 × 5

Resistance is given by $R = V/I$

(Allow the use of $R$ for resistance in this question)

The resistance is not constant / Diode is a non-ohmic (component)

For negative value(s) (of $V$) resistance is infinite / (very) large

(Allow a calculation)

For $V$ / value(s) less than 0.6 (V) the resistance is infinite / (very) large

(Accept 0.62 V)

For $V$ / value(s) greater than 0.6 (V) the resistance is small / less

For $V$ / value(s) greater than 0.6 (V) the resistance decreases

(as $V$ increases) (Also scores mark above)

Resistance correctly calculated at one point

(Assume values are in ohms if unit is not given)

Resistance correctly calculated at another point

(Allow '*voltage increases the resistance decreases*' if there is no reference to 0.6 V and the second mark above is not scored)

QWC 'Spelling and grammar' B1

**[7]**

**170.** sum of current(s) into a point / junction = sum of current(s) out (from the point / junction) B2

(–1 for omission of 'point' or 'sum' in the statement of the law)

(Algebraic sum of current(s) at a point = 0 scores 2/2)

**[2]**

**171.** (i) Thermistor B1

(ii) $I_1 = 51$ (mA) B1

$I_2 = 9$ (mA) B1

$I_3 = 29$ (mA) B1

**[4]**

**172.** (a) $R = R_1 + R_2$ / $R = 200 + 120$ / $R = 320$ C1

current = $\frac{8.0}{320}$ C1

current = $2.5 \times 10^{-2}$ (A) A0

(b) $V = 25 \times 10^{-3} \times 120$ / $V = \frac{120}{120 + 200} \times 8.0$

$V = 3.0$ (V) (Possible ecf) B1

(c) p.d. across the 360 (Ω) resistor = p.d. across the 120 (Ω) resistor / There is no current between **A** and **B** / in the voltmeter (Allow '*A & B have same voltage*' - BOD) B1

The p.d. calculated across 360 Ω resistor is shown to be 3.0 V / The ratio of the resistances of the resistors is shown to be the same. B1

**[5]**

**173.** (a) (i) length = $2\pi \times 2.8 \times 10^{-2} \times 20$ / length = $2\pi \times 2.8 \times 20$ M1
length = 3.52 (m) ≈ 3.5 (m) / length ≈ 350 (cm) A0

(ii) $R = \dfrac{\rho L}{A}$ (Allow any subject) C1

$R = \dfrac{4.9\times10^{-7}\times3.5}{8.4\times10^{-7}}$ C1

$R$ = 2.04 ≈ 2.0 (Ω) ($R$ = 2.05 ≈ 2.1 Ω if 3.52 m is used) A1

(b) (i) $V = 6.0 \times 2.04$ (Possible ecf) (Allow initial current 5.7 A to 6.0 A) C1
$V$ = 12.2 ≈ 12 (V) (Allow $V = 2.0 \times 2.04 \approx 4.1$ (V) 1 mark) A1

(ii) $P = VI$ (Allow $P = I^2R$ or $P = V^2/R$) C1
$P = 12 \times 6.0$ (Possible ecf)
$P = 72$ A1
watt / W / J $s^{-1}$ / VA B1

(iii) Any <u>four</u> from: B1 × 4
The temperature of the coil increases / the coil gets 'hotter' (Allow 'coil heats up')
The resistance / resistivity of coil increases (as its temperature increases)
The decrease in current is linked to $I = V/R$
More / frequent collisions of electrons and (vibrating) atoms / ions (as temperature / resistance increases)
The coil (eventually) reaches steady temperature / constant (higher) resistance

QWC 'Organisation' B1

**[14]**

**174.** particle(-like) / particulate (nature) / photon ('behaviour') B1

**[1]**

**175.** (i) A 'packet' of energy / radiation / A quantum of (EM) radiation / energy / light B1

(Do not allow '*particle of light*')

(ii) The minimum frequency (of the EM radiation) for emission of electrons / photoelectric effect B1

**[2]**

**176.** (i) Visible (light) B1

(ii) work function = 1.9 × 1.6 × $10^{-19}$ M1
work function = 3.04 × $10^{-19}$ (J) ≈ 3.0 × $10^{-19}$ (J) A0

(iii) 1. $E = hf$ / $E = \frac{hc}{\lambda}$ C1

$$E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{5.1 \times 10^{-7}}$$

$E = 3.9 \times 10^{-19}$ (J) A1

2. $hf = \phi + KE_{(max)}$ / $hf = \phi + ½\, mv^2$
(Allow $E = \phi + ½\, mv^2$ if $E$ is qualified in (iii)**1.**) C1
$3.9 \times 10^{-19} = 3.0 \times 10^{-19} + KE_{(max)}$ / $3.9 \times 10^{-19} = 3.04 \times 10^{-19} + KE_{(max)}$ C1
KE = 9.0 × $10^{-20}$ (J) / KE = 8.6 × $10^{-20}$ (J) (Possible ecf) A1

(iv) No change (to maximum KE of electron) B1
Each photon has same energy (but there are fewer photons) B1

(v) number of photons = $\frac{80 \times 10^{-3}}{3.9 \times 10^{-19}}$ (≈ 2.05 × $10^{17}$) (Possible ecf) C1

number of electrons = 0.07 × $\frac{80 \times 10^{-3}}{3.9 \times 10^{-19}}$

number of electrons = 1.44 × $10^{16}$ ($s^{-1}$) ≈ 1.4 × $10^{16}$ ($s^{-1}$) A1

**[11]**

**177.** $\lambda = \frac{h}{mv}$ (Allow any subject) C1

$5.1 \times 10^{-7} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times v}$ C1

$v = 1.43 \times 10^3 \approx 1.4 \times 10^3$ ($ms^{-1}$) A1

**[3]**

**178.** (i) any 3 from reflection, TIR, refraction, diffraction, interference B1+B1+B1
{also allow energy transfer, superposition, creation of standing waves but do not allow v = fλ , progressive waves}

(ii) polarisation B1

**[4]**

**179.** (a) (i) frequency = number of vibrations/waves/oscillations/cycles per sec B1
{reject f = 1/period unless period defined}

(ii) wavelength = distance between neighbouring corresponding pts B1
{Allow "crest to crest" "trough to trough" or labelled diagram or length of 1 cycle of the wave}

(b) in one second f waves are produced each of length λ B1
distance travelled in one second is therefore fλ OR (hence) v = fλ B1
OR speed = dist/time = λ/T B1
and T = 1/f hence v= f λ B1
{reject consistency of units approach}

**[4]**

**180.** (i) period = 1/500 = 0.002s (or 2ms) B1

(ii) at least 2 full (sine) waves of constant period (+/– 2mm) B1
of amplitude 3 cm (+/– 2mm in both directions) B1
correct 'period' of 4 cm (+/– 2mm throughout ) B1

(iii) correct substitution into v = fλ : e.g. 330 = 500λ C1
λ = 0.66 m {do not allow 0.6 but allow 0.7} A1

**[6]**

**181.** similarity: any valid point e.g. (both have) vibrations, frequency, amplitude, wavelength, period, displacement (not velocity) B1
difference:
e.g. no energy transfer for standing waves }
neighbouring points vibrate in phase for standing waves } B1
only standing waves have nodes and antinodes }
{allow standing waves are "trapped"/fixed/confined/don't move forward}

**[2]**

**182.** (i) arrows show vertical oscillations B1
maximum amplitude at top {allow ecf for horiz.} B1
less in middle AND very small (or zero) at base B1
{allow 1 mark only for unlabelled diagram showing representation of amplitude}
{2 marks for unlabelled diagram plus an arrow}
{allow single headed arrows}

(ii) wavelength = 4 × 0.36 = 1.44m B1

(iii) recall of $v = f\lambda$ B1
$f = v/\lambda$ = 330/1.44 (allow ecf) = 229 (or 230) Hz B1

(iv) if open at both ends each end must be an antinode OR diagram B1
hence wavelength = 0.72m {allow ecf} C1
and frequency = 458 (or 460) Hz {allow ecf} A1

**[9]**

**183.** (i) a progressive wave transfers energy (WTTE) B1
{allow "wave profile moves through space" OR crest/troughs move along the medium}
{allow "waves that move from one place to another" but not "waves move"}

(ii) longitudinal: vibrations/motions PARALLEL (to wave direction) B1
{allow back and forth}
transverse: vibrations/motions PERPENDICULAR (to wave direction) B1

**[3]**

**184.** $10^{-3}$ to $10^{-1}$ (m) (Allow range: 0.0005 m to 0.15 m) B1

**[1]**

**185.** Any <u>one</u> from:

1. Travels at the speed of light / $3 \times 10^8$ ($ms^{-1}$ in vacuum) B1
2. Travel in vacuum (Allow ‘free space’ but not just ‘space’)
3. Transverse (wave) / can be polarised
4. Consists of oscillating electric and magnetic fields
5. Can be reflected / refracted / diffracted / shows interference
6. (Behave as) photon(s)
7. Warms food

**[1]**

**186.** (e.m.f. =) $\frac{W}{Q}$ / (e.m.f. =) $\frac{78}{24}$ C1

(e.m.f. =) 3.25 ≈ 3.3 (V) A1

**[2]**

**187.** (a) <u>Energy</u> (transformed by a device working) at 1 kW for 1 hour B1

(b) $E = Pt$ / 5.8 = 0.12 × time / (time =) 48.3 (hr) C1
(time =) $1.74 \times 10^5 \approx 1.7 \times 10^5$ (s) A1

**[3]**

**188.** (a) Line crosses ‘y-axis’ at 1.4 (V) / $V = E$ or 1.4(V) when $I = 0$
$V = E - Ir$; since $I = 0$ (Hence $V = E$ or 1.4(V)) B1

(b) (i) (Graph extrapolated to give) current = 2.0 (A)
(Allow tolerance ± 0.1A) B1

(ii) $E = I_{(max)}\, r$ gradient = $r$ (Ignore sign) C1
($r = \frac{1.4}{2.0}$) (Attempt made to find gradient)
$r$ = 0.7(0) (Ω) $r$ = 0.7(0) (Ω) (Possible ecf) A1

(iii) (excessive) heating of <u>cell</u> / energy wasted <u>internally</u> /
cell might ‘explode’ / <u>cell</u> goes ‘flat’ (quickly) B1

**[5]**

**189.** Correct circuit for both lamps in parallel (ignore ammeter here) B1

Ammeter placed correctly in <u>series</u> with **P** B1

**[2]**

**190.** (i) The resistance of LDR/circuit changes (as light intensity changes) B1
When blade blocks light, resistance of LDR/circuit is large(r) (ora) B1
Correct statement about p.d (Possible ecf) B1

(ii) 1. ($V$ = 5.0 – 3.0)
2.0 (V) (Allow 1 sf answer) B1

2. $V = \dfrac{R_2}{R_1 + R_2} \times V_0$ $I = 2.0/2200 / 9.1 \times 10^{-4}$ (A) C1

$(3.0 = \dfrac{R}{R + 2200} \times 5.0)$ $(R = 3.0 / 9.1 \times 10^{-4})$

$R$ = 3300 (Ω) $R$ = 3300 (Ω) Possible ecf A1

(For $V_{LDR}$ = 2.0 V, $R$ = 1.47 kΩ. This scores 1/2)

(If 3.5 V given in (ii)**1.**, then $R$ = 940 Ω. This scores 2/2)

**[6]**

**191.** (resistance = ) p.d./current (Allow use of 'voltage') B2
((resistance =) ratio of p.d. to current 2/2)
((resistance =) voltage per (unit) current 2/2)
(($R$ = ) $V/I$ scores 1/2)
((resistance =) voltage per (unit) ampere scores 1/2)

**[2]**

**192.** (i) Parallel B1

(ii) **1.** $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$ / $= \frac{1}{R} = \frac{3}{8}$ C1

($R$ =) 6.0 (Ω) (Allow 1 sf answer) A1

**2.** $P = \frac{V^2}{R}$ (Allow $P = VI$ or $P = I^2R$) C1

( $P = \frac{12^2}{6}$ )

$P$ = 24 (W) (Possible ecf from (ii)**1.**) A1

(If 18 Ω used, $P$ = 8 (W). Allow 1/2)

**3.** $R = \frac{\rho L}{A}$ (Allow other subject) C1

$18 = \frac{6.9 \times 10^{-6} \times 0.85}{A}$ C1

$A = 3.26 \times 10^{-7} \approx 3.3 \times 10^{-7}$ ($m^2$) A1

($3.3 \times 10^{-5}$ ($m^2$) scores 2/3)

(If $R$ = 6.0 Ω then $A = 9.8 \times 10^{-7}$ ($m^2$). This scores 2/3)

**[8]**

**193.** (a) Into the page B1

(b) $I = \frac{\Delta Q}{\Delta t}$ (Allow other subject, with or without Δ) C1

(charge =) 7800 × 0.23 C1

$1.794 \times 10^3 \approx 1.8 \times 10^3$ (C) (Ignore minus sign) A1

($1.8 \times 10^6$ (C) scores 2/3)

(c) (number =) $\frac{1.79 \times 10^3}{e}$ (Possible ecf) C1

(number =) $1.12 \times 10^{22} \approx 1.1 \times 10^{22}$ A1

**[6]**

**194.** (a) Any <u>five</u> from: B1 × 5

1. Photoelectric (effect) mentioned
2. Photon(s) mentioned in correct context / $E = hf$
3. One-to-one 'interaction' between photon & electron
4. Surface electrons are involved
5. Electron released / photoelectric (effect) when photon energy > / = work function (energy)
6. Electrons emitted / photoelectric (effect) when frequency > / = threshold frequency
7. Energy is conserved (in the 'interaction' between photon and electron)
8. Reference to Einstein's equation: $hf = \phi + KE_{(\max)}$

[QWC: Spelling and Grammar]

(b) (i) 1. (energy of photon = 2.2 + 0.3) B1
2.5 (eV) B1

2. (energy =) 2.5 × <u>1.6× 10$^{-19}$</u> (Possible ecf from (b)(i)**1**.) C1
$4.0 \times 10^{-19}$ (J) (Allow 1 sf answer) A1

(ii) $(f =)\ \dfrac{4.0 \times 10^{-19}}{h}$ (Possible ecf) C1

$(f = \dfrac{4.0 \times 10^{-19}}{6.63 \times 10^{-34}})$

$(f =)\ 6.03 \times 10^{14} \approx 6.0 \times 10^{14}$ (Hz) (Allow $6 \times 10^{14}$) A1

(c) Each photon has more energy / There are fewer photons (in a given time because intensity is the same) B1
Smaller current B1

**[13]**

**195.** spreading (out of waves as they pass through an opening or an edge) B1
{NB ignore bending/changes direction/deviates/disperses}

**[1]**

**196.** (i) (circular) arcs drawn after gap: i.e. <u>reject any flatness</u> B1

(ii) waves must have plane central section {ignore curved edges} B1

evidence that wavelength stays constant shown in <u>either</u> diagram {judged by eye unless λ is labelled before and after gap} B1

Gap widths look about right w.r.t. λ i.e. ×2 and ×10 - generously judged by eye, looking at (i) first then comparing gap size with (ii). B1

**[4]**

**197.** Wavelength of light is very short B1
most gaps are very large in comparison to wavelength OR small gaps are needed (to observe diffraction) (AW) B1

**[2]**

**198.** (a) (i) amplitude = 1.2 (mm) B1

(ii) period = 2.4 (ms) B1
{allow $2.4 \times 10^{-3}$ ms if $2.4 \times 10^{-3}$ is correctly used in substitution in (b)(i)}

(b) (i) frequency = 1/period C1
1/0.0024 = 417Hz (OR 420) A1
{1/2.4 = 0.417 OR 0.42 OR 0.4 scores 1 mark}
{allow ecf from cand's period value}

(ii) recall of v = f λ OR c = f λ OR λ = vT OR 1500 = 417 λ C1
λ = 3.6 m A1
{ecf for cand's f: e.g. λ= 1500/0.417 = 3600 m scores 2 marks
OR λ = 1500/0.4 = 3750 m scores 2 marks}
λ = 1500/0.42 = 3571 m scores 2 marks

(iii) valid scale for cand's λ shown on position axis AND at least two full 'sine' waves drawn (waves can be very rough but not square waves } B1

amp. shown as 1.2 mm +/– ½ sq.: check first peak + trough only B1

first wavelength correct as 3.6 m +/– 1 sq. {allow ecf from (b)(ii)} B1

{NB If there is no scale on the position axis the 1st and 3rd marks cannot be scored}

**[9]**

**199.** (a) • Reference to incident & reflected waves or formation of a *standing wave* :e.g. detector receives waves directly from T and (by reflection) from P }
OR reflected wave interferes with outgoing wave (AW) } B1
*OR a" standing wave" OR "nodes AND antinodes" formed* }

waves interfere constructively for maxima OR destructively for minima}
OR *nodes formed where intensity is minimum OR antinodes at maxima*} B1

• Measure distance between maxima/minima OR *between nodes/antinodes* B1
evidence of max to max/min to min/node to node/antinode to antinode = 1/2λ B1

• Use v = fλ to find f B1
evidence that v is known to be speed of light /c/3 × $10^8$m/s B1

{NB allow answers referring to CRO: find period from CRO trace -- M1; use f = 1/T – A1}
{NB: "use c = fλ" scores 2 marks "use a (digital) frequency meter" scores 1 max}

(b) Place (polarising) grid (allow "POLAROID") between T and D AND ROTATE M1
{allow 'rotate transmitter' OR 'rotate detector'}
signal drops to zero if microwaves are plane polarised A1

{NB: "Rotate a SINGLE-slit AND signal drops to zero" scores maximum of 1 mark}

**[8]**

**200.** when two waves meet/overlap/interfere/collide/superpose (AW) B1
the resultant displacement is the sum of the displacements B1
{do not allow amplitude}
{NB allow 2 marks for good diagrams}

**[2]**

**201.** (i) wave sources with constant phase difference B1

{NB allow "in phase" and ignore reference to frequency/wavelength/amplitude}

(ii) $S_1$ and $S_2$ 'share the same light' (AW) B1

reference to diffraction at the single slit
OR to wavefronts e.g. "same wavefront reaches $S_1$ and $S_2$ (AW) B1

(iii) Constructive interference occurs at O B1
path difference is zero OR waves meet in phase (AW) B1

(iv) recall of formula $\lambda = ax/D$ in any valid form (e.g. $x = \lambda D/a$) C1

{NB allow undefined symbols provided they match the above as stated in the spec., otherwise they must be defined}

correct sub. with <u>consistent units</u>: $\lambda = 2 \times 10^{-3} \times 0.6 \times 10^{-3} / 1.8$ C1

$\lambda = 6.7 \times 10^{-7}$ m A1

{NB allow ecf if mm used: i.e 2 marks for $6.7 \times 10^{-1}$ OR $6.7 \times 10^{-4}$}

(v) 'fringe separation' (AW) would DECREASE B1

{NB allow "more fringes would be seen"}

because $x \propto \lambda$ (AW) B1

{NB allow 'colour change' arguments for full marks:

Colour would change B1;
to a colour closer to the blue end of visible spectrum (AW) B1}

**[10]**