Coimisiún na Scrúduithe Stáit
State Examinations Commission

Scéim Mharcála | *Scrúdú na hArdteistiméireachta 2006*

Fisic | *Ardleibhéal*

Marking Scheme | *Leaving Certificate Examination 2006*

Physics | *Higher Level*

General Guidelines

In considering this marking scheme the following points should be noted:

1) In many instances only key words are given -- words that must appear in the correct context in the candidate's answer in order to merit the assigned marks.

2) Words, expressions or statements separated by a solidus, /, are alternatives which are equally acceptable. Words which are separated by a solidus and which are underlined, must appear in the correct context by including the rest of the statement to merit the assigned mark.

3) Answers that are separated by a double solidus, //, are answers which are mutually exclusive. A partial answer from one side of the // may not be taken in conjunction with a partial answer from the other side.

4) The descriptions, methods and definitions in the scheme are not exhaustive and alternative valid answers are acceptable.

5) The detail required in any answer is determined by the context and manner in which the question is asked and also by the number of marks assigned to the answer in the examination paper. Therefore, in any instance, it may vary from year to year.

6) For omission of appropriate units, or incorrect units, one mark is deducted, when indicated.

7) Each time an arithmetical slip occurs in a calculation, one mark is deducted.

Section A (120 marks)

Each question carries 40 marks. Marks awarded for the **three** best answers.

Question 1

In investigating the relationship between the period and the length of a simple pendulum, a pendulum was set up so that it could swing freely about a fixed point. The length l of the pendulum and the time t taken for 25 oscillations were recorded.
This procedure was repeated for different values of the length.

The table shows the recorded data.

l/cm	40.0	50.0	60.0	70.0	80.0	90.0	100.0
t/s	31.3	35.4	39.1	43.0	45.5	48.2	50.1

The pendulum used consisted of a small heavy bob attached to a length of inextensible string.

Explain

(i) **why a small heavy bob was used**;
(ii) **why the string was inextensible. (9)**

small heavy bob: to reduce air resistance/friction // to keep string taut 3
string inextensible: so that length remains constant/fixed 6

{"So that formula is applicable to system/arrangement/apparatus" // "so that motion is SHM"
// "to limit the number of variables to two" … (3)}

Describe how the pendulum was set up so that it swung freely about a fixed point.
Give one other precaution taken when allowing the pendulum to swing. (7)

string placed between two coins/a split cork 4

small angle/no draughts /one plane only / avoid spinning 3

Draw a suitable graph to investigate the relationship between the period of the simple pendulum and its length. What is this relationship? Justify your answer. (24)

***T*/s**	1.25	1.42	1.56	1.72	1.82	1.93	2.00
T^2/s^2	1.57	2.01	2.45	2.96	3.31	3.72	4.02
$\sqrt{l}$/m$^{1/2}$	0.63	0.71	0.77	0.84	0.89	0.95	1.00

values of t divided by 25 (to get T) 3
axes correctly labelled (T^2 vs. l or T vs. $\sqrt{l}$) 3
at least six points plotted correctly **(-1 for each incorrect point plotted)** 2 x 3
straight line drawn **(consistent with plotted points)** 3
good distribution (about straight line) 3
T^2 proportional to l / $T \propto \sqrt{l}$ (**valid conclusion from graph required**) 3
straight line through the origin 3

[t^2 vs. l …. .. max. (6 x 3)]

Question 2
In an experiment to measure the wavelength of monochromatic light, a narrow beam of the light fell normally on a diffraction grating. The grating had 300 lines per millimetre. A diffraction pattern was produced. The angle between the second order image to the left and the second order image to the right of the central bright image in the pattern was measured. The angle measured was 40.6^o.

Describe, with the aid of a labelled diagram, how the data was obtained. (9)

diagram to show: spectrometer, grating labelled, light source // laser, grating labelled, screen 3
(-1 for no label)
focus on / line up /rotate T to obtain image on r.h.s. and note reading; repeat for image on l.h.s
// measure x between 2^{nd} order images on screen and D from screen to grating 3
(-1 if 2^{nd} order image on only one side of n=0 used)
subtract readings (to obtain angle) // use trigonometry /tan / sin / protractor to obtain angle 3
(a valid protractor method … 3 X 3)

How was a narrow beam of light produced? (6)

adjust width of slit (in the collimator/spectrometer) // use a laser 6

Use the data to calculate the wavelength of the monochromatic light. (15)

$n\lambda = d \sin \theta$ 3

$n = 2$ 3

$d = 1/(3.00 \times 10^5)$ m $= 3.33 \times 10^{-6}$ m $= 3.33 \times 10^{-3}$ cm $= 1/300$ mm 3

$\theta = 20.3^0$ 3

$\lambda = 5.78 \times 10^{-7}$ m (= 578 ≈ 580 nm) **(-1 for omission of or incorrect unit)** 3

[If n = 2 used with 40.6^o, (answer λ = 1083 nm), apply –1.
If n = 4 used with 40.6^o, (answer λ = 542 nm), apply -1.
If n = 4 used with 20.3^o, (answer λ = 289 nm), apply -1.]

Explain how using a diffraction grating of 500 lines /mm leads to a more accurate result. (6)

greater angle/distance between images 3
smaller % error (in the measurement of θ) 3

Give another way of improving the accuracy of this experiment. (4)

repeat and get average λ // repeat for different /higher order(s) 4
[specific adjustments to spectrometer // increase D or λ (for laser method) … are acceptable]

Question 3
A cylindrical column of air closed at one end and three different tuning forks were used in an experiment to measure the speed of sound in air. A tuning fork of frequency *f* was set vibrating and held over the column of air.
The length of the column of air was adjusted until it was vibrating at its first harmonic and its length *l* was then measured. This procedure was repeated for each tuning fork.
Finally, the diameter of the column of air was measured.

The following data was recorded.

f/Hz	512	480	426
l/cm	16.0	17.2	19.4
Diameter of column of air = 2.05 cm			

Describe
(i) how the length of the column of air was adjusted;
(ii) how the frequency of the column of air was measured;
(iii) how the diameter of the column of air was measured. (16)

length: (open) pipe <u>raised</u> /<u>lowered</u> while immersed in water // piston moved inside (open) pipe 3

frequency: read <u>frequency</u> (*f*) from (tuning) fork // refer to 'fork of known frequency'
// *f* of air column = *f* of tuning fork 6

diameter: (internal) pipe diameter measured // use a vernier (or digital) calipers
(-1 for omission of 'vernier' or use of metre rule) 7

How was it known that the air column was vibrating at its first harmonic? (9)

(first time) <u>resonance</u> / <u>loud sound</u> is observed 3 x 3

Using all of the data, calculate the speed of sound in air. (15)

$v = f\lambda$ 3

$\lambda = 4(\,l + 0.3\,d)$ 3

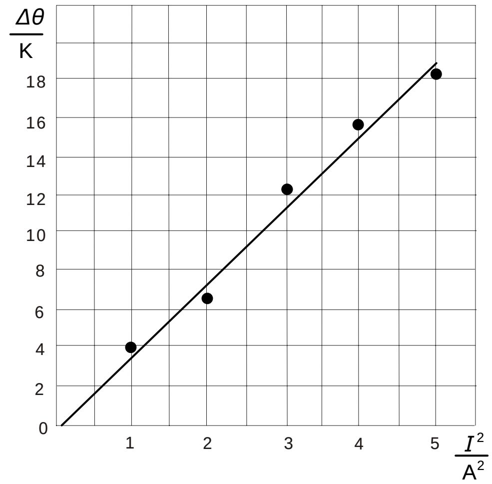
$v_1 = 340(.3)\text{ m s}^{-1}$; $v_2 = 342(.0)\text{ m s}^{-1}$; $v_3 = 341(.1)\text{ m s}^{-1}$ 2 x 3
(3 marks only for *one* or *two* correct values for *v*)

$v_{ave} = 341(.13)\text{ m s}^{-1}$ 3
(-1 for omission of or incorrect unit)

[If 'end correction' not used, award 4 x 3 max. In this case, values calculated are:
$v_1 = 327.7\text{ m s}^{-1}$; $v_2 = 330.24\text{ m s}^{-1}$; $v_3 = 330.58\text{ m s}^{-1}$; ➔ $v_{ave} = 329.5\text{ m s}^{-1}$]

Question 4

In an experiment to verify Joule's law a student passed a current through a heating coil in a calorimeter containing a fixed mass of water and measured the rise in temperature $\Delta\theta$ for a series of different values of the current I. The student allowed the current to flow for three minutes in each case.



Describe, with the aid of a labelled diagram, how the student arranged the apparatus. (12)

apparatus: power supply, coil, ammeter (3 marks per component) 3 x 3

correct arrangement with a means of varying voltage/current and reference to thermometer 3

(-1 if no thermometer)

Why was a fixed mass of water used throughout the experiment? (6)

temperature and current are the variables (in this experiment)
/ cannot involve a third variable (i.e different mass of water)
/ the rise in temperature depends on mass of water 6

(any reference to '*a variable*' merits 3 marks)

The student drew a graph, as shown. Explain how this graph verifies Joule's law. (7)

straight line graph through origin 3

$\Delta\theta \propto I^2$ / $P \propto I^2$ / $P = RI^2$ / P = (constant) I^2 4

Given that the mass of water in the calorimeter was 90 g in each case, and assuming that all of the electrical energy supplied was absorbed by the water, use the graph to determine the resistance of the heating coil. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. (15)

$RI^2\ t = mc\Delta\theta$ 3

correct substitution of values into formula (-1 for each incorrect substitution) 3

correct coordinates of one (or two) point(s) on line // correct Δx and Δy values 3

correct value for slope [acceptable range: 3.7 ↔ 3.9 (K A^{-2})] 3

R = (7.8 ↔ 8.2) Ω **(-1 for omission of or incorrect unit)** 3

[If a data point (in bold) is used in determining slope, … max. 4 x 3]

SECTION B (280 marks)

Answer **five** questions from this section. Each question carries 56 marks.

Question 5 Answer any **eight** of the following parts *(a), (b), (c),* etc.

(a) **State Newton's third law of motion. (7)**

action and reaction are equal // when body A exerts a force on body B, B exerts a force equal in magnitude — 4

(and) opposite // (but) opposite in direction (on A) — 3

(b) **Why is it easier to turn a nut using a longer spanner than a shorter one? (7)**

greater torque / (turning) moment /turning effect — 7

'distance from effort to fulcrum is greater' (4)

(c) **The average value for the solar constant in Ireland is 1.2×10^2 W m^{-2}. What is the average energy falling normally on an area of 5 m^2 of ground in Ireland in 1 minute? (7)**

energy per sec on 5 m^2 = $(1.2 \times 10^2)(5)$ or 600 J

// energy per minute on 1m^2 = $(1.2 \times 10^2)(60)$ or 7200 J (4)

energy per minute on 5 m^2 = $(1.2 \times 10^2)(5)(60)$ or 36,000 J or 3.60×10^4 J — 7

(units not required)

(d) **A sound wave is diffracted as it passes through a doorway but a light wave is not. Explain why. (7)**

wavelength of light (much) less than wavelength of sound — 7

(e) **What is the Doppler effect? (7)**

(apparent) change in frequency (of a wave) — 4

any reference to motion (of S or O or both) — 3

(f) **An RCD is rated 30 mA. Explain the significance of this current. (7)**

RCD trips /switches off / breaks circuit (at 30 mA or greater) — 7

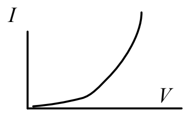
(g) **Why is Coulomb's law an example of the inverse square law? (7)**

$F \;\alpha$ // force inversely proportional to — 4

$1/d^2$ // distance squared — 3

[Formula or expression …. 3 marks. Specific example, e.g. d x 2 ➔ $F/4$ … 7 marks]

(h) **Sketch a graph to show the variation of current with potential difference for a semiconductor diode in forward bias. (7)**



I V labelled graph with non-linear curve — 4

correct shape — 3

(i) **Describe the Bohr model of the atom. (7)**

nucleus (any reference) — 4

electrons in orbit / shells / energy levels — 3

(j) **Name the three negatively charged leptons.**
or
How can a galvanometer be converted into a voltmeter? (7)

Name: electron (e) , muon (μ), tau (τ) — 3+2+2

How: high / large resistance — 4

in series — 3

('use a *multiplier*' .. 4 marks only)

Question 6

Define (i) velocity, (ii) angular velocity. (12)

(i) rate of change // $\frac{dx}{dt}$ / $\frac{ds}{dt}$ 3

of displacement // where (x =) s = displacement 3

['*speed in a given direction*' … 3 marks]

(ii) change in <u>angular displacement</u> /<u>angle</u> // $\frac{d\theta}{dt}$ // $(\omega) = \theta / t$ 3

per sec // θ <u>angular displ</u>. / <u>angle</u> // notation 3

Derive the relationship between the velocity of a particle travelling in uniform circular motion and its angular velocity. (12)

$$\theta = \frac{|arc|}{r} / \frac{vt}{r}$$ 3

$$\theta = \omega t$$ 3

$$\Rightarrow \frac{vt}{r} = \omega t$$ 3

$$v = \omega r$$ 3

Alternative method:
$\theta = s / r$
$\theta / t = s / rt$
$\omega = v / r$
$v = \omega r$

A student swings a ball in a circle of radius 70 cm in the vertical plane as shown. The angular velocity of the ball is 10 rad s^{-1}.
What is the velocity of the ball? How long does the ball take to complete one revolution? (9)

v (= ωr) = (10)(0.70) / 7.0 m s^{-1} 3

$$T = \frac{2\pi r}{v} / \frac{2\pi}{\omega}$$ 3

$$T = \frac{2\pi(0.70)}{7} / \frac{2\pi}{10}$$ / 0.63 s **(-1 for omission of or incorrect unit)** 3

Draw a diagram to show the forces acting on the ball when it is at position A. (6)

weight (W)downwards; <u>force(F)</u> /<u>reaction</u> (R) upwards **(-1 if either force omitted)** 3

centripetal force to left (due to friction or curled fingers) 3

(description without diagram … -1)

The student releases the ball when it is at A, which is 130 cm above the ground, and the ball travels vertically upwards. Calculate
(i) the maximum height, above the ground, the ball will reach;
(ii) the time taken for the ball to hit the ground after its release from A. (17)

$v^2 = u^2 + 2as$ 3

$0 = (7)^2 + 2(-9.8)s$ / s = 2.5(0) m 3

=> max. height = 2.5 + 1.30 / 3.8 m 3

Overall: A => max. height =>ground:

$s = ut + \frac{1}{2}at^2$ 3

$-1.30 = 7t - \frac{1}{2}(9.8)t^2$ 3

(time =) t = 1.59 s **(no penalty applied for units here)** 2

Alternative method for *time taken*:

from point A to max. height: $v = u + at$ / $0 = 7 - 9.8t$ / t = 0.71(43) s (3)

from max. to ground: [$s = ut + \frac{1}{2}at^2$ =>] $3.8 = 0(t) + 4.9t^2$ / t = 0.88 s (3)

total time = 0.71 + 0.88 / 1.59 s **(units not required)** (2)

Question 7
What is meant by the refraction of light? (6)

the bending (of light)	3
on passing from one medium to another	3

(correctly labelled diagram … 2 x 3)

A converging lens is used as a magnifying glass.
Draw a ray diagram to show how an erect image is formed by a magnifying glass. (12)

object inside focal point	3
two (appropriate) rays from object to lens	3
two rays emerge correctly from lens	3
rays produced back to form upright virtual image (on same side as object)	3

[max. of 3 marks if mirror used.
-1 if object or image not labelled.]

A diverging lens cannot be used as a magnifying glass. Explain why. (5)

diminished image	3
<u>always</u> formed	2

The converging lens has a focal length of 8 cm. Determine the two positions that an object can be placed to produce an image that is four times the size of the object? (15)

$1/u + 1/v = 1/f$	3
(magnification =) v / u or I / O stated or implied	3
for real image: $1 / u + 1/4u = 1/8$	3
=> $u = 10$ cm	3
for virtual image: : $1 / u - 1/4u = 1/8$ / $u = 6$ cm	3

(-1 for omission of or incorrect unit ….penalise once only)

The power of an eye when looking at a distant object should be 60 m^{-1}. A person with defective vision has a minimum power of 64 m^{-1}.
Calculate the focal length of the lens required to correct this defect. (12)

$P = P_1 + P_2$	3
$60 = 64 + P_2$ / $P_2 = -4$ (m^{-1})	3
$P = 1/f$ / $f = 1/P$ / $1/f = (-)4$	3
$f = (-)¼$ m / (-)25 cm **[-1 for omission of or incorrect unit]**	3

What type of lens is used? Name the defect. (6)

diverging / concave (lens)	3
short sight / short sightedness / myopia	3

Question 8
Distinguish between fission and fusion. (12)

fission is the splitting of a (large) nucleus 3
into two similar sized / smaller nuclei (with the emission of energy and neutrons) 3

fusion is the joining of two (small) nuclei 3
to form a larger nucleus (with the emission of energy) 3

The core of our sun is extremely hot and acts as a fusion reactor.
Why are large temperatures required for fusion to occur? (5)
nuclei are positively charged 3
(Coulomb / force of) repulsion must be overcome / large energy necessary to join them together 2

In the sun a series of different fusion reactions take place. In one of the reactions, 2 isotopes of helium, each with a mass number of 3, combine to form another isotope of helium with the release of 2 protons.
Write an equation for this nuclear reaction. (12)

correct equation 4 x 3

$${}_{2}^{3}He + {}_{2}^{3}He \rightarrow {}_{2}^{4}He + 2\,{}_{1}^{1}H$$

${}_{2}^{3}He$ (3)

${}_{2}^{4}He$ (3)

${}_{1}^{1}H\,(or\,{}_{1}^{1}p)$ (3)

Controlled nuclear fusion has been achieved on earth using the following reaction.

$${}_{1}^{2}\mathrm{H} + {}_{1}^{3}\mathrm{H} \longrightarrow {}_{2}^{4}\mathrm{He} + {}_{0}^{1}\mathrm{n}$$

What condition is necessary for this reaction to take place on earth?
Calculate the energy released during this reaction. (18)

large (initial) temperature / energy (required to start the reaction) 3

mass of reactants = 8.346×10^{-27} (kg): mass of products = 8.318×10^{-27} (kg) 3
loss in mass /defect mass = 2.8×10^{-29} kg 3
$E = m c^2$ 3
$E = (2.8 \times 10^{-29})(2.998 \times 10^{8})^2$ 3
$E = 2.5166 \times 10^{-12}$ J $\approx 2.52 \times 10^{-12}$ J **(-1 for omission of or incorrect unit)** 3

Give one benefit of a terrestrial fusion reactor under each of the following headings:
(i) fuel;
(ii) energy;
(iii) pollution. (9)

fuel: plentiful / readily available / cheap 3
energy: vast (energy released) / more (energy released gram for gram than from other sources) 3
pollution: no / little (radioactive) waste ; no / few greenhouse gases **(any one of these)** 3

(speed of light = 2.998×10^{-8} m s^{-1}; mass of hydrogen-2 nucleus = 3.342×10^{-27} kg ;
mass of hydrogen-3 nucleus = 5.004×10^{-27} kg; mass of helium nucleus = 6.644×10^{-27} kg;
mass of neutron = 1.674×10^{-27} kg)

Question 9
What is an electric current? Define the ampere, the SI unit of current. (12)

flow of <u>charge</u> / <u>electrons (and + holes)</u> 3

two (infinitely) long parallel wires (of negligible cross-sectional area) 3
1 m apart in vacuum 3
experience a force of 2×10^{-7} N per metre (length) 3

Describe an experiment to demonstrate the principle on which the definition of the ampere is based. (15)

power supply , <u>(two) aluminium(foil) strip(s)</u>/ <u>conducting strip(s)</u> 3
correct arrangement (maybe shown in diagram) 3
(indicate means of keeping) strips parallel 3
switch on current 3
strips <u>move</u> / <u>repel</u> 3

Sketch a graph to show the relationship between current and time for
(i) alternating current;
(ii) direct current. (9)

(i) axes labelled (I and t) 3
sinusoidal curve (at least one full wave) 3
[-1 if + and – current not shown]
(ii) (axes labelled if not already done in a.c. graph showing) correct curve 3

The peak voltage of the mains electricity is 325 V. Calculate the rms voltage of the mains? (6)

$V_{max} = \sqrt{2}\ V_{rms}$ 3
$V_{rms} = 325/\sqrt{2}$ / 229.81 / 230 V **(unit not required)** 3

What is the resistance of the filament of a light bulb, rated 40 W, when it is connected to the mains? (9)
$P = V^2 / R$ 3
$40 = (229.81)^2 / R$ 3
$R = 1320(.32)\ \Omega$ [$R = 1322(.5)\ \Omega$ if $V_{rms} = 230$ V used in calculation] 3
(-1 for omission of or incorrect unit)

Explain why the resistance of the bulb is different when it is not connected to the mains. (5)

cold <u>filament</u> /<u>coil</u> // hot <u>filament</u> /<u>coil</u> 3
has lower resistance // has higher resistance 2

'*resistance of coil depends on temperature* '
/ *different coil temperatures result in different resistance (values)*
/ *heating changes resistance of coil* (3)

Question 10 (a)

[Answer part *(a)* **or** part *(b).*]

(a) **During a nuclear interaction an antiproton collides with a proton. Pair annihilation takes place and two gamma ray photons of the same frequency are produced.**

What is a photon? Calculate the frequency of a photon produced during the interaction. (12)

packet /bundle /quantum of (*electromagnetic* or *light*) energy /radiation 3

m [= mass of proton + mass of antiproton] = 2(1.673 x 10^{-27}) / 3.346 x 10^{-27} kg 3

$E = m\ c^2$ / (3.346 x 10^{-27})(2.998 x $10^{8})^2$ / 3.0074 x 10^{-10} 3

(for one photon:) $f = E / h$ / {1.5037 x 10^{-10} / 6.626 x 10^{-34}} / 2.2694 x 10^{23} Hz 3

{ -1 for omission of or incorrect unit. Also, –1 if final answer is given as 2(2.2694 x 10^{23}) = 4.545 x 10^{23} Hz }

Why are two photons produced? Describe the motion of the photons after the interaction. (9)

so that momentum is conserved / so that momt. before = momt. after 6
they travel in opposite directions 3

How is charge conserved during this interaction? (6)
(total) charge before = +1-1 = 0 3
(total) charge after = 0 since photons have zero charge 3

After the annihilation, pairs of negative and positive pions are produced. Explain why. (6)

energy (of photons) is converted into matter / pair production occurs / to conserve charge 6

Pions are mesons that consist of up and down quarks and their antiquarks. Give the quark composition of (i) a positive pion, (ii) a negative pion. (9)

any quark , antiquark pair 3
π^+ => up and anti-down / $u\bar{d}$ 3
π^- => down and anti-up / $d\ \bar{u}$ 3

List the fundamental forces of nature that pions experience. (6)

electromagnetic, strong (nuclear), weak (nuclear), gravitational (any order) 2+2+1+1

A neutral pion is unstable with a decay constant of 2.5 × 10^{12} s^{-1}. What is the half-life of a neutral pion? (8)

$\lambda\ T_{1/2} = \ln 2$ [= 0.693] 3

$T_{1/2}$ = 0.693 / 2.5 x 10^{12} 3

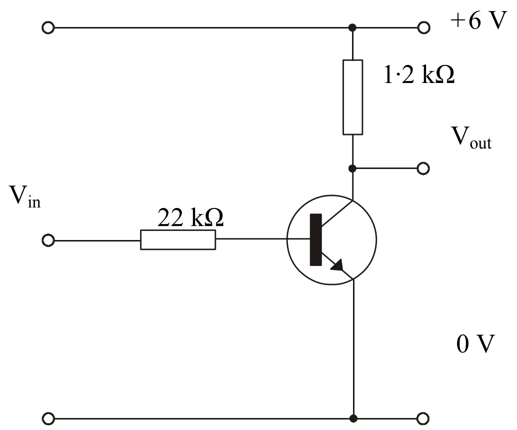
$T_{1/2}$ = 2.772 x 10^{-13} s [≈ 2.8 x 10^{-13} s] **(-1 for omission of or incorrect unit)** 2

(mass of proton= 1.673 × 10^{-27} kg; Planck constant = 6.626 × 10^{-34} J s;
speed of light = 2.998 × 10^8 m s^{-1})

Question 10 (b)

[Answer part *(a)* **or** part *(b)*.]

(b) **What is a transistor? Describe the structure of a bipolar transistor. (12)**



<u>electronic</u> / <u>semiconductor</u> device 3
acts as a <u>switch</u> / <u>amplifier</u> 3

three layers identified as pnp or npn 3
emitter, base, collector clearly identified in the structure (i.e. base between e and c) 3

The circuit diagram represents a voltage inverter.
What is the function of each resistor in the circuit? (6)
1.2 k forms part of a potential divider circuit / 1.2 k enables V_{out} across Tr1 to be changed 3
22 k is a protective resistor / 22 k limits current to (base of) transistor 3

Explain why the output voltage is almost 0 V when the input voltage is 6 V. (12)
(large) base current 3
Tr1 switched on / I_c flows 3
Tr1 resistance (very) low / large V across the 1.2 k 3
output voltage across Tr1 almost 0 V 3

Calculate the collector current when the input voltage is 6V.
(Assume that the output voltage is 0 V). (9)

$I = V/R$ 3
$I = 6/1200$ 3
$I = 0.005$ A **(-1 for omission of or incorrect unit)** 3

A voltage inverter is also a NOT gate.
Draw the symbol and truth table for a NOT gate. (12)
correct triangular symbol 3
one input and one output 3

truth table showing: I/P 0 => O/P 1 3
I/P 1 => O/P 0 3

What is the significance of the work of George Boole in modern day electronics? (5)
he developed Boolean algebra / developed the maths(logic) used with logic gates 5

Question 11
Read the following passage and answer the accompanying questions.

The growth of rock music in the 1960s was accompanied by a switch from acoustic guitars to electric guitars. The operation of each of these guitars is radically different.
The frequency of oscillation of the strings in both guitars can be adjusted by changing their tension. In the acoustic guitar the sound depends on the resonance produced in the hollow body of the instrument by the vibrations of the string. The electric guitar is a solid instrument and resonance does not occur.
Small bar magnets are placed under the steel strings of an electric guitar, as shown. Each magnet is placed inside a coil and it magnetises the steel guitar string immediately above it. When the string vibrates the magnetic flux cutting the coil changes, an emf is induced causing a varying current to flow in the coil. The signal is amplified and sent to a set of speakers.
Jimi Hendrix refined the electric guitar as an electronic instrument. He showed that further control over the music could be achieved by having coils of different turns.

(Adapted from Europhysics News (2001) Vol. 32 No. 4)

(a) **How does resonance occur in an acoustic guitar? (7)**
energy is transferred from strings to <u>hollow body</u> / <u>sound box</u> /<u>air within</u> 4
both vibrate at the same frequency 3

(b) **What is the relationship between frequency and tension for a stretched string? (7)**
frequency proportional to / $f \;\alpha$ 4

square root of tension / $\sqrt{T}$ 3

(c) **A stretched string of length 80 cm has a fundamental frequency of vibration of 400 Hz. What is the speed of the sound wave in the stretched string? (7)**
$v = f\lambda$ 4
$v = 400(1.6)$ / 640 m s^{-1} **(-1 for omission of or incorrect units)** 3

(d) **Why must the strings in the electric guitar be made of steel? (7)**
any reference to *magnetism* 7

(e) **Define magnetic flux. (7)**
$(\Phi =)\ BA$ 4
give notation 3

(f) **Why does the current produced in a coil of the electric guitar vary? (7)**
(induced) <u>emf</u> / <u>flux</u> varies (due to amplitude of vibrating string) 7

(g) **What is the effect on the sound produced when the number of turns in a coil is increased? (7)**
louder sound / greater (sound) intensity) / greater amplitude 7

(h) **A coil has 5000 turns. What is the emf induced in the coil when the magnetic flux cutting the coil changes by 8×10^{-4} Wb in 0.1 s? (7)**

$E = (-)N\Delta\phi / \Delta t$ (-1 if N omitted) 4

$E = 5000(8 \times 10^{-4} / 0.1)$ / 40 V 3
(-1 for omission of or incorrect units)

Question 12

Answer any **two** of the following parts *(a), (b), (c), (d).*

(a) **Define pressure. (6)**

force // F/A 3

per unit area // explain notation 3

Is pressure a vector quantity or a scalar quantity? Justify your answer. (6)

scalar 3

it acts in all directions / it has no direction 3

State Boyle's law. (6)

$P \ \alpha\ 1/V$ // PV = constant 3

for a fixed mass of gas at constant temperature 3

A small bubble of gas rises from the bottom of a lake. The volume of the bubble increases threefold when it reaches the surface of the lake where the atmospheric pressure is 1.01×10^5 Pa. The temperature of the lake is 4 °C.

Calculate

(i) the pressure at the bottom of the lake;

(ii) the depth of the lake. (10)

(acceleration due to gravity = 9.8 m s^{-2}; density of water = 1.0×10^3 kg m^{-3})

pressure at bottom (= 3 times pressure at top) = 3.03×10^5 Pa 3

pressure at bottom <u>due to water</u> = 2.02×10^5 Pa 3

$P = h\rho g$ 2

h (= $P / \rho g$) = $2.02 \times 10^5 / [(1.0 \times 10^3)(9.8)]$ / 20.6(1) m 2

(-1 for omission of or incorrect unit)

(b) **List the factors that affect the capacitance of a parallel plate capacitor. (6)**

(common) area (of plates),

distance (apart),

permittivity (of dielectric) / dielectric / medium (between plates) 3 x 2

The plates of an air filled parallel plate capacitor have a common area of 40 cm^2 and are 1 cm apart. The capacitor is connected to a 12 V d.c. supply.

Calculate

(i) the capacitance of the capacitor;

(ii) the magnitude of the charge on each plate. (15)

$$C = \frac{\varepsilon A}{d}$$ 3

$C = [(8.85 \times 10^{-12})(40 \times 10^{-4})] / (0.01)$ …. **(-1 for each incorrect substitution)** 3

$C = 3.5(4) \times 10^{-12}$ F 3

(-1 for omission of or incorrect units)

$Q = CV$ 3

$Q = (3.54 \times 10^{-12})(12)$ / $4.2(5) \times 10^{-11}$ C 3

(-1 for omission of or incorrect units)

What is the net charge on the capacitor? Give a use for a capacitor. (7)

(net charge) = 0 4

blocks d.c. /smoothing /tuning circuits / timing circuits / flash guns (for cameras) 3

(any valid answer)

(permittivity of free space = 8.85×10^{-12} F m^{-1})

Question 12

(c) **Define (i) power, (ii) specific heat capacity. (9)**

(i) work done per second / rate at which work is done 3

(ii) energy/heat required to raise the temperature 3
of 1 kg (of a substance) by 1 K / 1 ^{o}C 3

400 g of water at a temperature of 15 ^{o}C is placed in an electric kettle. The power rating of the kettle is 3.0 kW.
Calculate

(i) the energy required to raise the temperature of the water to 100 ^{o}C;
(ii) the energy supplied by the kettle per second;
(iii) the least amount of time it would take to heat the water to 100 ^{o}C. (15)

$E = m c\Delta\,\theta$ 3
E = (0.40)(4200)(85) / 1.428 x 10^5 J 3
(-1 for omission of or incorrect units)

3000 J (per second) / 3000 W / 3 kW 3
(-1 for omission of or incorrect units)

time taken = (1.428 x 10^5) / (3000) 3
time = 47.6 s ≈ 48 s 3
(-1 for omission of or incorrect units)

In reality, the time taken to heat the water will be greater. Explain why. (4)
energy will be lost to surroundings / absorbed by kettle / lost by evaporation // limescale on element 4

(specific heat capacity of water = 4200 J kg^{-1} K^{-1})

(d) **The first Nobel Prize in Physics was awarded in 1901 for the discovery of X-rays. What are X-rays? Who discovered them? (9)**

electromagnetic radiation 3
of short wavelength / high frequency 3

Rontgen 3

In an X-ray tube electrons are emitted from a metal cathode and accelerated across the tube to hit a metal anode. How are the electrons

(i) emitted from the cathode;
(ii) accelerated? (6)

by thermionic emission / by heating the cathode 3

by the (E.) H.T / high voltage (between the anode and cathode) 3

Calculate the kinetic energy gained by an electron when it is accelerated through a potential difference of 50 kV in an X-ray tube.
Calculate the minimum wavelength of an X-ray emitted from the anode. (13)

E_k (= W) = $q\ V$ 3
= $(1.6 \times 10^{-19})(50 \times 10^3)$ / 8.0×10^{-15} J 3
(-1 for omission of or incorrect units)

$E = h\,c/\lambda$ 3
$\lambda = [6.6 \times 10^{-34} \times 3.0 \times 10^8] / (8.0 \times 10^{-15})$ 2
$\lambda = 2.475 \times 10^{-11}$ m (≈ 2.5×10^{-11} m ==> 0.025 nm) 2
(-1 for omission of or incorrect units)

(Planck constant = 6.6×10^{-34} J s; speed of light = 3.0×10^8 m s^{-1};
charge on electron = 1.6×10^{-19} C)