Pearson BTEC Level 3 Nationals Extended Diploma

January 2020

Paper Reference **31706H**

Engineering

Unit 1: Engineering Principles

Information Booklet of Formulae and Constants

Do not return this Information Booklet with the question paper.

Instructions

- You will need the information in this booklet to answer most questions. You may need to recall a few formulae and constants that are not provided in this booklet and you may be rewarded for doing so.
- Read the information carefully.
- You must not write your answers in this booklet.
- Only your answers given in the question paper will be marked.

Turn over ▶

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Formulae and constants

Maths

Laws of indices

$a^m \times a^n = a^{(m+n)}$

$\frac{a^m}{a^n} = a^{(m-n)}$

$(a^m)^n = a^{mn}$

Laws of logarithms

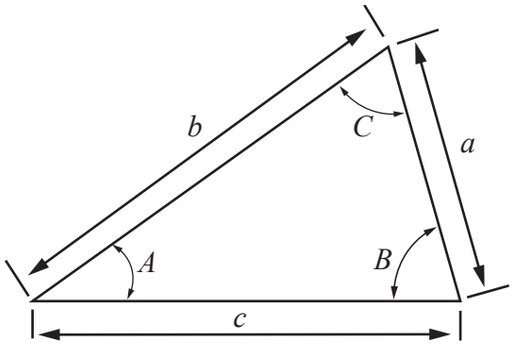
$\log AB = \log A + \log B$

$\log \frac{A}{B} = \log A - \log B$

$\log A^n = n \log A$

Note: the laws apply to Naperian/natural logarithms $ln(\square)$

Trigonometric rules



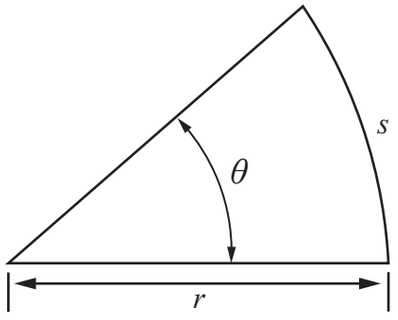
Sine rule

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \quad \text{or} \quad \frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

Cosine rule

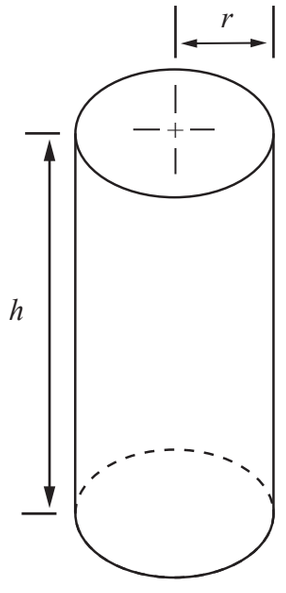
$a^2 = b^2 + c^2 - 2bc \cos A$

Volume and area of regular shapes



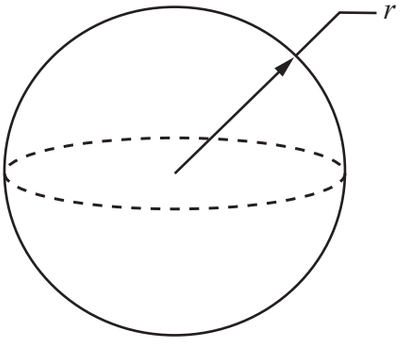
Length of an arc of a circle $s = r\theta$ (where θ is expressed in radians)

Area of a sector of a circle $A = \frac{1}{2} r^2\theta$ (where θ is expressed in radians)



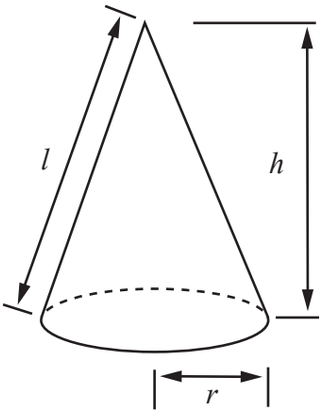
Volume of a cylinder $V = \pi r^2 h$

Total surface area of a cylinder $TSA = 2\pi rh + 2\pi r^2$



Volume of sphere $V = \frac{4}{3}\pi r^3$

Surface area of a sphere $SA = 4\pi r^2$



Volume of a cone $V = \frac{1}{3}\pi r^2 h$

Curved surface area of a cone $CSA = \pi r l$

Quadratic formula

To solve $ax^2 + bx + c = 0$, $a \neq 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Physical constants

Acceleration due to gravity $g = 9.81\text{m/s}^2$

Permittivity of free space $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ H/m

Equations of linear motion with uniform acceleration

v = final velocity, u = initial velocity, a = acceleration, t = time and s = distance

$v = u + at$

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

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

$s = \frac{1}{2}(u + v)t$ or $s = \frac{u + v}{2}t$

Stress and strain

Direct stress	$\sigma = \frac{F}{A}$
Direct strain	$\varepsilon = \frac{\Delta l}{l}$
Shear stress	$\tau = \frac{F}{A}$
Shear strain	$\gamma = \frac{a}{b}$
Young's Modulus (modulus of elasticity)	$E = \frac{\sigma}{\varepsilon}$
Modulus of rigidity	$G = \frac{\tau}{\gamma}$

Work, power, energy and forces

Force	$F = ma$
Components of forces	$F_x = F\cos\theta$, $F_y = F\sin\theta$ (where θ is measured from the horizontal)
Mechanical work	$W = Fs$
Mechanical power	$P = Fv$, $P = \frac{W}{t}$
Mechanical efficiency	$\text{Efficiency } (\eta) = \frac{P_{out}}{P_{in}}$
Force to overcome limiting friction	$F = \mu N$ (where N is the normal force)
Gravitational potential energy	$PE = mgh$
Kinetic energy	$KE = \frac{1}{2}mv^2$

Angular parameters

Centripetal acceleration	$a = \omega^2 r$ or $a = \frac{v^2}{r}$
Power	$P = T\omega$
Rotational inertia	$I = kmr^2$ The inertial constant: k = 0.5 for a solid cylinder (flywheel) k = 1 for a thin walled hollow cylinder (along the axis of rotation).
Rotational kinetic energy	$KE = \frac{1}{2} I\omega^2$
Angular frequency	$\omega = 2\pi f$
Frequency	$f = \frac{1}{\text{time period}}$
Radians to degrees conversion	$\theta_{(\text{degrees})} = \frac{360\theta_{(\text{radians})}}{2\pi}$ (where 2π radians = $360°$)
Degrees to radians conversion	$\theta_{(radians)} = \frac{2\pi\theta_{(\text{degrees})}}{360}$

Fluid principles

Continuity of volumetric flow	$A_1 v_1 = A_2 v_2$
Continuity of mass flow	$\rho A_1 v_1 = \rho A_2 v_2$
Hydrostatic thrust on an immersed plane surface	$F = \rho g A x$
Density	$\rho = \frac{m}{V}$

Static and DC electricity theory

Current/electron flow	$I = \frac{q}{t}$
Coulomb's law	$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$
Resistance	$R = \frac{pl}{A}$
Resistance: temperature coefficient	$\frac{\Delta R}{R_0} = \alpha \Delta T$
Ohm's Law DC circuit	$I = \frac{V}{R}$
Total for resistors in series	$R_T = R_1 + R_2 + R_3 \ldots$
Total for resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots$
Power	$P = IV,\ P = I^2R,\ P = \frac{V^2}{R}$
Electrical efficiency	$\text{Efficiency } (\eta) = \frac{P_{out}}{P_{in}}$
Kirchhoff's Current Law	$I = I_1 + I_2 + I_3 \ldots$
Kirchhoff's Voltage Law	$V = V_1 + V_2 + V_3 \ldots$ or $\sum pd = \sum IR$

Capacitance

Capacitance	$C = \frac{\varepsilon A}{d}$
Time constant	$\tau = RC$
Charge stored	$Q = CV$
Energy stored in a capacitor	$W = \frac{1}{2} CV^2$
Capacitors in series	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \cdots$
Capacitors in parallel	$C_T = C_1 + C_2 + C_3 \ldots$
Voltage across a discharging capacitor	$V_c = V_s e^{\left[\frac{-t}{\tau}\right]}$ (where V_c = capacitor voltage and V_s = supply voltage)

Magnetism and electromagnetism

Electric field strength	$E = \frac{F}{q}$ or $E = \frac{V}{d}$ for uniform electric fields
Magnetic flux density	$B = \frac{\Phi}{A}$
Magneto motive force	$F_m = NI$
Magnetic field strength or magnetising force	$H = \frac{NI}{l}$
Permeability	$\frac{B}{H} = \mu_0 \mu_r$
Reluctance	$S = \frac{F_m}{\Phi}$
Induced EMF	$E = Blv$, $E = -N\frac{\mathrm{d}\Phi}{\mathrm{d}t} = -L\frac{\mathrm{d}i}{\mathrm{d}t}$
Energy stored in an inductor	$W = \frac{1}{2} LI^2$
Inductance of a coil	$L = N\frac{\Phi}{I}$
Transformer equation	$\frac{V_1}{V_2} = \frac{N_1}{N_2}$

Single Phase Alternating Current Theory

Time period	$T = \frac{1}{f}$
Capacitive reactance	$X_c = \frac{1}{2\pi fC}$
Inductive reactance	$X_L = 2\pi fL$
Ohm's Law AC circuits	$I = \frac{V}{Z}$
Root mean square voltage	$\text{r.m.s. voltage} = \frac{\text{peak voltage}}{\sqrt{2}}$
Total impedance of an inductor in series with a resistance	$Z = \sqrt{X_L^2 + R^2}$
Total impedance of a capacitor in series with a resistance	$Z = \sqrt{X_c^2 + R^2}$
Waveform average value	$\text{Average value} = \frac{2}{\pi} \times \text{maximum value}$
Form factor of a waveform	$\text{Form factor} = \frac{\text{r.m.s. value}}{\text{average value}}$

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson BTEC
Level 3 Nationals
Extended Diploma

Centre Number | | | | | | |

Learner Registration Number | | | | | | | | |

Monday 13 January 2020

Morning (Time: 2 hours) | Paper Reference **31706H**

Engineering

Unit 1: Engineering Principles

You must have:
Information Booklet of Formulae and Constants
Ruler, protractor, pencil and calculator.

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and learner registration number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- You may need to recall a few formulae and constants that are not provided in the Information Booklet of Formulae and Constants and you may be rewarded for doing so.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You may use a non-programmable calculator that does not have the facility for symbolic algebraic manipulation or allow the storage and retrieval of mathematical formulae.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question, show all your working and always answer to an appropriate degree of accuracy.

Turn over ▶

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SECTION A

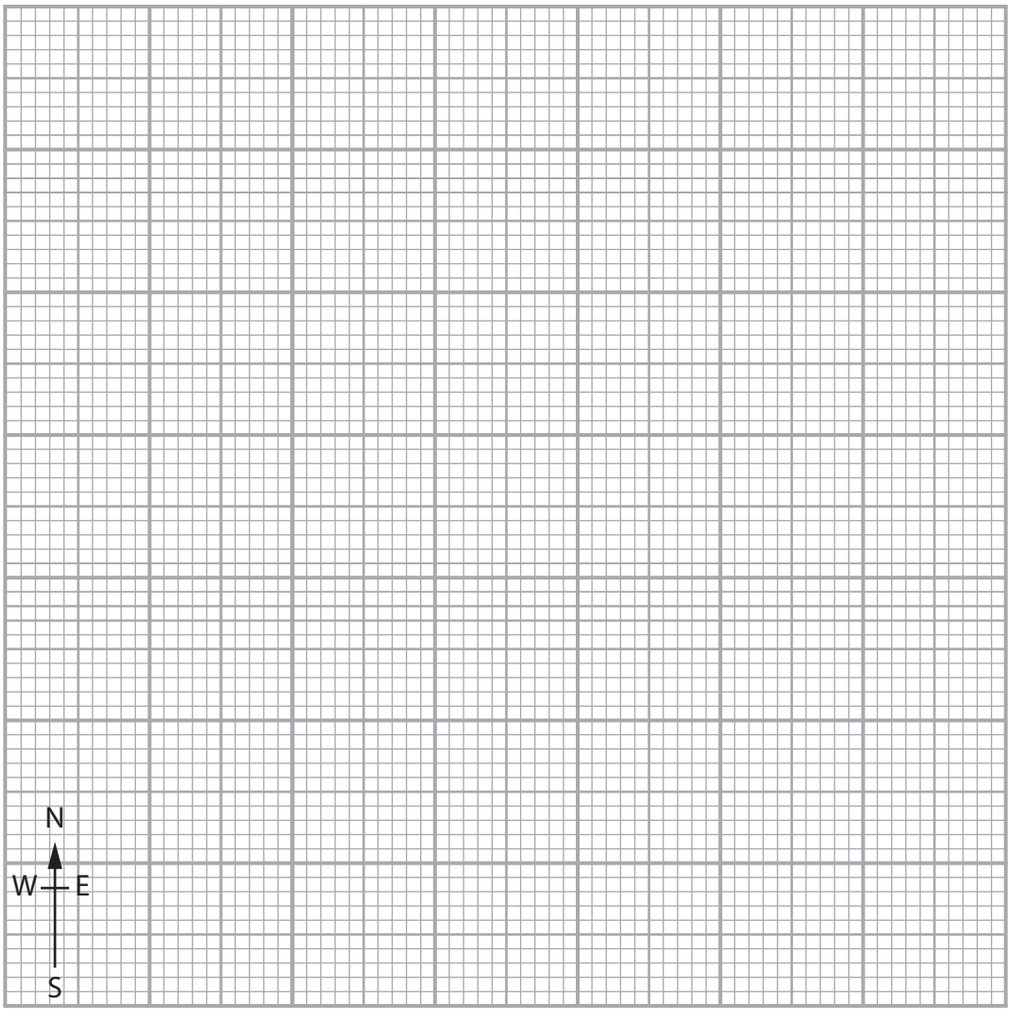
Applied Mathematics

Answer ALL questions. Write your answers in the spaces provided.

1 An aeroplane travels east at a velocity of 250 m/s and at the same time is blown north with a velocity of 50 m/s.

Draw a vector diagram of the velocities, including the resultant velocity of the aeroplane.

You should include labels and axes values on your diagram.



(Total for Question 1 = 4 marks)

2 The diagram shows a cone that is used to provide a reference line.

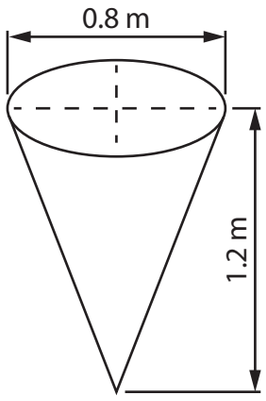


Diagram not to scale

Calculate the volume of the cone.

Answer: .....

(Total for Question 2 = 3 marks)

3 A helicopter takes off vertically from the ground and is stationary at point A.

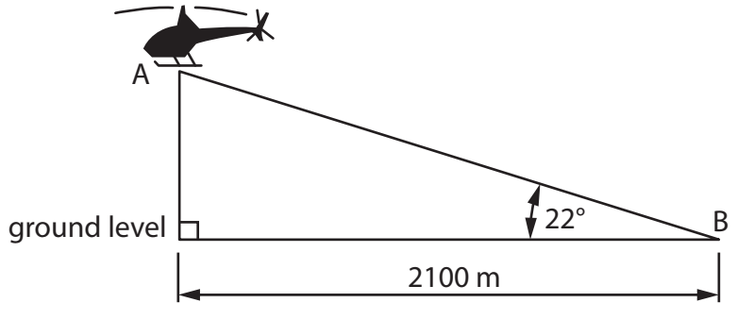


Diagram not to scale

The helicopter is observed from point B.

Calculate the height above ground level of the helicopter at point A.

Answer: .....

(Total for Question 3 = 4 marks)

4 The results of tests on an electronic circuit are represented by the following simultaneous equations:

Equation 1: $12a + 3b = 16$
Equation 2: $4a + 15b = 24$

Calculate the values of a and b.

Answer: .....

(Total for Question 4 = 4 marks)

5 Air pressure is represented by the formula:

$$P = P_0 e^{\frac{h}{k}}$$

where P is the pressure at height h and P_0 is the air pressure at sea level.

(a) Simplify the formula using logarithms and make h the subject of the formula.

(4)

Answer: .....

(b) Calculate the value of h when $P = 70 \times 10^3$ Pa, $P_0 = 100 \times 10^3$ Pa, and $k = -8150$

(1)

Answer: .....

(Total for Question 5 = 5 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Mechanical Principles

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

6 Identify **one** method that would be used to find the density of a material.

- ☒ **A** Archimedes' principle
- ☒ **B** Kirchhoff's law
- ☒ **C** Newton's law
- ☒ **D** Pythagoras' theorem

(Total for Question 6 = 1 mark)

7 Identify the unit of measure for shear stress.

- ☒ **A** Kilograms per metre squared
- ☒ **B** Litres squared per second
- ☒ **C** Metres squared per second
- ☒ **D** Newtons per metre squared

(Total for Question 7 = 1 mark)

8 A car is on a road with a set of traffic lights ahead.

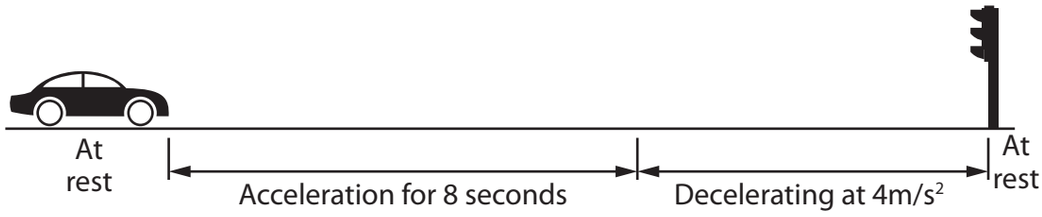


Diagram not to scale

The car starts from rest. The car then accelerates at a constant rate of 3 m/s² for 8 seconds.

(a) Calculate the velocity of the car after 8 seconds.

(2)

Answer: .....

The car then decelerates at a constant rate of 4 m/s² and stops at the traffic lights.

(b) Calculate the distance travelled by the car while it is decelerating.

Give your answer in an appropriate unit.

(4)

Answer: .....

(Total for Question 8 = 6 marks)

9 A bicycle wheel rotates at 120 revolutions per minute. The radius of the bicycle wheel is 280 mm.

(a) Calculate the angular velocity of the bicycle wheel.

(3)

Answer: .....

(b) Calculate the centripetal acceleration of the bicycle wheel.

(3)

Answer: .....

(Total for Question 9 = 6 marks)

10 Explain what is meant by the term non-concurrent forces.

.....

.....

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.....

(Total for Question 10 = 2 marks)

11 A packing crate is placed onto an inclined plane. The inclined plane is friction free.

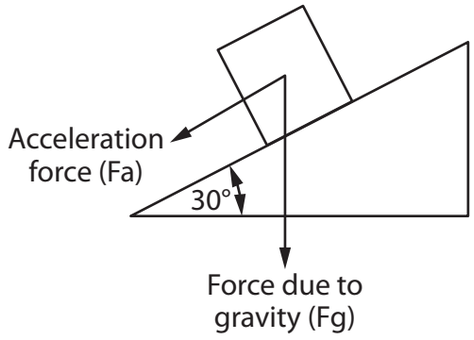


Diagram not to scale

The force due to gravity (Fg) acting on the crate is 75 N.

Calculate the acceleration force (Fa) acting to move the crate down the slope.

Answer: .....

(Total for Question 11 = 5 marks)

12 A storage tank has a capacity of 18 m^3.

The tank is filled with water through a gradually tapering pipe that runs full.

The inlet diameter of the pipe is 50 mm and the outlet diameter is 30 mm.

Assume the water enters the pipe with a velocity of 2 m/s and that the tank is empty.

Calculate the time taken (in seconds) for the tank to fill.

Answer: .....

(Total for Question 12 = 9 marks)

TOTAL FOR SECTION B = 30 MARKS

SECTION C

Electrical and Electronic Principles

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

13 Identify the unit of electrical power.

- ☒ **A** Coulomb
- ☒ **B** Farad
- ☒ **C** Volt
- ☒ **D** Watt

(Total for Question 13 = 1 mark)

14 Identify the property of a material that allows it to store electrical energy in an electric field.

- ☒ **A** Capacitance
- ☒ **B** Hysteresis
- ☒ **C** Permittivity
- ☒ **D** Viscosity

(Total for Question 14 = 1 mark)

15 A variable resistor is used to adjust electrical resistance.

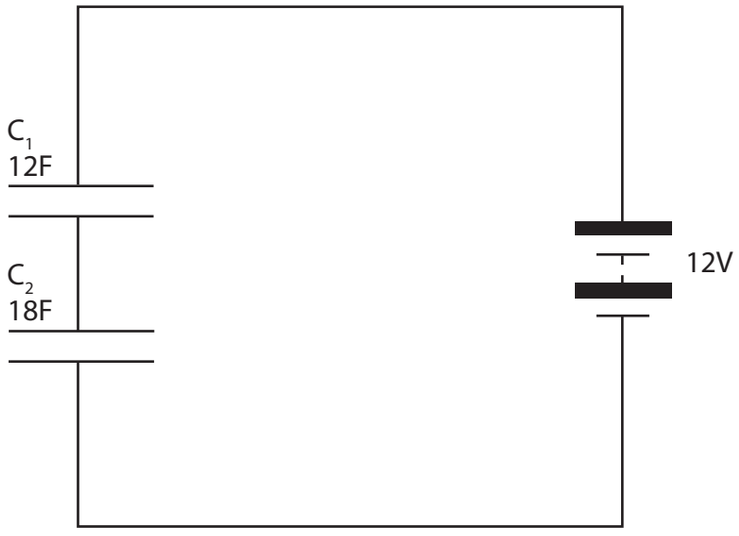
State **one** use of a circuit that includes a variable resistor.

.....

.....

(Total for Question 15 = 1 mark)

16 A DC power source is connected to two capacitors in a series network.



Calculate the total capacitance of the two capacitors.

Answer: .....

(Total for Question 16 = 3 marks)

17 A conductor is connected to a 12V DC supply. A charge of 36 coulombs (C) passes along the conductor in 24 seconds.

(a) Calculate the current in the conductor.

(2)

Answer: .....

(b) Calculate the resistance of the conductor.

(3)

Answer: .....

(Total for Question 17 = 5 marks)

18 A conductor with a length of 250 mm is moving at right angles through a magnetic field of flux 2.2 T. The conductor is moving at a velocity of 8 m/s.

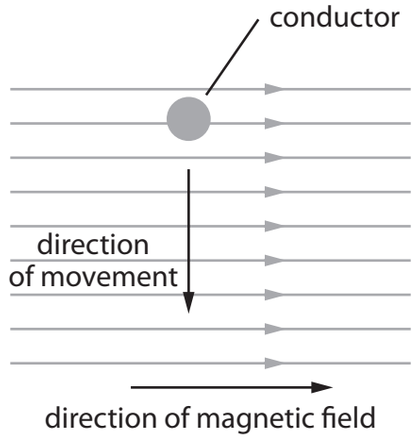


Diagram not to scale

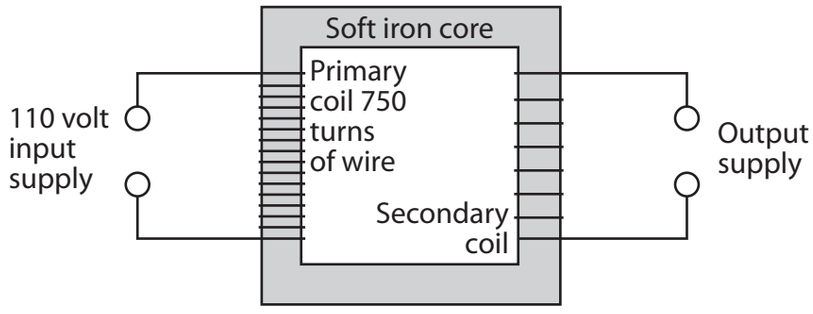
Calculate the induced EMF.

Give your answer in an appropriate unit.

Answer: .....

(Total for Question 18 = 4 marks)

19 A transformer has 750 primary turns and is designed to be supplied by a 110 V AC supply.



A peak voltage of 34 V is required as the output from the transformer.

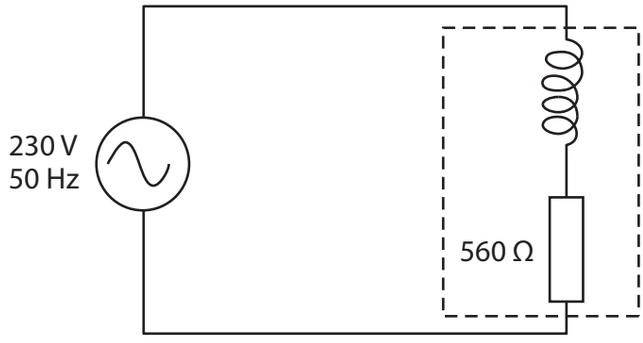
Calculate the number of secondary turns required on the transformer.

Answer: .....

(Total for Question 19 = 6 marks)

20 A coil is connected to a 230 V AC power supply that has frequency of 50 Hz.

The current in the coil is 0.125 A, and the resistance of the coil is 560 Ω.



Calculate the inductance (L) of the coil.

Answer: .....

(Total for Question 20 = 9 marks)

TOTAL FOR SECTION C = 30 MARKS
TOTAL FOR PAPER = 80 MARKS

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Process Passports

Choose three Processes/ Tools that are applicable in the workshops and complete a ‘passport’ for these. Use descriptive language to describe how the process is done step by step and then outline health and safety considerations. (below is one for welding)

Welding

Process Description:

1. Gather the tools and materials you will need to begin welding. This means the welding machine, electrodes, cables and clamps, and the metal to be welded.
2. Set up a safe work area, preferably with a table constructed of steel or other non-flammable material.
3. Prepare the metal to be welded. If the metal consists of two pieces that are to be joined in the welding process, you may need to *prep*, *or weld prep* them, by grinding a bevelled edge on the sides that are to be joined.
4. Attach clamps to hold your metal pieces together.
5. Attach the ground clamp to the larger piece of stock that is being welded. Make sure there is a clean location so that the electrical circuit can be completed with minimal resistance at the ground location.
6. Turn on your welding machine. You should hear a humming sound from the transformer. The sound of the cooling fan running may or may not be heard.
7. Hold the stinger in your dominant hand by the insulated handle, with the rod in a position so that striking the tip of it against the plate you are welding will be as natural a movement as possible.
8. Strike the electrode against the surface of the metal, pulling it back slightly when you see an electric arc occur.
9. travel across the path of your weld with the electrode until you can keep a consistent arc, moving at a consistent speed, and in line with the path you want to weld.
10. Clean your finished weld.

Health & Safety:

Health hazards from welding, cutting, and brazing operations include exposures to metal fumes and to ultraviolet (UV) radiation. Safety hazards from these operations include burns, eye damage, electrical shock, cuts, and crushed toes and fingers. Many of these can be controlled with proper work practices and personal protective equipment (PPE).

Process/ Tool:	
Process Description:	
Health & Safety:	

Process/ Tool:	
Process Description:	
Health & Safety:	

Process/ Tool:	
Process Description:	
Health & Safety:	