Education

KwaZulu-Natal

Department of Education

REPUBLIC OF SOUTH AFRICA

CURRICULUM DIRECTORATE

LEARNER ASSISTANCE REVISION DOCUMENT

P1 SOLUTIONS

GRADE 12 - 2020

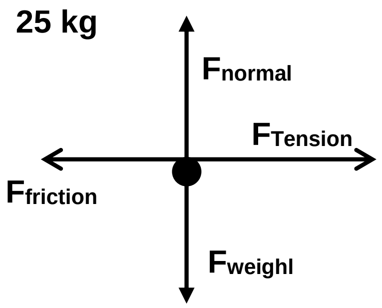
PHYSICAL SCIENCES

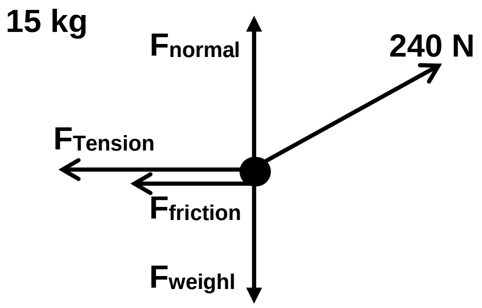
PHYSICS P1- SOLUTIONS

1. **Force diagrams**

a)	P – Normal force , Q – gravitational force
b)	P – Normal force , Q – gravitational force, R– Applied force, S- kinetic frictional force
c)	P – Normal force , Q – gravitational force, R– Applied force, S– kinetic frictional force
d)	P– Tension force Q– gravitational force
e)	P– gravitational force
f)	A – Normal force B – Applied force C –Frictional force D–Gravitational force
2.	**HOMEWORK : FREE BODY DIAGRAMS,**

1.





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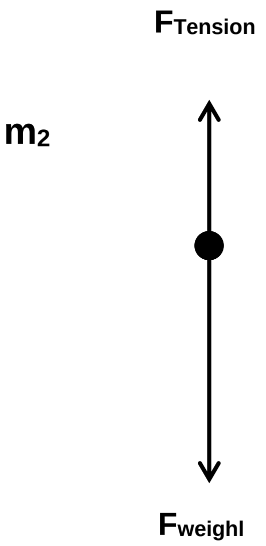
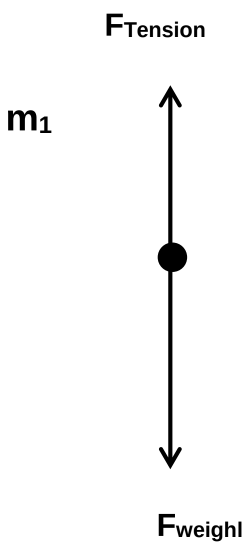
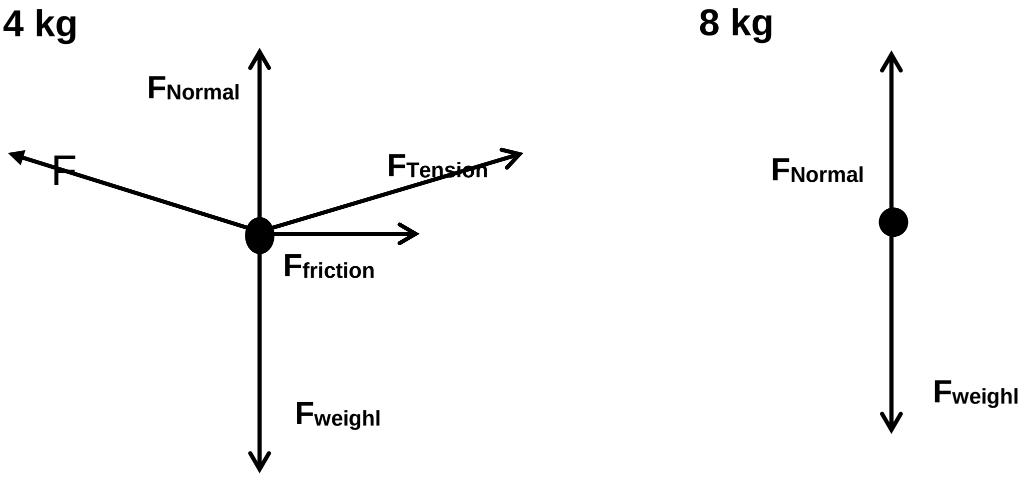




3.



$F_{net} = ma$

1.Take initial motion to the right as being positive

1.1 $R_x = R\cos\theta = 100\cos 60^0 = 50$ N
$F_{net} = ma$
$R_x + (-F_f) = ma$
$50 - 12 = 20a$
$a = 1, 9$ ms^{-2}

1.2 $F_f = \mu_K F_N$, $F_N = mg + R_y = 20x9.8+17.321 = 213.321$N
$12 = \mu_K(213.321)$
$\mu_K = 0,0563$

1.3 $\Delta x = v_i\Delta t + ½ a\Delta t^2$
$= 0 + ½ (1, 9) (10)^2$
$= 95$ m

2. Take the initial upward motion of the crate as being positive

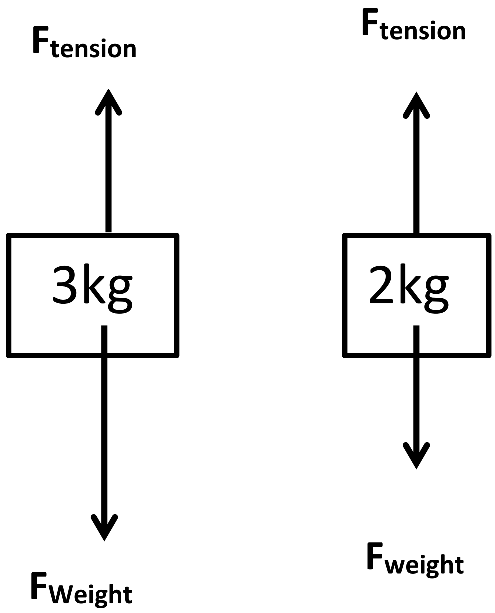
2.1 $F_{net} = ma$

$F_{cable} + (-F_{weight}) = ma$, constant velocity »»» a=0
$F_{cable} + (-500) (9.8) = (500) (0)$
$F_{cable} = 500(9.8) = 4900$ N

2.2 $F_{net} = ma$

$F_{cable} + (-F_{weight}) = ma$
$F_{cable} + (-500) (9.8) = (500) (2)$
$F_{cable} = 5900$ N

3.



Take the downward motion of the 3kg mass piece as being positive

3kg

$F_{net} = ma$

$F_{weight} + (-F_T) = ma$

$(3 \times 9.8) - F_T = 3a$

$29,4 - F_T = 3a$

$F_T = 29,4 - 3a$ ……. (1)

2kg

$F_{net} = ma$

$F_{weight} + (-F_T) = m(-a)$

$(2 \times 9.8) - F_T = -2a$

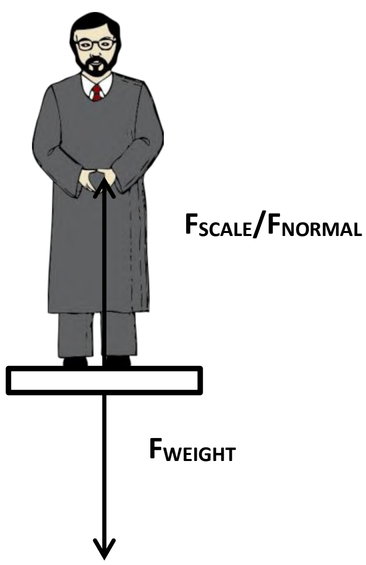
$19,6 - F_T = -2a$……. (2)

Substitute (1) in (2)

$19,6 - (29,4 - 3a) = -2a$

$a = 1,96\ ms^{-2}$

4. Take the initial upward motion of the lift to be positive



4.1 $F_{net} = ma$

$F_{scale} + (-F_{weight}) = ma$

$F_{scale} - (80 \times 9.8) = (80)(2)$

$F_{scale} = 944\ N$

4.2 $F_{net} = ma$

$F_{scale} + (-F_{weight}) = m(-a)$

$F_{scale} - (80)(9.8) = (80)(-2)$

$F_{scale} = 624$ N

4.3 $F_{NET} = ma$

$F_{scale} + (-F_{weight}) = m(-a)$

$F_{scale} - (80)(9.8) = (80)(0)$, constant velocity »»» a=0

$F_{scale} = 784$ N

4.4 $a = g = 9.8\ ms^{-2}$

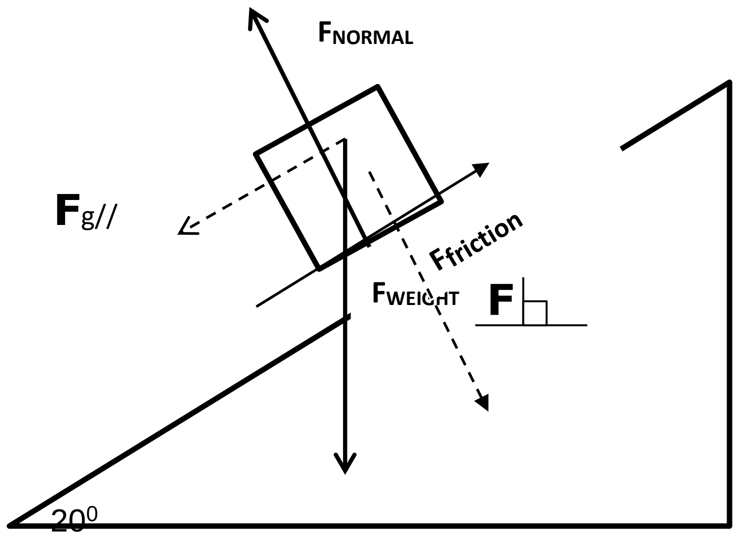
$F_{net} = ma$

$F_{scale} + (-F_{weight}) = m(-a)$

$F_{scale} - (80)(9.8) = (80)(-9.8)$

$F_{scale} = 0$ N

5. Take the motion down the incline as positive.



5.1 Constant velocity »»» $\Sigma F = F_{net} = 0$ N, $a = 0\ ms^{-2}$

$F_{NET} = ma$ $\qquad$ $Fg_{//} = m.g.\sin\theta = 50 \cdot 9.8 \cdot \sin 20^0$

$F_{g//} + (-F_f) = m \cdot (a)$ $\qquad$ $= 167{,}5898$ N

$167{,}\ 5898 + (-F_f) = 0$

$F_f = 167,\ 59$ N, up the slope

5.2 $\mu = \tan\theta = \tan 20^0 = 0,\ 3639$

OR $F_f = \mu_k F_N$ $\qquad$ $F_N = mg\cos\theta = 50(9,\ 8\cos 20^0) = 460{,}449$N

$167,\ 59 = \mu_k \cdot 460{,}449$

$\mu_k = 0.3639$

6.

6.1 $RX = R \cdot \cos\theta = 150 \cdot \cos 15^0 = 144,\ 8888$ N

$F_{net} = ma$

$R_X = ma$

$144,8888 = 30a$
$a = 4,83\ ms^{-2}$

6.2 $F_{net} = ma$
$R_X + F_f = ma$
$144,8888 + (-24) = 30 \cdot a$
$a = 4,03 ms^{-2}$
6.3 $F_N = F_w - R_y$, $R_y = R\sin\theta = 100 \sin 15^0 = 25,882N$
$= (30)(9.8) - 25,882$
$= 268,81\ N$

$F_f = \mu_k F_N$
$24 = \mu_k(268,81)$
$\mu_k = 0,0893$

VERTICAL PROJECTILE MOTI0N SOLUTIONS

Activity 1

1. 1.1 $vf^2 = vi^2 + 2a\Delta y$

$(0)^2 = (4)^2 + 2(-9,8)\ \Delta y$

$0 = 16 + (-19,6)\ \Delta y$

$-16 = -19,6 \Delta y$

$\therefore\ \Delta y = 0,81\ m$

1.2
$v f = v i + a\ \Delta t$
$0 = (-4) + (9,8)\ \Delta t$
$\Delta t = 0,41\ s$
∴ The ball takes 0, 41 s to reach the highest point in its projection (5)

1.3.
Time upwards = time downwards
∴ total time in the air is
$(2)(0,41) = 0,82\ s$

1.4. Total displacement = $\Delta y = 0$ m (1)
Displacement is measured in a straight line from the initial position (the thrower's line from the original to the final position
(the thrower's hand is the initial and final position).

Activity 2

2.1 $3 - 2,04 = 0,96$ s

2.2

Option 1

$\Delta y = v_i \Delta t + 12a \Delta t^2$

$= (10)(3) + 12(-9, 8)(3)^2$

$= 14, 1$ m

$\Delta y = 14, 1$ m below the starting point

$v_f2 = v_i2 + 2a\Delta y$

$0 = 100 + 2(-9, 8) \Delta y$

$\Delta y = 5, 1$ m

Maximum height above the ground = 5, 1 + 14, 1 = 19, 2 m

Option 2

$\Delta y = v_i \Delta t + 12a \Delta t^2$

$= 0 + 12(-9, 8)(3 - 1, 02)$

$= -19, 21$ m

$\Delta y = 19, 21$ m (maximum height above the ground)

Option 3

$v_f2 = v_i2 + 2a\Delta y$

$(-19, 4) = 0 + 2(-9, 8) \Delta y$

$\Delta y = 19, 2$ m (maximum height above the ground

Activity 3

1. 15 $m.s^{-1}$ (1)

2. Inelastic collision

The speed/velocity at which the ball leaves the floor is less / different than that at which it strikes the floor OR The speed/ velocity of the ball changes during the collision.

Therefore, the kinetic energy changes/is not conserved. (2)

3 . $v_f^2 = v_i^2 + 2a\Delta y$

$(20)^2 = (10)^2 + 2(9, 8) \Delta y$

$\therefore \Delta y = 15, 31$ m (3)

Displacement from floor to maximum height

$v_f2 = v_i2 + 2a\Delta y$

$(0)^2 = (-15)^2 + 2(9, 8) \Delta y$

$\Delta y = -11, 48$ m

Total displacement

$= -11, 48 + 15, 3$ = 3, 82 m or 3, 83 m

Activity 4

4.1 B

4.2 A

4.3 C

MOMENTUM & IMPULSE

Activity 1

1.1 Momentum is defined as the product of mass and velocity of an object.
1.2 Impulse is the product of the net force and the time in which the net force acts on an object.
1.3 Elastic collision is defined as collision in which the kinetic energy is conserved.
1.4 Inelastic collision is defined as collision in which the kinetic energy is not conserved.
1.5 Principle of conservation of linear momentum it states that the total linear momentum of an isolated system remains constant.
1.6 An isolated system is the one on which the net external force acting on the system is zero.

Activity 2

2.1
Diagram A:
$m = 150 \div 1000 = 0,15$ kg
$v_i = +18\ m{\cdot}s^{-1}$
$v_f = -12\ m{\cdot}s^{-1}$

Diagram B:
$m = 0,15$ kg
$\vec{v}_i = +18\ m{\cdot}s^{-1}$
$\vec{v}_f = 0\ m{\cdot}s^{-1}$
Let the direction towards the wall be positive

$m = 150$ g $= 0,15$ kg (divide the mass by 1000)
$v_i = 18\ m{\cdot}s^{-1}$
$p_i = mv_i$
$= (0,15)(18)$
$= 2,7\ kg{\cdot}m{\cdot}s^{-1}$ towards the wall

2.2

$m = 150$ g $= 0,15$ k
$v_f = -12\ m{\cdot}s^{-1}$
$P_f = mv_f$
$= (0,15)(-12)$
$= 1,8\ kg{\cdot}m{\cdot}s^{-1}$ away from the wall

2.3

$m = 0,15$ kg
$\Delta p = mv_f - mv_i$
$= (0,15)(-12 - 18)$
$= -4,5\ kg{\cdot}m{\cdot}s^{-1}$

∴Δ p is 4,5 kg·m·s^{-1} away from the wall

2.4
Diagram A: $Fnet = \frac{\Delta P}{\Delta t}$
$= \frac{MV_f - MV_i}{\Delta t}$
$= \frac{(0{,}15)(-12) - (0.15)(+18)}{0{,}1}$

∴Force exerted by the wall is 45 N away from the wall

Diagram B $F_{net} = \frac{\Delta P}{\Delta t}$
$= \frac{mvf - mvi}{\Delta t}$
$= \frac{0{,}15(0) - 0{,}15(18)}{0{,}1}$

= -27 N

∴ Force exerted by the wall is 27N away from the wall

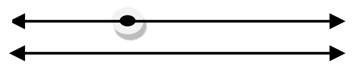
2.5 p_f = -1,8 kg.m.s^{-1} away from the wall

p_i = +2,7 kg.m.s^{-1} toward the wall

$\Delta p = m_{vf} - m_{vi}$

= -1, 8 - (+2, 7)

= 4, 5 kg.m.s^{-1} away from the wall



$F_{net}\Delta t = \Delta p$
= (0,175) [(–30) – (12)] = –7, 35 N·s
Therefore 7, 35 N·s away from the bat (4)

2.

F_{net} Δt = –7, 35 = F_{net} (0, 05)
∴ $F_{net} = \frac{-7{,}35}{0{,}05}$ =-147N
Therefore 147 N away from the bat (3)
3. 147 N towards the bat. According to Newton's Third Law of Motion the force of the bat on the ball is equal to the force of the ball on the bat, but in the opposite direction, (5)
F_{bat} on ball = $-F_{ball}$ on bat

Activity 4

4.1 An isolated system is the one on which the net external force acting on the system is zero.

4.2

m_1 = 4 000 kg and m_2 = 3 000 kg v_{1i} = +1, 5 m·s^{-1} v_{2i} = 0 m·s^{-1}

v_{1f} =? v_{2f} = + 2, 8 m·s^{-1}

Σ p i = Σ p f

$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$

(4000) (1, 5) + (3000) (0) = (4000) v_{1f} + (3000) (2, 8)

4000 v_{1f} = 6000 – 8400

v_{1f} = 0,6 m·s^{-1}

∴ 0, 6 m·s^{-1} to the west

4.3

$\Sigma E_{Ki} = ½ m_1 v_{1i}^2 + ½ m_2 v_{2i}^2$
= ½ 4000) (0, 6)^2+ ½ (3000) (2, 8)^2
= 720 + 11760

$\Sigma E_{K f} = ½ m_1 v_{1f}^2 + ½ m_2 v_{2f}^2$

=½ (4000) (1, 5)^2 + ½ (3000) (0)^2

= 4500 J

4500 J $\neq$ 12480 J

∴ Collision is inelastic

Work, Energy and Power

Activity 1

1.1 Work energy and power - The net work done on an object is equal to the change in the object's kinetic energy.

1.2 Conservative forces - A force for which the work done (in moving an object between two points) is independent of the path taken.

1.3 Non – conservative forces - A force for which the work done (in moving an object between two points) depends on the path taken.

1.4 Isolated system - A system in which the net external force acting on the system is zero.

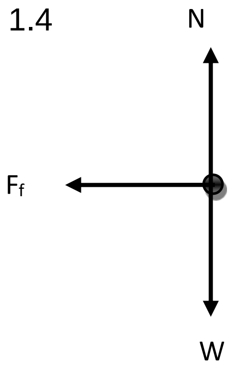
1.5 Principle of Mechanical energy - The total mechanical energy (sum of gravitational potential energy and kinetic energy) in an isolated system remains constant.

1.7 Power - The rate at which work is done or energy is expended.

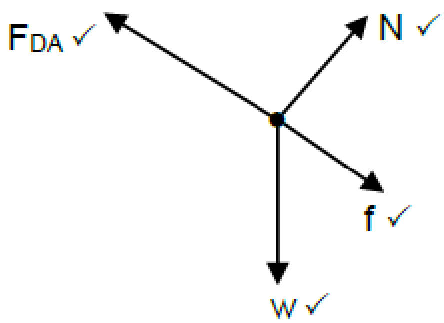
Activity 2
1.1 B
1.2 D
1.3 D
1.4 A
1.5 B
1.6 B

Activity 3

1.1 The total mechanical energy (sum of gravitational potential energy and kinetic energy) in an isolated system remains constant.
1.2 No.
1.3
1.4



1.4.1



1.4.2 The net work done on an object is equal to the change in the object's kinetic energy.

1.4.3 A force for which the work done (in moving an object between two points) depends on the path taken.

Activity 4

1.1 WFapplied = Fapplied·Δx·cos θ = (220)(10)(cos 0°) = (220)(10)(1)

= 2 200 J (3)

1.2. WFnormal = Fnormal· Δx· cos θ = mg· Δx · cos 90°= (50)(9,8)(10)(0)

= 0 J (3)

1.3. WFfriction = Ffriction·Δx · cos θ = (40)(10)(cos 180°) = (40)(10)(−1)

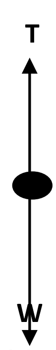
= −400 J (3)

1.4. Wnet = ΣW = WFapplied + WFfriction = (2 200) + (−400) = 1 800 J (3)

Activity 5

1.1 The net work done on an object is equal to the change in the object's kinetic energy.(2)

1.2



1.5 $W_{Fg} = F_g \cdot \Delta x \cdot \cos\theta$ = (6)(9,8)(1.6)(cos 0°)= 94.08 J (3)

DOPPLER EFFECT SOLUTIONS

Assignment

1. Doppler Effect is the change in frequency (or pitch) of the sound detected by a listener, because the sound source and the listener have different velocities relative to the medium of sound propagation.

2.

2.1 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$

$$f_L = \frac{340+0}{340-25} 350 = 377{,}78 Hz$$

2.2 $f_L = \frac{340+0}{340+25} 350 = 326{,}03 Hz$

3. $f_L = \frac{340+5}{340-0} 450 = 456{,}62 Hz$

4.1 $f_L = \frac{340+0}{340-240} 1200 = 4080 Hz$

4.2 $f_L = \frac{340+240}{340-0} 4080 = 6960 Hz$

5. $f_L = \frac{340+0}{340-25} 350 = 377{,}78 Hz$

$$450 = \frac{340 + vL}{340 - 0} 400$$

v_L =42,5 m.s^{-1}

More exercises

1.1

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$$

$$f_L = \frac{1500}{1500 - 20}(250000)$$

= 253,38 x 10^3 Hz

1.2 Remains the same

2.1 Doppler Effect

2.2

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$$

$$90/100\, f_s = \frac{340}{340 + v_s}(f_s)$$

$\therefore v_S$ = 37,78 m•s^{-1}

2.3 Smaller than

3.1 Doppler Effect

3.2

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$$

$$90/100\, f_s = \frac{340}{340 + v_s}(f_s)$$

$\therefore v_S$ = 37,78 m•s^{-1}

The detected frequency is independent of the distance between the source and the observer.

4.1 Towards

4.2

4.3 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$

$450 = \frac{340+0}{340-20} fs$

153000- 9000 = 340fs

f_s = 423,53 Hz

ELECTROSTATICS SOLUTIONS

QUESTION ONE

1.1 The electrostatic force between charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them

1.2 $Q_{new} = \frac{Q+Q2}{2}$

$= \frac{-6x10^{-6} + 2x10^{-6}}{2}$

$= -2 \; x \; 10^{-6}$C

1.3 $n_{electrons} = \frac{Q}{qe}$

$= \frac{-2X10^{-6}}{-1{,}6 \; X10^{-19}}$

$= 1{,}25x10^{13}$ electrons

1.4 F = k $\frac{Q1Q2}{r^2}$

$= 9x10^9 \frac{2X10^{-6}.2X10^{-6}}{(20X10^{-2})2}$

$= 9x10^3$ N

1.51.5 $F = k\frac{Q1Q2}{r^2}$

$=9x10^9\frac{2X10^{-6}.4X10^{-6}}{(30X0^{-2})2}$

$=8X10^{-1}$ N

$F_R^2 = F_X^2 + F_Y^2$

$= (9x10^3)^2 + (4X10^{-1)2}$

$= 9X10^3$ N

Tan $\theta = \frac{8x10^{-1}}{9x10^3}$

$\theta = 5{,}09x10$

QUESTION 2

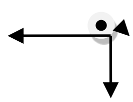
2.1 The electrostatic force between charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them

2.2 $F = k\frac{Q1\,Q2}{r^2}$

$=9X10^9\frac{4x10^{-6}\,.2x10^{-6}}{(50x10^{-3)}2}$

$2{,}88X10^1$N

2.3



2.4 $F = k\frac{Q1\,Q2}{r^2}$

$=9X10^9\frac{8X10^{-6}\,.2X10^{-6}}{(100X10^{-3)}2}$

$= 1{,}44X10^1$N

$F_{NET} = F_1 + F_2$

$= 2{,}88\,X10^1 + 1{,}44X10^1$

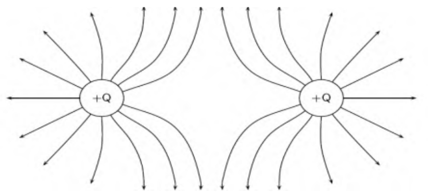
$= 1{,}44X10^1$N

Tan $\theta = \frac{2{,}44x10^1}{1{,}44x10^1}$

$\theta = 5{,}95x10^1$

QUESTION 3

3.1 Electric field is a region of space in which an electric charge experiences a force.

3.2 

3.3 $E_1 = \frac{kQ}{r^2}$

$= 9X10^9 \frac{3x10^{-9}}{(10x10^{-3})^2}$

$= 2,7x10^5$ N.C^{-1}

$E_2 = \frac{kQ}{r^2}$

$= 9x10^9 \frac{5x10^{-9}}{(30x10^{-3})^2}$

$= 5$ x10^4 N.C^{-1}

$E_{NET} = E_1 + E_2$

$= E_1 = \frac{kQ}{r^2}$

$= 9X10^9 \frac{3x10^{-9}}{(10x10^{-3})^2}$

$= 5$ x $10^{4\,+}$ $2,7x10^5$

$= 3, 20$ x10^5 N.C^{-1}

3.4 $E = \frac{F}{e}$

$3, 20$ x$10^5 = \frac{F}{1,6\ x10^{-19}}$

$F = 5, 12$ x10^{-14} N

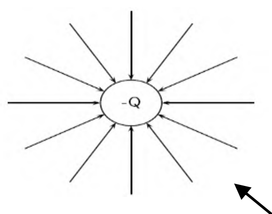
QUESTION 4

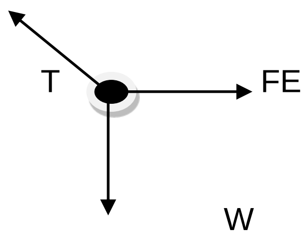
4.1 Because we need to charge the sphere.

4.2 $E_1 = \frac{kQ}{r^2}$

$= 9X10^9 \frac{4,8x10^{-8}}{(5x10^{-2})^2}$

$= 1,73 \text{ x}10^5 \text{ N.C}^{-1}$

4.3 

4.4 

4.5 $F = k\frac{Q1\,Q2}{r^2}$

$= 9X10^9 \frac{4,8x10^{-8}.4x10^{-8}}{(5X10^{-2})2}$

$= 8,29X10^{-3}N$

4.6 $E = \frac{F}{Q}$

$E = \frac{8,29X10-3}{4,8\,x10^{-8}}$

$F = 1,\ 73 \text{ x}10^5 \text{ NC}^{-1}$

QUESTION 5

5.1 Electric field is a region of space in which an electric charge experiences a force.

5.2 $n_e = \frac{Q}{qe}$

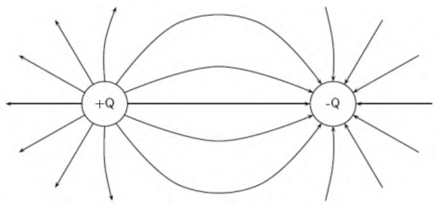
$= \frac{10\,x10^{-6}}{1,6x10^{-19}}$

$= 6,\ 25 \text{ x}10^{13}$ electrons

5.3 E= $\frac{kQ}{r^2}$

= 9 x10$^9\frac{10x10^{-6}}{(2x10^{-2})2}$

= 2, 25 x10^8 NC^{-1}

5.4 

5.5 The electrostatic force between charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them

5. F = k $\frac{Q1\,Q2}{r^2}$

= 9X10$^9\frac{10,x10^{-6}.20x10^{-6}}{(3x^{-2})2}$

= 2, 00 x10^{-3} N

ELECTRIC CIRCUITS SOLUTIONS

MULTIPLE CHOICE QUESTIONS

1. A
2. A
3. C
4. B
5. A
6. D
7. C

1.1 $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$ ✓

$= \frac{1}{60} + \frac{1}{60}$ ✓

$\therefore R_p = 30\ \Omega$ ✓

1.2 $R_{ext} = 30 + 25 = 55\ \Omega$ ✓

Emf = I(R + r) ✓

$\therefore$ 12 ✓= I (55 + 1, 5) ✓

$\therefore$ I = 0, 21 A ✓

1.3 V = IR ✓
= (0, 21)(30) ✓
= 6, 3 V ✓

QUESTION 2

2.1 1, 5 V ✓

2.2 gradient/m = $\frac{\Delta V}{\Delta I}$
$= \frac{0{,}65 - 1{,}5 ✓}{1{,}0 - 0 ✓}$
= - 0,85 Ω ✓

2.3 Internal resistance ✓✓

2.4 Decreases ✓
When I increase:
"Lost volts"/ Ir increases. ✓
V_{ext} = <u>emf – Ir decreases.</u> ✓

QUESTION 3

3.1 12 V ✓

3.2

3.2.1

<u>Option 1</u>	**<u>Option 2</u>**
$I = \frac{V}{R}$ ✓ $= \frac{9{,}6}{2{,}4}$ ✓ = 4 A	emf = IR + Ir✓ 12 = I(2,4) + 2,4✓ ∴ I = 4 A✓

3.2.2 emf = IR + Ir ✓
12 = 9, 6 + 4r ✓
∴ r = 0, 6 Ω ✓

3.3

<u>Option 1</u>	**<u>Option 2</u>**
emf = I(R + r) ✓ 12 = 6(R + 0,6) ✓ R_{ext} = 1,4 Ω $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ ✓	Emf = $V_{terminal}$ + Ir ✓ 12 = $V_{terminal}$ + 6(0,6) ✓ ∴ $V_{terminal}$ = 8,4 V $I_{2,4\ \Omega} = \frac{V}{R} = \frac{8{,}4}{2{,}4}$ = 3,5 A

$\frac{1}{1{,}4} = \frac{1}{2{,}4} + \frac{1}{R}$ ✓ $\therefore$ R = 3,36 Ω Each tail lamp : R = 1,68 Ω ✓	$I_{\text{tail lamps}}$ = 6 – 3,5 = 2,5 A $R_{\text{tail lamps}} = \frac{V}{I}$ ✓ $= \frac{8{,}4}{2{,}5}$ ✓ = 3,36 Ω $R_{\text{tail lamp}}$ = 1,68 Ω ✓
Option 3 V = IR ✓ 12 = (6)R ✓ R_{ext} = 2 Ω $\therefore R_{\text{parallel}}$ = 2 – 0,6 = 1,4 Ω $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ ✓ $\frac{1}{1{,}4} = \frac{1}{2{,}4} + \frac{1}{R}$ ✓ $\therefore$ R = 3,36 Ω Each tail lamp R = 1,68 Ω ✓	**Option 4** For parallel combination: $I_1 + I_2$ = 6 A $\therefore \frac{V}{2{,}4} + \frac{V}{R_{\text{taillamps}}}$ ✓ = 6 ✓ 8,4✓ $\left(\frac{1}{2{,}4} + \frac{1}{R_{\text{taillamps}}}\right)$✓ = 6 $\therefore R_{\text{tail lamps}}$ = 3,36 $R_{\text{tail lamp}}$ = 1,68 Ω ✓

3.4 Increases ✓
Resistance increases, current decreases ✓
Ir (lost volts) decreases ✓

QUESTION 4

4.1 The <u>current in a conductor is directly proportional to the potential difference</u> ✓ across its ends at <u>constant temperature</u>. ✓

OR

The <u>ratio of potential difference to current is constant</u>✓ at <u>constant temperature.</u> ✓

4.2

4.2.1 $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$ ✓ $= \frac{1}{1{,}4} + \frac{1}{1{,}4}$ ✓ $\therefore$ R_p = 0, 7 Ω ✓

OR

$R_p = \frac{R_1 R_2}{R_1 + R_2}$ ✓ $= \frac{1{,}4 \times 1{,}4}{1{,}4 + 1{,}4}$ ✓= 0, 7 Ω ✓

4.2.2

OPTION 1:

emf = I(R + r) ✓

∴ $\underline{12 = I(0,7 + 0,1)}$ ✓

∴ I = 15 A

$R = \frac{V}{I}$

$0,7 = \frac{V}{15}$ ✓

∴V = 10,5 V ✓

OPTION 2:

$I = \frac{V}{R}$ ✓ $= \frac{12}{0,8}$ ✓ = 15 A

V = IR
= (15)(0,7) ✓
= 10,5 V ✓

emf = I(R + r)
12 = $V_{external}$ + (15)(0,1) ✓

$V_{external}$ = 12 – (15)(0,1)
= 10.5 V ✓

$V_{\text{"lost"}}$ = Ir = (15)(0,1) ✓= 1,5 V
$V_{external}$ = 12 – 1,5 V = 10,5 V✓

$I_{headlight} = \frac{15}{2}$ = 7,5 A✓

V = IR = (7,5)(1,4) = 10,5 V✓

OPTION 3

Voltage divides 0,7: 0,1 / 7:1

∴$V_{headlight} = \frac{7}{8}$ ✓✓x 12 ✓

= 10,5 V ✓

= 11,83 V ✓

4.2.3

OPTION 1

$P = \frac{V^2}{R}$ ✓

$= \frac{10,5^2}{1,4}$ ✓

= 78, 75 W ✓

OPTION 2

I (light) = 7, 5 A

P = VI ✓
= (10, 5) (7, 5) ✓
= 78.75 W ✓

OPTION 3

I (light) = 7, 5 A

P = I^2R ✓
= $(7, 5)^2(1, 4)$ ✓
= 78.75 W ✓

4.3 Decreases ✓

(Effective/ total) resistance decreases. ✓
(Total) current increases. ✓
"Lost volts" / $V_{internal}$ / Ir increases, thus potential difference / V (across headlights) decreases.✓
$P = \frac{V^2}{R}$ decreases.

QUESTION 5

5.1 9 V ✓
Potential difference measured when:
switch is open / no current flows / circuit is open/no work done is in external circuit ✓

5.2

Emf = IR + Ir ✓
9 ✓= V_{ext} + (3)(0,3) ✓∴ V_{ext} = 8,1 V
V_{ext} = I(R_1 + R_2)
8,1 = 3(3R) ✓ ∴ R_1 = 0,9 Ω ✓

5.3 Decreases ✓

5.4 Increases ✓
Resistance decreases. ✓
Current increases. ✓
Ir increases.

QUESTION 6

6.1 Any two:
Temperature ✓
Cross sectional area (thickness) of material ✓
Length

6.2

Conductor Q ✓ For the same potential difference, ✓ wire Q has a higher current than wire P. ✓ Therefore wire Q has a lower resistance than wire P. ✓

OR

Conductor Q✓ The gradient of the graph for wire Q is bigger than that for wire P. ✓ Gradient = $\frac{I}{V}$ is bigger✓, thus $\frac{V}{I}$ = R is smaller. ✓

QUESTION 7

7.1 $V_{int} = 45 – 43,5 = 1,5$ V ✓

$I = \frac{V}{R}$ ✓ $= \frac{1,5}{0,5}$✓ $= 3$ A

$V_{12\,\Omega} = IR_{12\,\Omega} = 3 \times 12$ ✓$= 36$ V

$V_{//} = 43,5 – 36 = 7,5$ V ✓ ✓

(If only $V_{//} = 7,5$ V: 2 marks)

$I = \frac{V_{//}}{R} = \frac{7,5}{10}$✓ $= 0,75$ A ✓

7.2 $I_R = 3 – 0,75 = 2,25$ A ✓

$R = \frac{V_{//}}{I} = \frac{7,5}{2,25}$✓ $= 3,33\ \Omega$ ✓

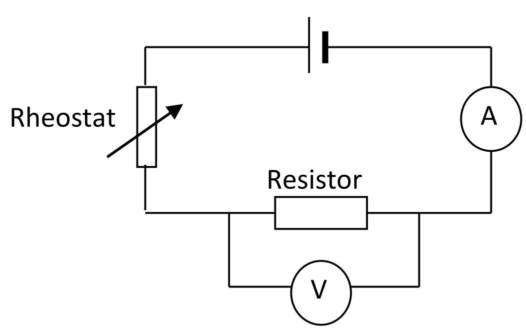
7.3 Increases ✓

The total resistance increases, ✓

Therefore the current decreases✓ therefore $V_{internal}$ decrease ✓ therefore reading on V increases.

QUESTION 8

8.1



Criteria for circuit diagram	**Mark**
Battery connected to the resistor as shown – correct symbols used.	✓
Rheostat connected in series with resistor – correct symbols used.	✓
Ammeter connected in series so that it measures the current through resistor – correct symbols used.	✓
Voltmeter connected in parallel across resistor – correct symbols used.	✓

8.2 Temperature ✓

8.3 B ✓

The ratio $\frac{V}{I}$ is greater than that of A. ✓✓

QUESTION 9

9.1 $\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2}$ ✓ $= \frac{1}{4} + \frac{1}{16}$ ✓

$\therefore R = 3{,}2\ \Omega$

$R_{effective} = 3{,}2\ \Omega + 2\ \Omega + 0{,}8\ \Omega$ ✓
$= 6\ \Omega$ ✓

9.2

Option 1:	**Option 2:**
V = IR ✓ 12 = I(6) ✓ I = 2 A ✓	emf = I(R + r) ✓ 12 = I(5,2 + 0,8) ✓ I = 2 A ✓

9.3 $V_{parallel} = IR$ ✓
$= (2)(3,2)$ ✓
$= 6,4\ V$

$V_{8\Omega} = \frac{6{,}4}{2}$ ✓ $= 3,2\ V$ ✓

QUESTION 10

10.1 **Option 1**

$$\frac{1}{R_e} = \frac{1}{r_1} + \frac{1}{r_2} \checkmark = \frac{1}{9} + \frac{1}{23} \checkmark \therefore R = 6,47\ \Omega$$

R_{tot} = 6, 47 + 2 + 0, 2 ✓= 8, 67 Ω

$$I = \frac{V}{R} \checkmark = \frac{12}{8{,}67 \checkmark} = 1,38\ A \checkmark$$

Option 2

$$\frac{1}{R_e} = \frac{1}{r_1} + \frac{1}{r_2} \checkmark = \frac{1}{9} + \frac{1}{23} \checkmark \therefore R = 6,47\ \Omega$$

R_{ext} = 6, 47 + 2 ✓= 8, 47 Ω

Emf = I(R + r) ✓∴ 12 = I (8, 47 + 0, 2) ✓∴ I = 1, 38 A ✓

10.2 Decreases ✓
(Effective) resistance of circuit decreases ✓ (No current through 15 Ω and 8 Ω resistances)
Current (I) increases ✓
Ir (lost volts) increases ✓
$V_{external}$ decreases

QUESTION 11

11.1 The current through a conductor is directly proportional to the potential difference across its ends at constant temperature. ✓✓

11.2 Equal ✓
2 A divides equally at T (and since I_M = 1 A it follows that I_N = 1 A) ✓

11.3 emf = IR + Ir ✓∴ 17 = 14 + Ir ✓∴ Ir = 3 V

$$r = \frac{V_{lost}}{I} \checkmark = \frac{3}{2} \checkmark = 1,5\ \Omega \checkmark$$

11.4 $V_N = IR_N$ ✓= (1) (2) ✓= 2 V ✓

11.5 V_Y = 14 – 2 = 12 V ✓
$V_Y = IR_Y$ ✓∴ 12 = (2) RY ✓
∴ R_Y = 6 Ω ✓

ELECTRODYNAMICS SOLUTIONS

QUESTION 1

1.1 Q/split ring commutator/commutator Q (1)

1.2 Replace Q/split ring commutator with slip rings. (1)

1.3 AC can be stepped-up at power stations to reduce energy loss during transmission. (2)

1.4.1

$$I_{rms/wgk} = \frac{I_{max/maks}}{\sqrt{2}} \checkmark$$

$$= \frac{0,35}{\sqrt{2}} \checkmark$$

$$\therefore I_{rms/wgk} = 0,25 \text{ A} \checkmark$$

1.4.2

OPTION 1 $P_{ave} = \frac{V_{rms}^2}{R}$ ✓ $60 = \frac{240^2}{R}$ ✓ $\therefore R = 960\ \Omega$ ✓
OPTION 2 $P_{ave} = I^2_{rms} R$ ✓ $60 = (0,25)^2 R$ ✓ $\therefore R = 960\ \Omega$ ✓
OPTION 3 $R = \frac{V_{rms}}{I_{rms}}$ ✓ $= \frac{240}{0,25}$ ✓ $= 960\ \Omega$ ✓

QUESTION 2

2.1

2.1.1 slip rings (1)

2.1.2 brush (es) (1)

2.2 Maintains electrical contact with the slip rings.

OR

To take current out/in of the coil. (1)

2.3

Mechanical /kinetic energy to electrical energy. (1)

2.4 1½ (1)

2.5

OPTION 1
$f = \frac{1}{T}$ ✓ $= \frac{1}{0{,}02}$ ✓ $= 50$ Hz ✓ (3)
OPTION 2
$f = \frac{\text{number of cycles}}{\text{time}}$ ✓ $= \frac{1{,}5}{0{,}03}$ or/of $\frac{1}{0{,}02}$ or/of $\frac{0{,}5}{0{,}01}$ ✓ $= 50$ Hz ✓ (3)

(3)

2.6 Parallel to (1)

2.7

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{311}{\sqrt{2}} ✓ = 219{,}91\ V$$

✓

$$I_{rms} = \frac{I_{max}}{\sqrt{2}} = \frac{21{,}21}{\sqrt{2}} ✓ = 14{,}998\ A$$

$$P_{ave} = V_{rms}I_{rms} ✓$$
$$= (219{,}91)(14{,}998)$$
$$= 3\ 298{,}21\ W ✓$$

QUESTION 3

3.1

3.1.1 A: coil / rotor / armature

B: brushes

C: commutator OR

Split-ring (commutator) (3)

3.1.2

ANY ONE:

Takes current into the coil.

Maintains contact with the commutator. (1)

3.1.3 DC motor (1)

3.1.4

Due to the motor effect.

OR

There is an interaction between the external magnetic field and the magnetic field produced by the current in the conductor. (2)

3.2.1

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$$

$$= \frac{1}{\sqrt{2}} \checkmark$$

$$= 0{,}707 \text{ V} \checkmark$$

3.2.2 0, 04 s

3.2.3

OPTION 1

$P_{ave} = V_{rms}I_{rms}$ ✓

$= \left(\frac{V_{max}}{\sqrt{2}}\right)\left(\frac{I_{max}}{\sqrt{2}}\right)$ ✓ (1 mark for formula

$= \left(\frac{1}{\sqrt{2}}\right)$ ✓ $\left(\frac{2}{\sqrt{2}}\right)$

$= 1\ W$ ✓

OPTION 2

$P_{ave} = V_{rms}I_{rms}$ ✓

$= \left(\frac{1}{\sqrt{2}}\right)\left(\frac{I_{max}}{\sqrt{2}}\right)$ ✓

$= \left(\frac{1}{\sqrt{2}}\right)\left(\frac{2}{\sqrt{2}}\right)$ ✓

$= 1\ W$ ✓

QUESTION 4

4.1 Electromagnetic induction. (1)

4.2 Rotate the coil faster/Increase the number of coils/ Increase the strength of the magnetic field. (1)

4.3 Slip rings (1)

4.4.1 It is the value of the voltage in a DC circuit that will have the same heating effect as an AC circuit.

Accept:

The time averaged voltage of an AC.

$V_{rms} = \frac{V_{max}}{\sqrt{2}}$ where V_{max} is the maximum (peak) voltage of the AC.✓✓

(2)

4.4.2

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$$

$$= \frac{339,45}{\sqrt{2}} \checkmark$$

V_{rms} = 240,03 V✓ (3)

[8]

QUESTION 5

5.1.1

OPTION 1

$$P_{av} = \frac{V^2_{rms}}{R} \checkmark$$

$$100\checkmark = \frac{\left(\frac{340}{\sqrt{2}}\right)^2}{R} \checkmark \checkmark$$

R = 578 Ω✓

OPTION 2

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{340}{\sqrt{2}} \checkmark = 240,04$$

$$P_{ave} = \frac{V^2_{rms}}{R} \checkmark$$

$$100\checkmark = \frac{240,04^2}{R} \checkmark$$

R = 578 Ω ✓

5.1.2

OPTION 1	OPTION 2
$P_{av} = I_{rms}V_{rms}$ ✓ $100 = I_{rms}\frac{340}{\sqrt{2}}$ ✓ $I_{rms} = \frac{100}{\frac{340}{\sqrt{2}}}$ $= 0{,}417\ A$ ✓	$V_{rms} = I_{rms}R$ ✓ $\frac{340}{\sqrt{2}} = I_{rms}(578)$ ✓ $I_{rms} = 0{,}417\ A$ ✓

(3)

5.2 Can be stepped up or down/ can be transmitted with less power loss. (1)

QUESTION 6

6.1.1

Move the bar magnet very quickly

up and down inside the coil (2)

6.1.2 Electromagnetic induction (1)

6.1.3 Commutator/ split rings (1)

6.2.1

$$I_{rms} = \frac{V_{rms}}{R} \checkmark$$

$$= \frac{220}{40{,}33} \checkmark$$

$$= 5{,}45\ A$$

$$W = I_{rms}^2 R\Delta t$$

$$= (5{,}45^2)(40{,}33)(1) \checkmark$$

$$= 1\ 197{,}9\ J\ \textbf{OR/\textit{OF}}\ 1\ 200{,}10\ J \checkmark$$

6.2.2

OPTION 1

$$V_{rms} = \frac{V_{max}}{\sqrt{2}}$$

$$220 = \frac{V_{max}}{\sqrt{2}}$$

V_{max} = 311,13 V

$$I_{max} = \frac{V_{max}}{R} = \frac{331{,}13}{40{,}33} \checkmark$$

$= 7{,}71$ A ✓

OR/OF

$$P_{ave} = \frac{V_{max}I_{max}}{2}$$

$$1200{,}1 = \frac{(311{,}13)I_{max}}{2}$$

I_{max} = 7,71 A

OPTION 2

$P_{average} = V_{rms}I_{rms}$ ✓

$1200{,}1 = (220)I_{rms}$ ✓

I_{rms} = 5,455 A

$I_{max} = \sqrt{2}(5{,}455)$

$= 7{,}71$ A ✓ (7,715 A)

OPTION 3

$P_{average} = I^2_{rms}R$ ✓

$1200{,}1 = I^2_{rms}(40{,}33)$ ✓

I_{rms} = 5,455 A

$I_{max} = \sqrt{2}\, I_{rms}$

$= \sqrt{2}(5{,}455)$

$= 7{,}71$ A ✓

QUESTION 7

7.1

7.1.1 North pole (1)

7.1.2 Q to P (1)

7.2.1

$$I_{rms} = \frac{I_{max}}{\sqrt{2}} \checkmark$$

$$I_{rms} = \frac{8}{\sqrt{2}} \checkmark$$

$= 5,66$ A

$V_{rms} = I_{rms} R \checkmark$

$220 = (5,66)R \checkmark$

$R = 38,87\ \Omega \checkmark$

OR

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$$

$$220 = \frac{V_{max}}{\sqrt{2}} \checkmark$$

$V_{max} = 311,12$ V

$V_{max} = I_{max} R \checkmark$

$311,12 = (8)R \checkmark$

$R = 38,89\ \Omega \checkmark$

7.2.2

OPTION 1

$P_{average} = V_{rms}I_{rms}$ ✓
$= (220)(5,66)$ ✓
$= 1\ 245,2$ W

$P = \dfrac{W}{\Delta t}$ ✓

$1245,2 = \dfrac{W}{7200}$ ✓

$W = 8\ 965\ 440$ J ✓

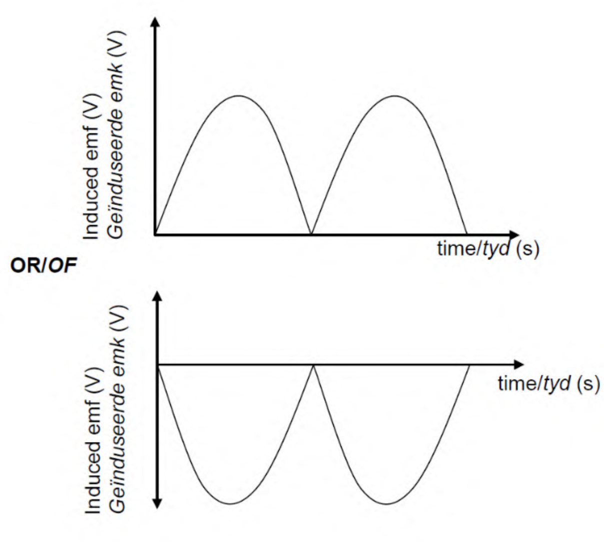
$P_{average} = I_{rms}^2 R$
$= (5,66)^2(38,89)$
$= 1245,86$
$E = Pt$
$= (1245,86)(7200)$
$= 8970192$J

QUESTION 8

8.1.1DC-generator

Uses split ring/commutator (2)

8.1.2



(2)

8.2.1

OPTION 1	**OR/*OF***
$V_{rms} = \frac{V_{max}}{\sqrt{2}}$ $P_{ave} = V_{rms} I_{rms}$ ✓ $800 = \frac{340}{\sqrt{2}}(I_{rms})$ ✓ $I_{rms} = 3,33$ A ✓	$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{340}{\sqrt{2}} = 240,416$ $P_{ave} = V_{rms} I_{rms}$ ✓ $800 = I_{rms}(240,416)$ ✓ $I_{rms} = 3,33$ A ✓

8.2.2

$P_{ave} = V_{rms} I_{rms}$ ✓

for the kettle

$2000 = \frac{340}{\sqrt{2}}(I_{rms})$ ✓

$I_{rms} = 8,32$ A

$I_{tot} = (8,32 + 3,33)$ ✓

$= 11,65$ A ✓

‘

PHOTOELECTRIC EFFECT SOLUTIONS

QUESTION 1

1.1 It is the minimum energy that an electron in the metal needs to be emitted from the metal surface (2)

1.2 Frequency/Intensity (1)

1.3 The minimum frequency required to remove an electron from the surface of the metal. (2)

1.4

$$\left.\begin{array}{l} E = W_0 + E_k \\ hf = hf_0 + E_k \end{array}\right\} \checkmark \text{ Any one}$$

$(6{,}63 \times 10^{-34})(6{,}50 \times 10^{14})\checkmark = (6{,}63 \times 10^{-34})(5{,}001 \times 10^{14})\checkmark + \frac{1}{2}(9{,}11 \times 10^{-31})v^2\checkmark$

$\therefore\ v = 4{,}67 \times 10^5\ m{\cdot}s^{-1}\checkmark$

OR

$$\left.\begin{array}{l} E_K = E_{light} - W_o \\ \quad\ = hf_{light} - hf_o \end{array}\right\} \checkmark \text{ Any one}$$

$= (6{,}63 \times 10^{-34})(6{,}50 \times 10^{14} - 5{,}001 \times 10^{14})\checkmark$

$= 9{,}94 \times 10^{-20}\ J$

$E_K = \frac{1}{2} mv^2\checkmark$

$$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{(2)(9{,}94 \times 10^{-20})}{9{,}11 \times 10^{-31}}}\checkmark$$

$v = 4{,}67 \times 10^5\ m{\cdot}s^{-1}\checkmark$

1.5 The photocurrent is directly proportional to the intensity of the incident light.

QUESTION 2

2.1.1 The minimum frequency (of a photon/light) needed to emit electrons from (the surface of) a metal. (substance)

OR

The frequency (of a photon/light) needed to emit electrons from (the surface of) a metal. (substance) with zero kinetic energy. (2)

2.1.2 Silver

Threshold/cutoff frequency (of Ag) is higher

OR

To eject electrons with the same kinetic energy from each metal, light of a higher frequency/energy is required for silver. Since E = Wo + Ek(max) (and Ek is constant), the higher the frequency/energy of the photon/light required, the greater is the work function/Wo. (3)

2.1.3 Planck's constant (1)

2.1.4 Sodium (1)

2.2.1

Energy radiated per second by the blue light

$$= \left(\frac{5}{100}\right)(60 \times 10^{-3}) \checkmark = 3 \times 10^{-3}\ \text{J·s}^{-1}$$

$$E_{photon/\mathit{foton}} = \frac{hc}{\lambda} \checkmark$$

$$= \frac{(6{,}63 \times 10^{-34})(3 \times 10^{8})}{470 \times 10^{-9}} \checkmark$$

$$= 4{,}232 \times 10^{-19}\ \text{J}$$

Total number of photons incident per second

$$= \frac{3 \times 10^{-3}}{4{,}232 \times 10^{-19}} \checkmark$$

$$= 7{,}09 \times 10^{15} \checkmark$$

(5)

2.2.2

7, 09 x 1015 (electrons per second)

OR

Same number as that calculated in Question 10.2.1 above 2.2.1 (1)

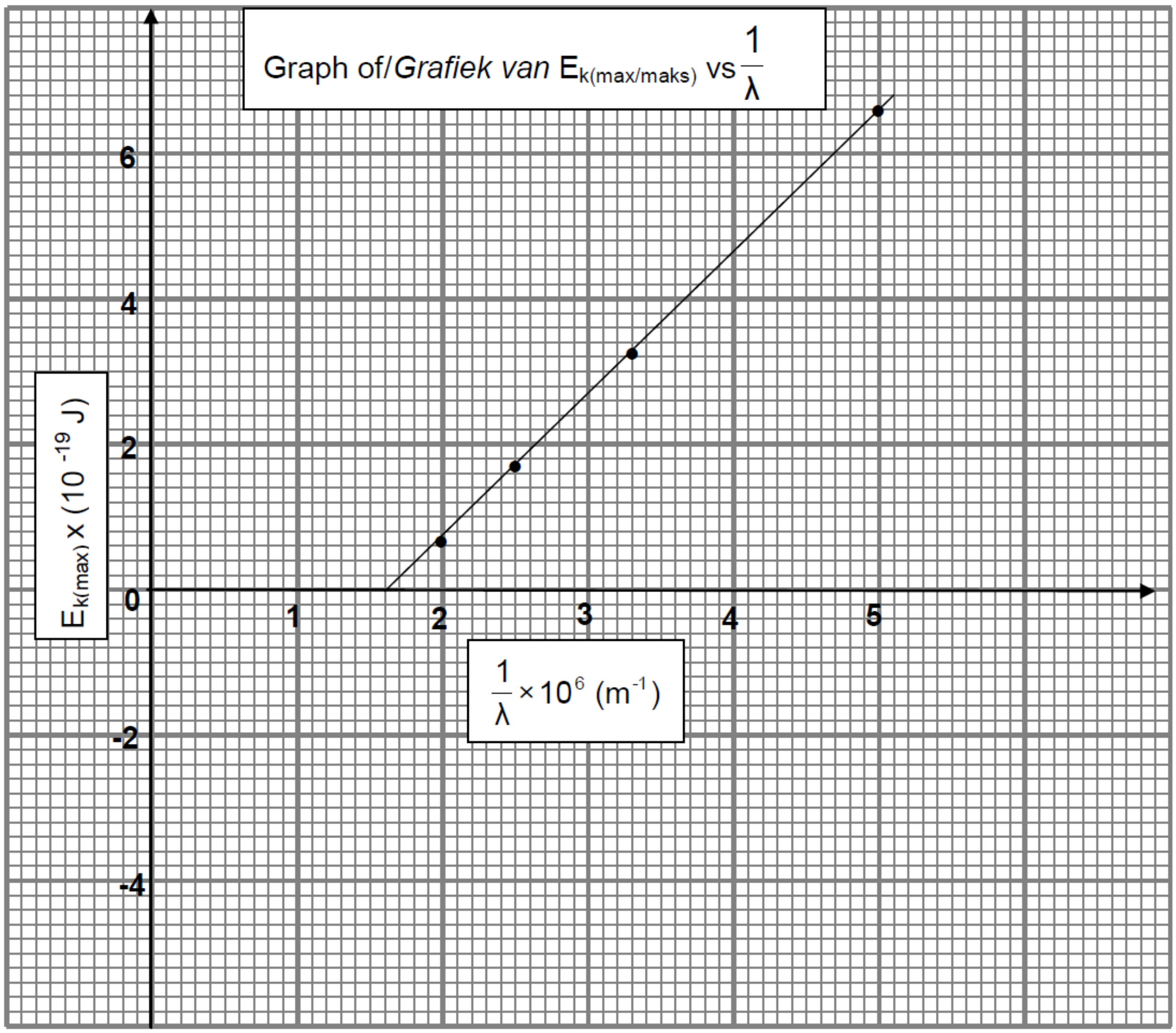
[13]

QUESTION 3

3.1 It is the process whereby electrons are ejected from a metal surface when light (of suitable frequency) is incident on it. □□

(2)

3.2



3.3.1

OPTION 1

$\frac{1}{\lambda} = 1,6 \times 10^{6}\ m^{-1}$ ✓

$f_o = c\frac{1}{\lambda}$ ✓

$= (3 \times 10^{8})(1,6 \times 10^{6})$ ✓

$= 4,8 \times 10^{14}$ Hz✓ (4)

OPTION 2

By extrapolation: y-intercept = $-W_c$

$W_o = hf_o$ ✓

$3,2 \times 10^{-19}$✓ $= (6,63 \times 10^{-34})f_o$ ✓

$f_o = 4,8 \times 10^{14}$ Hz✓ (4)

3.3.2

$$\underline{hc = \text{Gradient}} \quad \checkmark$$
$$= \frac{\Delta y}{\Delta x}$$
$$= \frac{6{,}6 \times 10^{-19}}{(5 - 1{,}6) \times 10^{6}} \checkmark$$
$$= 1{,}941 \times 10^{-25} \text{ (J·m)}$$
$$h = \frac{\text{gradient}}{c}$$
$$h = \frac{1{,}941 \times 10^{-25}}{3 \times 10^{8}} \checkmark$$
$$= 6{,}47 \times 10^{-34} \text{ J·s} \checkmark$$

OR

$$W_o = \frac{hc}{\lambda_o} \text{ or / of } W_o = hc\frac{1}{\lambda_o}$$
$$3{,}2 \times 10^{-19} \checkmark = h(3 \times 10^{8})(1{,}6 \times 10^{6}) \checkmark$$
$$h = 6{,}66 \times 10^{-34} \text{ J·s} \checkmark$$

QUESTION 4

4.1 photoelectric effect

4.2 $h\frac{c}{\lambda} = Wo + \frac{1}{2}mv^2$

$(6, 63 \times 10^{-34})(3 \times 10^{8}) \div 200 \times 10^{-9} = 8, 00 \times 10^{-19} + 0, 5 \times 9, 11 \times 10^{-31} \times v^2$

$v = 653454, 89 \text{ m.s}^{-1}$

QUESTION 5

5.1 The minimum frequency (of a photon/light) needed to emit electrons from (the surface of) a metal (substance).

5.2

OPTION 1

$$\left.\begin{array}{l} E = W_o + E_{k(max)} \\ E = W_o + \frac{1}{2}mv^2_{max} \\ h\frac{c}{\lambda} = hf_0 + \frac{1}{2}mv^2_{max} \end{array}\right\} \checkmark \text{Any one}$$

$$\frac{(6{,}63\times10^{-34})(3\times10^{8})}{\lambda} \checkmark = (6{,}63\times10^{-34})(5{,}548\times10^{14}) \checkmark + \frac{1}{2}(9{,}11\times10^{-31})(5{,}33\times10^{5})^2 \checkmark$$

$\lambda = 4 \times 10^{-7}$ m ✓ (5)

OPTION 2

$$\left.\begin{array}{l} E = W_o + E_{k(max)} \\ E = W_o + \frac{1}{2}mv^2_{max} \\ hf = hf_0 + \frac{1}{2}mv^2_{max} \end{array}\right\} \checkmark \text{Any one}$$

$$(6{,}63 \times 10^{-34})f = (6{,}63\times10^{-34})(5{,}548\times10^{14}) \checkmark + \frac{1}{2}(9{,}11\times10^{-31})(5{,}33\times10^{5})^2 \checkmark$$

$f = 7{,}5 \times 10^{14}$ Hz

$c = f\lambda$

$3 \times 10^8 = (7{,}5 \times 10^{14})\lambda$ ✓

$\lambda = 4 \times 10^{-7}$ m ✓ (5)

5.3 Smaller (less) than □ (1)

5.4 The wavelength/frequency/energy of the incident light (photon/hf) is constant□.

Since the speed is larger, the kinetic energy is larger □ the work function/W_0/threshold frequency smaller. □

(3)