Question 1

(*d*) State Faraday's law of electromagnetic induction.

(size of an) induced emf is proportional to **(3)**
the rate of change of flux (through a circuit) **(3)**

Describe an experiment to demonstrate Faraday's law.

coil, meter, magnet **(3)**
reading on meter when coil is moved relative to magnet **(3)**
faster movement gives larger reading **(3)**

A hollow copper pipe and a hollow glass pipe, with identical dimensions, were arranged as shown in the diagram. A student measured the time it took a strong cylindrical magnet to fall through each cylinder. It took much longer for the magnet to fall through the copper pipe. Explain why.

(falling) magnet creates changing magnetic flux/field **(3)**
emf induced **(3)**
current flows in copper (only) **(4)**
generating magnetic fields which oppose the motion (of the falling magnet) **(3)**

Question 2

(b) **State the principle on which a moving-coil galvanometer is based.**

a current carrying conductor experiences a force 3
in a magnetic field 3

Draw labelled diagrams to show how a galvanometer may be converted to function as

(i) **an ammeter**
(small) resistance 3
connected in parallel 3

(ii) **a voltmeter.**
(large) resistance 3
connected in series 3

A galvanometer with a resistance of 100 Ω shows a full-scale deflection when a current of 2 mA passes through it. How can the galvanometer be converted to function as an ammeter reading up to 5 A?

$V_{shunt} = V_{galvanometer}$ *(stated or implied)* 3

$I_{shunt} \times R_{shunt} = I_{galvanometer} \times R_{galvanometer}$ 3

$I_{shunt} = 4.998$ A 3

correct substitution 3

$R_{shunt} = 0.0400\ \Omega$ (= 40.016 mΩ) *(–1 for omission of or incorrect units)* 3

Name another device based on the same principle as the moving-coil galvanometer.

(d.c.) motor / moving-coil loudspeaker 6

The induction coil was invented by Dr Nicholas Callan, an Irishman. The diagram shows an induction coil that is used to produce a very high voltage from a low voltage source.
Explain the functions of the parts labelled A and B in the diagram.

A: to generate a large emf 6

B: to produce sparks 6

Give an application of the induction coil.

any correct answer, e.g. create a spark in engine of a car (spark plugs) / electric fence *etc.* 5

Question 10 (b)

What is electromagnetic induction? Who invented the induction coil?

emf induced	3
(when) conductor cuts magnetic flux	3
Callan	3
	9

What is the function of an induction coil?

changes low voltage dc		3
to high voltage dc	**(-1 if d.c. omitted)**	3
		6

In an induction coil, a primary coil with a few turns of thick wire and a secondary coil with many turns of thin wire are wrapped on the same soft -iron core.
Why is there a large number of turns in the secondary coil?

emf (induced) proportional // $E \propto$	3
to number of turns // $(-)N\frac{\Delta\phi}{\Delta t}$	3

(***'to get a large voltage'*, 3 marks)**

Explain why the primary coil has thick wire.

(thick wire) has low resistance // greater efficiency	3
large current (flows) // reduced <u>heating</u>/<u>energy</u> losses	3

Why are both coils wrapped on the same soft -iron core?

greater <u>flux linkage</u>/<u>efficiency</u> // less energy losses	3
	15

List two other types of electromagnetic waves with energy less than that of light waves.

microwaves, infra red	2×3

Give one property that is common to all types of electromagnetic waves.

same speed / travel through vacuum // can be <u>polarised</u> / <u>reflected</u> / <u>diffracted</u> etc.	2
	8

The telephone used to transmit the messages to Dublin contained a moving -coil loudspeaker. Describe, with the aid of a labelled diagram, how a loudspeaker operates.

Diagram showing:	cone, magnet, coil	**(–1 per each missing label)**	3×3
	coil in magnetic field		3
	changing current (in coil)		3
	force on coil / coil vibrates		3
			18

Question 4

Question 10 (b)

State the principle of conservation of energy.

energy cannot be created or destroyed // total energy is constant **(-1 if *conserved* is used instead of *constant*)** 3

may change from one form to another // in a closed system 3

What is the main energy conversion that takes place in an electric motor?

electrical (energy) 3

to mechanical / kinetic (energy) 3

What is the function of :

(i) the commutator,

so that coil rotates in one direction / (it) reverses current (every half-cycle) 5

(ii) the carbon brushes,

to link power supply to coil / to enable current to enter coil (as it rotates) 5

(iii) the magnet, in an electric motor?

to provide a magnetic field / to interact with the current-carrying coil / (to help) create the torque 5

Why does the motor turn when current flows through the coil?

a current-carrying <u>coil</u>/<u>conductor</u> 3

experiences a <u>force</u> /<u>torque</u> 3

in a magnetic field 3

The induction motor was invented by Nicholas Tesla. Give an advantage of an induction motor over a dc motor.

no brushes (to replace)

not affected by (minor) voltage fluctuations

<u>less</u>/ <u>no</u> electrical interference

<u>stabilised</u>/<u>smoother</u>/<u>constant</u> rate of rotation, etc.

less friction

no sparking any *one* advantage 5

Describe an experiment to demonstrate the principle on which the induction motor operates.

apparatus:	aluminum disc, magnet	**(3 marks each item: -1 if magnetic material used)**	2 x 3
arrangement:	place disc on (pointed) pivot		3
procedure:	rotate magnet over disc		3
observation:	disc rotates (in same direction as magnet)		3

Question 12 (c)

State Faraday's law of electromagnetic induction.

induced e.m.f. / voltage is proportional // $E \, \alpha \, d\phi / dt$ **or** $E = d\phi / dt$ (accept E or V) 3

to rate of cutting / change of (magnetic) flux // correct notation 3

Describe an experiment to demonstrate Faraday's law.

apparatus	coil, magnet, galvanometer or equivalent	3
arrangement	connect coil to G	3
procedure	move magnet towards coil	3
observation	the faster the movement, the greater the deflection / (induced) voltage	3

-1 per missing item.
A suitable diagram could merit 3 x 3
Observation must be stated for final 3 marks

A resistor is connected in series with an ammeter and an ac power supply. A current flows in the circuit. The resistor is then replaced with a coil. The resistance of the circuit does not change.

What is the effect on the current flowing in the circuit?

current is reduced 4

Justify your answer.

back emf induced in coil (**-1 if *back* omitted**) // coil has a self-inductance (**-1 if *self* omitted**) // Lenz's law reference 6

Question 6

(i) List three factors that affect the force on a current-carrying conductor placed near a magnet. (7)

magnetic flux density (B), current (I), length (l), sin θ — any three — 3 + 2 + 2

(ii) What energy transformation takes place in an electric motor? (7)

electrical energy — 4

to kinetic energy — 3

(iii) What is the function of a commutator in a dc motor? (7)

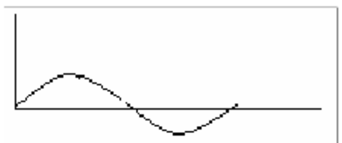
allows current to always flow // so that torque — 4

into the same end of the coil (and out the other end) // is always in the same direction — 3

(iv) Draw a sketch of the output voltage from an ac generator. (7)

varying (voltage) wrt time — 4

sinusoidal shape — 3



(v) How are the slip rings connected to an external circuit in an ac generator? (7)

brushes — 4

springs / carbon / metal — 3

(vi) A transformer and an induction coil can both be used to change a small voltage into a larger voltage. What is the basic difference in the operation of these two devices? (7)

transformer: a.c. input // a.c. output // current flows through secondary — 4

induction coil: d.c.input // (adjusted for) d.c. output // sparks across gap in secondary — 3

(vii) Name the Irish physicist who invented the induction coil. (7)

(Dr. Nicholas) Callan — 7

(viii) Give two factors that affect the efficiency of a transformer. (7)

(I^2R) heat losses in coils / eddy currents (in core) / poor flux linkage / poor core design / hysteresis losses / coil resistance — any two — 4 + 3

Question 7

(*h*) What is the average emf induced in a coil of 20 turns when the magnetic flux cutting it decreases from 2.3 Wb to 1.4 Wb in 0.4 s?

$E = (-)N\left(\frac{\Delta\phi}{\Delta t}\right)$ / $E = (-)\frac{20(0.9)}{0.4}$ — 4

$E = 45$ V — 3

Question 8

What is electromagnetic induction?

conductor / wire / coil / loop cuts magnetic flux 3

emf / voltage induced 3

State the laws of electromagnetic induction.

(magnitude of the) induced emf is proportional to // $E \propto / = \frac{d\phi}{dt}$ 3

rate of cutting flux // notation **(–1 per missing item)** 3

induced current /emf in such a direction 3
as to oppose the change that causes it 3

[If laws given as: $E = -N\frac{d\phi}{dt}$ + notation award a maximum of (3×3) marks]

A bar magnet is attached to a string and allowed to swing as shown in the diagram. A copper sheet is then placed underneath the magnet. Explain why the amplitude of the swings decreases rapidly.

induced voltage/emf in copper 3
current flows (in copper sheet) 3
(generating a) magnetic field 3
opposing motion of magnet 3

(‘damping occurs’ or ‘motion is damped’ …. 2 × 3)

What is the main energy conversion that takes place as the magnet slows down?

kinetic/potential (energy) ➔ heat /electrical (energy) 6

(award 3 marks for any relevant conversion)

A metal loop of wire in the shape of a square of side 5 cm enters a magnetic field of flux density 8 T. The loop is perpendicular to the field and is travelling at a speed of 5 m s^{-1}.

(i) **How long does it take the loop to completely enter the field?**

$t = \frac{5\,\text{cm}}{500\,\text{cm s}^{-1}}$ 3

$t = 0.01$ s 3

(–1 for omission of or incorrect units)

(ii) **What is the magnetic flux cutting the loop when it is completely in the magnetic field?**

$\phi = BA$ 4

$\phi = (8)(0.05 \times 0.05)$ / 0.02 weber 3

(–1 for omission of or incorrect units)

(iii) **What is the average emf induced in the loop as it enters the magnetic field?**

$\text{average emf} = \frac{\Delta\phi}{\Delta t}$ (state/imply) 4

$\text{emf} = \frac{0.02}{0.01}$ / 2 volt 3

(–1 for omission of or incorrect units)

Question 9

Define magnetic flux. (6)

$\phi = BA$ 3

notation 3

State Faraday's law of electromagnetic induction. (6)

(magnitude of the) emf induced (in conductor) is proportional to // E (or e) $\propto$ (or $=$) 3

the rate of change of (magnetic) flux (cutting the conductor) // $\frac{d\phi}{dt}$ 3

A square coil of side 5 cm lies perpendicular to a magnetic field of flux density 4.0 T. The coil consists of 200 turns of wire.
What is the magnetic flux cutting the coil? (9)

$A = (0.05)^2 = 0.0025$ 3

ϕ $(= BA) = (4)(0.0025)$ 3

$\phi = 0.01$ Wb **(-1 for omission of or incorrect unit)** 3

The coil is rotated through an angle of 90° in 0.2 seconds. Calculate the magnitude of the average e.m.f. induced in the coil while it is being rotated. (7)

$E = N(\Delta\phi/\Delta t)$ 3

$\Delta\phi / \Delta t = 0.01 - 0)/0.2$ or $= 0.05$ 2

[E= 200(0.05)] ➔ $E = 10$ V **(-1 for omission of or incorrect unit)** 2

Question 10

(g) **Why does a magnet that is free to rotate point towards the North?**
any reference to (earth's) magnetic field / like poles repel / unlike poles attract 7

Question 11

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 hollow body / sound box /air within 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 / $f \propto$ 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) emf / flux 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

(f) Draw a sketch of the magnetic field due to a long straight current-carrying conductor. (7)
(concentric) circles with arrows (indicating correct direction of field) 4

conductor with arrow (indicating direction of current in the conductor) 3
(no direction for field … -1. no direction for current … -1.)