ENGINEERING SCIENCE - CSEE 2017

Solutions from: [Maktaba by TETEA](https://maktaba.tetea.org)

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1.

i	ii	iii	iv	v	vi	vii	viii	ix	x
D	D	B	E	B	D	C	B	C	A

2a. Mechanical advantage (M.A) is the ratio between the work output and the work done input OR

- is the ratio of the force that performs the useful work of a machine to the force that is applied to the machine
- It has no SI units.

2b. Velocity ratio (V.R.) is the ratio between the velocity of effort and the velocity of the load OR

- is the ratio between the effort distance and load distance
- It has no SI units.

2c. Efficiency (η) is the ratio between the velocity ratio (V.R.) and mechanical advantage (M.A.)

3. Noise is an unpleasant sound or unwanted disturbance which is always irregular while a musical note is a periodic and regular sound which is pleasing to the ear

4. It is due to the change in thickness and length of strings and flutes, which leads to produce different harmonic frequencies and overtones, hence the notes of the same pitch become different.

5. Strength is the capacity of an object to withstand great forces of pressure while toughness is the ability of the material to absorb energy or the applied force/load to it without fracturing.

6. Burns caused by steam are more severe than water at 100°C due to:

a. The steam has more warmth vitality than water due to its dominant warmth of vaporization
b. Steam has more heat energy than boiling water along with latent heat of vaporization, hence having two types of energy compared to water which only has the heat of boiling
c. Steam has more kinetic energy of its water molecules, so once it strikes the skin, a lot of energy is released as it condenses into liquid causing more severe burns than those

caused by water.

7a. According to Newton's Third Law of Motion, for motion to occur there must be an equal and opposite reaction. While you are standing in the car, there is only forward force. No backward force is present in order to act as a reaction, hence no friction of the road or friction on the tyre which will push the car forward, hence the car will not move.

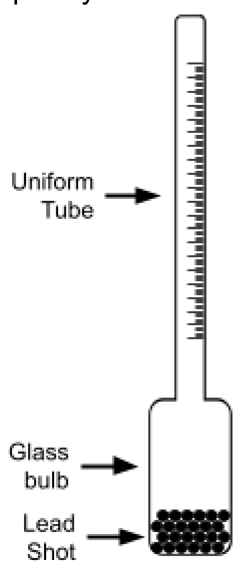
7b. On the smooth surface, there will be less or no friction force which pushes back the ground and makes you move forward, hence there will be no motion, as Newton's Third Law of Motion is concerned.

8a. Three principle methods of heat transmission are:

i. Conduction
ii. Convection
iii. Radiation

8b. Main scale reading: 15mm
Thimble-scale reading: 0.18mm
Total reading: $15 + 0.18 = 15.18$mm

9a. Simple Hydrometer Diagram



10. Properties of the image formed by a plane mirror

i. It is virtual
ii. Upright or Erect
iii. Left-right reversed
iv. Same distance from mirror as distance of object from the mirror
v. Has the same size as that of the object

11. Heavy vehicles are difficult to stop because they resist the change in motion or inertia of motion due to the fact that they have large momentum due to their larger mass, compared to light vehicles which have less momentum due to their smaller mass, hence less inertia of motion.

12a. i. Angular acceleration (α) is the rate of change of angular velocity. Its units are $\frac{rad}{s^2}$

ii. Degree is the angle of rotation of the body moving in circular motion

12b. Data given:

Initial angular velocity: $\omega_1 = 20\frac{rev}{min} = 20\frac{rev}{min} \cdot \frac{1}{60}\frac{min}{s} = \frac{1}{3}\frac{rev}{s}$

Final angular velocity: $\omega_2 = 40\frac{rev}{min} = 40\frac{rev}{min} \cdot \frac{1}{60}\frac{min}{s} = \frac{2}{3}\frac{rev}{s}$

Time taken to accelerate: $t = 10\, sec$

i. Angular acceleration:

$$\alpha = \frac{\omega_2 - \omega_1}{t} = \frac{\frac{2}{3}-\frac{1}{3}}{10} = \frac{\frac{1}{3}}{10} = \frac{1}{30}\frac{rev}{s^2}$$

Angular acceleration is: $\alpha = \frac{1}{30}\frac{rev}{s^2}$

ii. Number of revolutions in 10 seconds

Revolutions =

$$\omega_1 t + \frac{1}{2}\alpha t^2 = \frac{1}{3} \cdot 10 + \frac{1}{2} \cdot \frac{1}{30} \cdot 10^2 = \frac{10}{3} + \frac{100}{60} = \frac{10}{3} + \frac{5}{3} = \frac{15}{3} = 5$$

5 revolutions.

13a. i. Second Law of Refraction:

The ratio of the sine of the angle of incidence and the sine of the angle of refraction is constant.

i.e. $\frac{\sin\theta_i}{\sin\theta_r}$ = Constant, where θ_i is the angle of incidence and θ_r is the angle of refraction.

ii. Data Given:

Angle of incidence: $\theta_1 = 60°$

Refraction index of air: $n_1 = 1$

Angle of refraction: θ_2

Refractive index of glass: $n_2 = 1.5$

Snell's Law of Refraction:

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$1 \sin 60° = 1.5 \sin\theta_2$

$1 \cdot \frac{\sqrt{3}}{2} = 1.5 \sin\theta_2$

$\frac{\sqrt{3}}{3} = \sin\theta_2$

$\theta_2 = \sin^{-1}\left(\frac{\sqrt{3}}{3}\right) \approx 35.26°$

Angle of refraction is approximately $35.26°$

13b. i. Data Given:

Apparent depth: $0.5 = \frac{1}{2}$m

Refractive index of water: $n = \frac{4}{3}$

Real depth: d

$n = \frac{Real\ depth}{Apparent\ depth}$

$\frac{4}{3} = \frac{d}{\frac{1}{2}}$

$d = \frac{2}{3}$m or approximately 0.67m

ii. Data Given:

Real Depth: 28cm

Refractive index of water: $n = \frac{4}{3}$

Apparent depth: d

$n = \frac{Real\ depth}{Apparent\ depth}$

$\frac{4}{3} = \frac{28cm}{d}$

$4d = 84cm$

Apparent depth: $d = 21$cm

Displacement: $28 - 21 = 7$cm

13c. Data Given:

Apparent depth: d

Refractive index of glass: $n = 1.5$

Real depth: 12mm

$n = \frac{Real\ depth}{Apparent\ depth}$

$1.5 = \frac{12mm}{d}$

$1.5d = 12mm$

Apparent depth: $d = \frac{12}{1.5} = 8$mm

The scratch appears to be $12 + 8 = 20$mm away from its image.

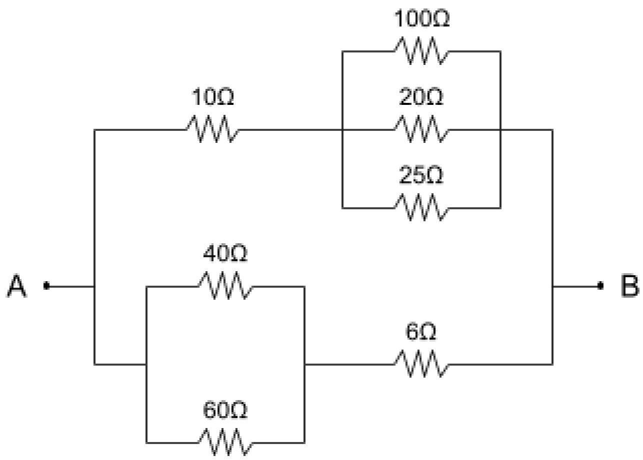
14a. i. Ohm's Law

The potential difference (p.d.) across a conductor is directly proportional to the current flowing through the conductor, assuming temperature is constant.

ii. Potential difference is the voltage across the terminals of the battery when current is being drawn from it through an external circuit.

Electromotive force (e.m.f.) is the potential difference between the terminals of the battery when no current is flowing through an external circuit (e.g. the circuit is open).

14b. i. Data Given:



$R_1 = 10\Omega$ $R_2 = 100\Omega,\ R_3 = 20\Omega,\ R_4 = 25\Omega$

$R_5 = 40\Omega,\ R_6 = 60\Omega$ $R_7 = 6\Omega$

R_2, R_3, R_4 are in parallel, so their total resistance R_{T1} can be found by:

$$\frac{1}{R_{T1}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{100} + \frac{1}{20} + \frac{1}{25} = \frac{1}{100} + \frac{5}{100} + \frac{4}{100} = \frac{10}{100} = \frac{1}{10}$$

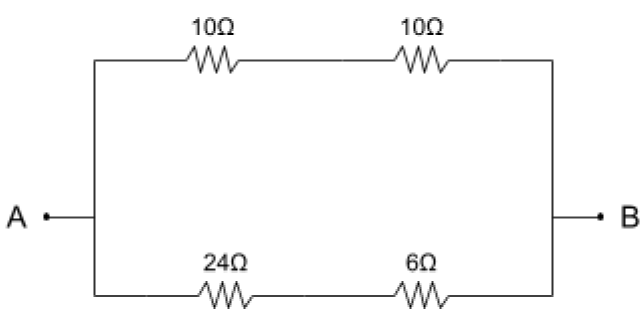
$R_{T1} = 10\Omega$

R_5, R_6 are also in parallel, so their total resistance R_{T2} can be found by:

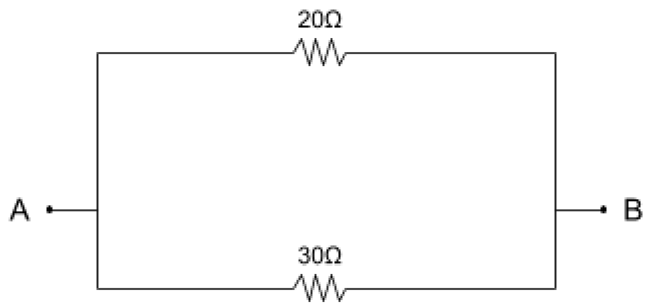
$$\frac{1}{R_{T2}} = \frac{1}{R_5} + \frac{1}{R_6} = \frac{1}{40} + \frac{1}{60} = \frac{3}{120} + \frac{2}{120} = \frac{5}{120} = \frac{1}{24}$$

$R_{T1} = 24\Omega$

We can redraw the diagram as follows:



We can add the resistors in series together to get:



These are in parallel, so we have:

$\frac{1}{R} = \frac{1}{20} + \frac{1}{30} = \frac{3}{60} + \frac{2}{60} = \frac{5}{60} = \frac{1}{12}$

Total resistance is $R = 12\Omega$

14b. ii. Potential difference is constant across all components of a parallel circuit, so both top and bottom will have the same voltage of $240V$. In the bottom, we have two resistors in series: $R_{T1} = 24\Omega$ and $R_7 = 6\Omega$ with a combined resistance of 30Ω. This means that the current in this branch is $I = \frac{V}{R} = \frac{240}{30} = 8A$

So the potential difference of the first part will be $V = 8 \cdot 24 = 192V$, since the 60Ω and 40Ω resistors are in parallel, both will have the same potential difference of $192V$

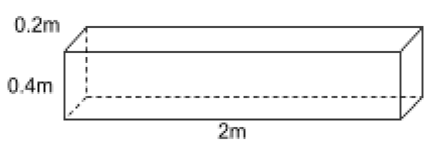
15a. i. Pressure is the force which acts normally, per unit area. The SI unit is $\frac{N}{m^2}$

ii. Factors on which the pressure in liquid depends:

- Density of the liquid
- Depth of the liquid
- Acceleration due to gravity

iii. At large depth, the pressure of water increases in the dam in such a way that the wall of the dam could be broken, so in order to overcome this greater pressure, the walls at the bottom of the dam must be made much thicker.

15b. i. Data:



Density: $\rho = 400\frac{kg}{m^3}$

Volume: $2 \cdot 0.2 \cdot 0.4 = 0.16m^3$

Mass: $400\frac{kg}{m^3} \cdot 0.16m^3 = 64kg$

Force: $F = mg = 64 \cdot 9.81 = 627.84N$

Maximum pressure will occur when the block is on its smallest surface, which measures $0.2m \times 0.4m$

Area: $0.2 \cdot 0.4 = 0.08m^2$

Maximum Pressure: $\frac{627.84N}{0.08m^2} = 7848\frac{N}{m^2}$

ii. Minimum pressure will occur with the greatest area, which measures $2m \times 0.4m$

Area: $2 \cdot 0.4 = 0.8m^2$

Minimum Pressure: $\frac{627.84N}{0.8m^2} = 784.8\frac{N}{m^2}$

15c. i. Data:

Density: $\rho = 13600\frac{kg}{m^3}$

Height: $500mm = 0.5m$

Area of Base: $5.0cm^2 = 5cm^2 \cdot \frac{1m}{100cm} \cdot \frac{1m}{100cm} = 0.0005m^2$

Pressure: $\rho gh = 13600\frac{kg}{m^3} \cdot 9.81\frac{m}{s^2} \cdot 0.5m = 66708\frac{N}{m^2}$

ii. Force = Pressure × Area

$$F = 66708\frac{N}{m^2} \cdot 0.0005m^2 = 33.354N$$

16a. Law of Conservation of Momentum

For two or more bodies in an isolated system acting upon each other, their total momentum remains constant unless an external force is applied.

So in a collision the sum of momentums before collision is equal to the sum of momentums after the collision.

16b. i. Data:

Mass of truck: $m_1 = 2.4$ tonnes

Velocity of truck: $v_1 = 4.7\frac{m}{s}$

Mass of car: m_2

Velocity of car: $v_2 = 0\frac{m}{s}$

Velocity of both: $v_3 = 1.2\frac{m}{2}$

$$m_1v_1 + m_2v_2 = m_3v_3$$

$$2.4 \cdot 4.7 + m_2 \cdot 0 = (2.4 + m_2) \cdot 1.2$$

$$9.4 = 2.4 + m_2$$

$m_2 = $ 7 tonnes

ii. Kinetic Energy: $K.E = \frac{1}{2}m \cdot v^2$

$v = 4.7\frac{m}{s}$

$m = 2.4\, tonnes \cdot \frac{1000kg}{1\, ton} = 2400kg$

$KE = \frac{1}{2} \cdot 2400 \cdot (4.7)^2 = 26508J$

iii. Kinetic Energy: $K.E = \frac{1}{2}m \cdot v^2$

$m = 9.4\, tonnes \cdot \frac{1000kg}{1\, ton} = 9400kg$

$v = 1.2\frac{m}{s}$

$KE = \frac{1}{2} \cdot 9400 \cdot (1.2)^2 = 6768J$