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The Institution of Electrical Engineers.

GRADUATESHIP EXAMINATION.

MAY, 1938.

ENGLISH.

(Time allowed : 3 hours.)

(Attempt FOUR *questions, including Nos.* 1 *and* 2, *which are awarded more marks than the remaining questions.)*

1. Write an essay (*one hour*) on *one* of the following subjects :—

(*a*) Electrical equipment and its efficiency.
(*b*) Walking tours.
(*c*) A second-hand bookstall.
(*d*) Rubber and its uses.

2. The following passage from *The Times* contains about 540 words. Give the substance of it in a *précis* not exceeding 180 words.

FORESTRY IN ENGLAND

A PERIOD OF TRANSITION

In " the good old days " owners looked on their woods from the point of view of amenity and sport, and not at all as a potential source of income. To them a wood was a thing of beauty and a provider of covert, and to convert it into cash was a disgraceful thing to do. They felt, rightly, that the country's beauty was in their trust, and they accepted it as their duty to hand on that trust intact to their successors.

Gradually, however, it is becoming realized that the negative policy of refusing ever to fell a tree defeats its own ends—the life of a tree is not unlimited, and a dying tree is not a lovely object. Further, it is becoming recognized that the commercial production of timber, if it is sympathetically carried out, is no enemy to the preservation of game. Owners are becoming aware, in fact, that woodlands can produce a steady annual income without detriment to any other interest.

This recognition of the possibilities of forestry is as yet far from universal. For every estate on which the woods are run as a successful commercial proposition there are probably 20 on which the woodlands show a financial loss. But the fact that the management of estate woodlands should be as much of a commercial undertaking as any other industry is becoming increasingly realized, and because of this, it is not too optimistic to look forward to a real improvement in home-grown timber production in the future. There are obstacles to be overcome if the forest industry is to be put on a sound basis, but none of them are insurmountable. Most of them are a legacy from the past. Chief among them are lack of silvicultural knowledge, and lack of organized marketing.

To make good the lack of available silvicultural knowledge three possibilities suggest themselves—the institution at the universities of more comprehensive courses in British forestry for the education of future owners and agents ; the initiation of a Woodland Advisory Service to cover the whole country ; and the provision of facilities for the thorough training of estate foresters. The training courses for woodmen, which have recently been started, are a step in the right direction, but much more remains to be done, and it is hoped that in the not far distant future the whole question of forest education will be tackled seriously on the general lines suggested above.

The importance of marketing can hardly be exaggerated. Until the last few years no attempt was made to secure a sustained output of timber from the country's woodlands as a whole. Production was irregular in the extreme, and the produce was largely of indifferent quality. The formation of the Home-Grown Timber Marketing Association is at any rate an indication that producers are beginning to realize that without organized marketing and a sustained yield there can be no assured price or market. It is true that good marketing is at present carried out only on a small minority of estates, but the number is increasing steadily, and this increase is the best augury for improved and stabilized prices in the future.

3. As an exercise in the workmanlike use of words define and describe *three* of the following :—

a thermos flask, the dial of a watch, a pair of garden shears, a flange, a hacksaw, a bicycle tyre.

4. Explain the following words and phrases taken from the passage in Question 2.

amenity, potential source of income, detriment, the provision of facilities, indifferent quality, organized marketing, stabilized prices.

5. Write two letters, (*a*) asking for three fountain-pens to be sent to you on approval, (*b*) returning two of them and paying for the third.

APPLIED MECHANICS (INCLUDING STRENGTH OF MATERIALS).

(*Time allowed : 3 hours.*)

(*Not more than* SIX *questions to be attempted.*)

Candidates are expected to show by their answers that they are conversant with the mechanical principles involved in the questions. A mere numerical calculation from a formula, without any explanation, will receive little credit.

1. A uniform ladder rests with its foot on horizontal ground, and its upper end against a vertical wall. If the coefficient of friction between the ladder and both wall and ground is 0·3, find the least angle of inclination to the horizontal at which it will rest without slipping.

2. The system of levers in a small testing machine is shown diagrammatically in Fig. 1. A load is applied to a specimen at F

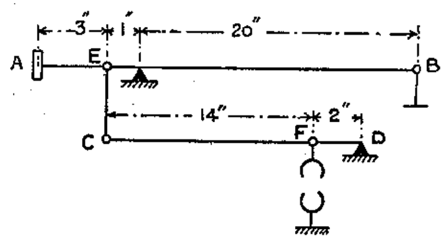

FIG. 1.

by means of weights placed on a pan at B. The levers AB and CD, of uniform section, weigh 6 lb. and 4 lb. respectively ; the link EC and the shackle at F each weighs 2 lb., and the pan at B weighs 1 lb. Find (*a*) the counterpoise to be placed at A in order to balance the system under zero load, and (*b*) the weight then required to be placed on the pan at B in order to produce a load of 800 lb. on the specimen.

3. A locomotive developing 1 000 h.p. draws a train weighing 500 tons at 60 miles per hour along a level track. Assuming the power and resistances to remain constant, at what steady speed will the train climb a gradient of 1 in 200 ? If, while on the gradient, the steam is shut off, how far will the train then travel, and what time will elapse, before it comes to rest without applying the brakes ?

4. A flywheel mounted on a shaft is subjected to an external torque of 10 lb.–ft., which increases the speed of revolution from zero to 200 r.p.m. in 10 minutes. On reaching this speed the external torque is removed, and the flywheel allowed to run down. It comes to rest after a further 15 minutes. Assuming that the moment of the frictional resistances is constant throughout, calculate this moment and the moment of inertia of the flywheel.

5. Two vessels sail simultaneously from two ports A and B. A is due north of, and 100 miles distant from B. The vessel leaving A steers south-west at 9 miles per hour, while that leaving B steers north-west at 12 miles per hour. Determine their distance apart when they are closest to each other, and the time taken to reach these points.

6. A bullet weighing 0·1 lb. is fired horizontally into, and remains embedded in, a block of wood weighing 50 lb., suspended by wires 10 ft. long so as to act as a pendulum. If, after impact, the pendulum swings through an angle of 15 deg. to the vertical, calculate the speed of the bullet.

7. A body having a mass of 5 lb. is attached to the lower end of a vertical spring, and oscillates vertically with a frequency of 2 per sec., and an amplitude of 3 inches. Calculate the maximum kinetic energy of the mass, and the maximum tension in the spring.

8. A horizontal bar 2 in. diameter and 60 ft. long is lifted by two vertical slings placed 13 ft. from each end. The bar weighs 10 lb. per ft. Find the greatest stress in the bar, and the point at which it occurs.

9. A cast-iron beam has the cross-section shown in Fig. 2. If the maximum stress is given by $\frac{M}{Z}$, where M is the bending moment, find the value of Z.

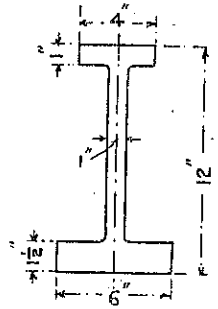

FIG. 2.

10. Obtain an expression for the strain energy per unit volume absorbed by an elastic body subjected to a uniform tensile stress.

Calculate the total strain energy in a round bar 10 ft. long, the central 5 ft. being 1 in. diameter, and the remainder 2 in. diameter, when a tensile load of 10 tons is applied. Compare this with the energy that would be absorbed if the bar were 1 in. diameter throughout. $E = 13\,400$ tons per sq. in.

11. Deduce the equations connecting twisting moment, maximum shear stress, and angle of twist in a round shaft.

A shaft is required to transmit 120 h.p. at 300 r.p.m. The angle of twist must not be greater than 1 deg. in a length of 20 diameters. Find the least diameter required.

Modulus of rigidity 12 000 000 lb. per sq. in.

12. Determine the forces (stating whether tension or compression) in each member of the frame shown in Fig. 3.

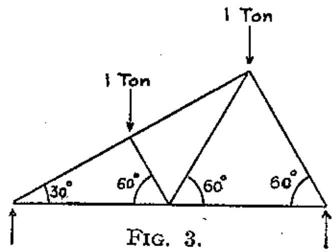

FIG. 3.

HEAT, LIGHT AND SOUND.

(*Time allowed : 3 hours.*)

(*Attempt not more than* TWO *questions in each Section.*)

HEAT.

1. Distinguish between the coefficient of apparent expansion and that of absolute expansion of a liquid, and obtain a relationship between them. Describe a simple method of finding directly the coefficient of absolute expansion of a liquid.

The density of mercury at 0° C. is 13·596 grammes per c.c. and at 100° C. it is 13·352 grammes per c.c. Find the mean coefficient of expansion of mercury over this range of temperature.

2. Describe and explain a modern method for the determination of the mechanical equivalent of heat, showing how the result is obtained from the observations made and stating the precautions required to ensure accuracy.

Explain also how the mechanical equivalent of heat may be found from the specific heats of a gas at constant pressure and at constant volume.

3. Discuss the principal phenomena associated with the change of state from solid to liquid.

100 grammes of ice at — 10° C., and 1 000 grammes of molten lead at 400° C., are mixed in a vacuum vessel. The resulting temperature is 74° C. Calculate the melting point of lead. The latent heat of fusion of ice is 80 and of lead 5·4 calories per gramme, and the specific heats of ice, of molten lead and of solid lead, are 0·5, 0·04, and 0·03, respectively.

4. Give a short account of the characteristics and properties of radiant heat.

Describe and explain how it may be shown that (*a*) radiant heat is reflected and refracted in the same way as light, (*b*) the radiating and absorbing powers of a surface are directly proportional to one another.

LIGHT.

5. State the laws of reflection of light, and apply them to deduce an expression which may be used to calculate the focal length of a spherical mirror in terms of the distances from the mirror of an object and the image produced by the mirror.

Explain how a concave spherical mirror may be used to produce either a real or a virtual image of an object.

6. Explain the terms " total internal reflection " and " critical angle."

Describe briefly *either* a natural phenomenon due to total internal reflection, *or* a practical application of it.

Rays of light from a luminous point on the lower face of a rectangular glass slab 2 cm. thick strike the upper face. The totally reflected rays outline a circle of radius 3·55 cm. on the lower face of the slab. Find the refractive index of the glass.

7. A convergent lens, between an object and a screen D cm. apart, produces a real image on the screen when placed in either of two positions separated by d cm. Obtain an expression for the focal length of the lens in terms of these distances.

An image of an object placed perpendicular to the axis of a convergent lens is formed on a screen and is 0·5 cm. in width. The object and screen remaining fixed in position, it is found that when the lens is moved 20 cm. along its axis an image 2 cm. in width is formed on the screen. Find the focal length of the lens and the width of the object.

8. Explain what is meant by deviation, dispersion, and dispersive power, for light passing through a prism of transparent material. Obtain expressions for these quantities in the case of a prism of small refracting angle.

Explain also how two prisms may be combined to produce dispersion without deviation.

SOUND.

9. Describe how the frequency of a tuning fork may be determined by using a sonometer, no other tuning fork being available.

A sonometer wire of length 50 cm. is in unison with a tuning fork. The weights stretching the wire are then immersed in water when the length of the wire in unison with the tuning fork becomes 45 cm. Find the ratio of the tensions of the wire in the two cases, and determine the specific gravity of the material of the weights.

10. A closed organ pipe and an open organ pipe have the same fundamental frequency. Explain why the qualities of the notes produced by the two pipes are different.

Describe how (*a*) the formation of nodes and antinodes may be demonstrated, (*b*) the end correction may be determined.

11. Explain carefully how beats are produced, and show how their frequency is related to the frequencies of the vibrating sources producing them.

An organ pipe is in unison with a tuning fork of frequency 288, both being at a temperature of 15° C. What will be the frequency of the beats if the temperature is reduced to 0° C. ? The velocity of sound in air at 0° C. is 332 metres per second.

12. Write a short account of any two of the following : (*a*) resonance, (*b*) the production and practical use of echoes, (*c*) the Doppler effect.

INORGANIC CHEMISTRY.

(*Time allowed : 3 hours.*)

(*Not more than* SIX *questions to be attempted.*)

1. State fully the experimental evidence and reasoning on which is based the conclusion that the gramme-molecular weight of any gas occupies approximately a volume of 22·4 litres at 0° C. and 760 mm. pressure.

2. What are the chief ores of zinc and how is the metal extracted from one of them ?

Give an account of the reactions of this metal with (*a*) sulphuric acid, (*b*) sodium hydroxide.

3. Discuss the principles involved in the process of liquefaction of gases on a large scale.

Mention some of the more important uses to which liquid air is now put.

4. How is ethylene usually prepared ? What impurities are usually present and how may they be removed ?

10 c.c. of a gaseous hydrocarbon were exploded with an excess of oxygen. A contraction of 15 c.c. was observed. After the explosion treatment of the residual gases with potassium hydroxide produced a further contraction of 20 c.c. Deduce the molecular formula of the hydrocarbon.

5. Distinguish briefly but clearly between thermal dissociation and thermal decomposition, and describe an experiment in which thermal dissociation may be shown to have taken place.

Calculate the degree of dissociation of ammonium chloride at 400° C. if at that temperature the vapour density is 14·5.

H = 1 ; N = 14 ; Cl = 35·5.

6. Describe two methods for obtaining phosphorus from calcium phosphate.

How may yellow phosphorus be converted into (*a*) orthophosphoric acid, (*b*) phosphorus pentachloride ?

7. Discuss the action of nitric acid of various concentrations on copper.

How could (*a*) nitrogen, (*b*) oxygen, be obtained from nitric acid ?

8. Name the more important types of oxides. State, from a consideration of their reactions, to which types the following oxides belong : Nitric oxide, lead dioxide, magnesium oxide, aluminium oxide, stannic oxide, nitrogen tetroxide.

9. From what sources, and by what methods, is iodine obtained ? State the reactions which occur when—

(*a*) Hydrogen sulphide is passed into an aqueous suspension of iodine ;

(*b*) Iodine is added to (*a*) cold and (*b*) hot solutions of potassium hydroxide.

10. How is carbon monoxide obtained (*a*) in the laboratory, (*b*) on a large scale ? Write a brief account of the more important uses of this gas in industry.

11. Describe fully the action of heat on the following substances : (*a*) Potassium chlorate, (*b*) ammonium dichromate, (*c*) mercuric nitrate, (*d*) orthophosphoric acid, (*e*) sulphur.

12. Give in each case two tests for distinguishing between : (*a*) Sodium sulphite and sodium sulphate ; (*b*) methane and hydrogen ; (*c*) calcium carbonate and zinc carbonate ; (*d*) nitrous oxide and oxygen ; (*e*) ferrous sulphide and a mixture of iron and sulphur.

ELECTRICAL TECHNOLOGY.

(Time allowed: 3 hours.)

(SIX *questions, in all, to be answered;* THREE *in Part A and* THREE *in Part B.)*

Candidates are expected to show by their answers that they are conversant with the electrical principles involved in the questions. A mere numerical calculation from a formula, without any explanation, will receive little credit.

PART A.

1. A battery with an e.m.f. of 12 volts and a resistance of 0·2 ohm supplies three circuits, *a*, *b*, and *c*, arranged in parallel. *a* has a resistance of 3 ohms, *b* of 10 ohms, and *c* a total resistance of 1 ohm, with a back e.m.f. of 8 volts. Find the current flowing in each branch and the p.d. at the terminals of the battery.

2. Explain what is meant by the electrical equivalent of heat. A condenser having a capacitance of 20 μF is charged to a potential difference of 1 000 volts. If the condenser is discharged through a wire 10 cm. long and 0·5 mm. in diameter weighing 0·15 gramme, estimate the temperature to which the wire will be raised if all the energy in the condenser is used in heating it.

Specific heat of wire = 0·09.

3. Describe the chemical reactions which take place in one form of secondary battery during charge and discharge, and define "ampere-hour efficiency" and "watt-hour efficiency."

The relation between the discharge current I and the time of discharge t of a battery is given by $I^n t = K$, where n and K are constants. If a battery gives a discharge of 20 amperes for 8 hours and a discharge of 40 amperes for 2·6 hours, find for how long it will give a discharge of 30 amperes.

4. A conductor rail has a cross-section of 15 cm^2. and a specific resistance of 7·6 microhms per cm. cube at 0° C. If the temperature coefficient of the material is 0·005 per deg. C, estimate its resistance in ohms per kilometre when the temperature of the conductor is 50° C. Find also the voltage-drop and the watt loss per metre when the conductor is carrying a current of 1 500 amperes at this temperature.

5. Define the terms "Magnetomotive force" and "Flux density," and work out the equation for determining the number

of ampere-turns needed to send a given magnetic flux round a magnetic circuit. A circular iron ring 20 cm. in diameter has an air-gap 1 mm. wide cut in it. The area of cross-section of the iron is 3·6 cm^2. Estimate the number of ampere-turns needed to send a flux of 50 000 maxwells (0·0005 weber) through the air-gap. Neglect fringing, and assume the relative permeability of the iron to be 650.

6. Describe, with sketches, the connections of a direct-reading potentiometer, and show how it may be used (*a*) to measure the e.m.f. of a primary battery, (*b*) to calibrate an ammeter reading to about 30 amp. State what additional apparatus is required for the tests.

PART B.

7. Obtain an expression for the e.m.f. developed by a direct-current dynamo in terms of the flux per pole, the speed, the number of armature conductors, the number of poles, and the number of circuits through the armature.

Show that the torque exerted by a given armature may be estimated in terms of these quantities and the current flowing through the armature.

8. Describe, with sketches and diagram of connections, a motor starter suitable for a direct-current motor of about 10 h.p.

A 10-h.p. 230-volt motor with an armature of 0·2 ohm resistance has an efficiency of 85% at full load. If the maximum permissible current at starting is the full-load current, and if the current is allowed to fall to 75% of its full load value before altering the resistance, find the resistances necessary in the first three steps of the starter.

9. Explain what is meant by the phase difference between two alternating currents.

A circuit having a resistance of 10 ohms and an inductance of 0·06 henry is connected in parallel with a condenser having a capacitance of 80 μF and an effective resistance of 5 ohms across a 200-volt 50-cycle a.c. supply.

Estimate the currents flowing in each circuit, and the phase difference between them. Find also the total current taken from the supply.

10. Draw a vector diagram for a transformer, showing the phase relations between the primary and secondary voltages and currents.