INTERNATIONAL SECONDARY CERTIFICATE EXAMINATION
MAY 2023

# PHYSICAL SCIENCES: PAPER I

## MARKING GUIDELINES

Time: 3 hours | 200 marks

**These marking guidelines are prepared for use by examiners and sub-examiners, all of whom are required to attend a standardisation meeting to ensure that the guidelines are consistently interpreted and applied in the marking of candidates' scripts.**

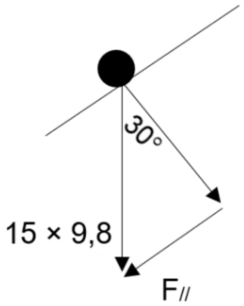
**The IEB will not enter into any discussions or correspondence about any marking guidelines. It is acknowledged that there may be different views about some matters of emphasis or detail in the guidelines. It is also recognised that, without the benefit of attendance at a standardisation meeting, there may be different interpretations of the application of the marking guidelines.**

## QUESTION 1 MULTIPLE CHOICE

| Q. No. | Answer | Reason |
|---|---|---|
| 1.1 | B | Only force acting on stone while moving in the air is the gravitational force, causing constant acceleration of 9,8 $m \cdot s^{-2}$ |
| 1.2 | C | Max: 8 + 3 = 11 N min: 8 – 3 = 5 N<br>Forces between these are possible |
| 1.3 | D | Theory |
| 1.4 | A | $a = \dfrac{G(431\,M)}{\left(\frac{13}{2}r\right)^2}$<br>$= \dfrac{(431)(4)}{13^2}\dfrac{GM}{r^2}$<br>$= \dfrac{(431)(4)}{13^2}(9{,}8)$ |
| 1.5 | C | $E_k = \frac{1}{2}mv^2$ if velocity is $v$ and $x = vt$ for distance covered<br>$E_k' = \frac{1}{2}m(\sqrt{2}\,v)^2$ if velocity is $\sqrt{2}\,v$ and $x' = \sqrt{2}\,vt$<br>$= 2(\frac{1}{2}mv^2)$ $= \sqrt{2}\,(x)$<br>$= 2\,E_k$ |
| 1.6 | B | Gradient $= F \,/\, \frac{1}{t}$<br>$= Ft$<br>$= \Delta p$ |
| 1.7 | C | $E = \dfrac{kQ}{r^2}$<br>$E \propto \dfrac{1}{r^2}$<br>Which is a straight-line graph. |
| 1.8 | A | In top branch: equal resistors thus 9 V over each – point A at 9 V<br>In bottom branch resistors are in ratio 1:2 thus 6 V : 12 V<br>At point B volts is 6 V<br>$V_{AB}$ = 9 – 6 = 3 V or $V_{AB}$ = 12 – 9 = 3 V |
| 1.9 | D | Theory |
| 1.10 | C | Shortest $\lambda$ means $f$ is highest ($c = \lambda f$ and c is constant)<br>$E = hf$, highest $f$ means biggest $E$ |

## QUESTION 2 KINEMATICS

2.1



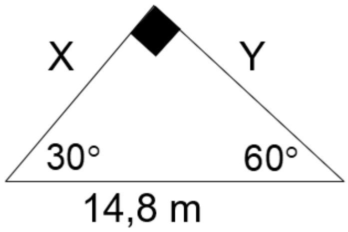

$F_{//} = (15)(9,8)\sin 30°$

$= 73,5\ \text{N}$

Constant $v$ implies $F_{//} = F_A$

$= 73,5\ \text{N}$

2.2




$\cos 30° = \dfrac{x}{14,8}$ (or sin 60°) OR sin rule

$x = 12,82\ \text{m}$

$12,82 - 1,2$ (method) $= 11,62\ \text{m}$

2.3 Acceleration is the rate of change of velocity

2.4 $y = 14,8 \sin 30° = 7,4\ \text{m}$ (OR Pythagoras OR 14,8 OR sin rule)
AWARD THE MARK FOR $14,8\sin 30°$ or $14,8\cos 60°$ or Pythagoras, NOT the answer of 7.4.

$y = v_i t + \frac{1}{2}at^2$

$7,4 = 0 + \frac{1}{2}a(4)^2$

$= 8a$

$a = 0,925\ (0,93)\ \text{m}\cdot\text{s}^{-2}$

2.5 $v_f = v_i + at$

$= 0 + (0,925)(4)$ e.c.o. 2.4

$= 3,7\ \text{m}\cdot\text{s}^{-1}$

OR $v_f^2 = v_i^2 + 2a\Delta x$

= 0 +2(0,93)(7,4)

= 3,7 $\text{m.s}^{-1}$

2.6 $F_R = ma$

$= (15)(0,925)$ e.c.o. 2.4

$= 13,88\ \text{N}$

2.7 When a net force, $F_{net}$, is applied to an object of mass, $m$, it accelerates in the direction of the net force. The acceleration, $a$, is directly proportional to the net force and inversely proportional to the mass. OR i.t.o. momentum : Net force equal rate of change of momentum

2.8 $F_R = F_A + F_f$

13,88 (e.c.o. 2.6) $= (15)(9,8)\sin 60° + F_f$

$F_f = 13,88 - 127,3$

$= -113,3$ N

$= 113,3$ N up the slope

## QUESTION 3 KINEMATICS

3.1 3.1.1 positive

3.1.2 2 s

3.1.3 $9{,}8\ \text{m}\cdot\text{s}^{-2}$

3.1.4 gradient $=$ acceleration

$$a = \frac{30-0}{t-2}$$

$9{,}8(t-2) = 30$ (subs) (e.c.o. 3.1.3)

$$t = 3{,}06 + 2$$
$$= 5{,}06\ \text{s} \cong 5\ \text{s}$$

OR $v_f = v_i + at$

$$30 = 0 + 9{,}8(t-2)$$
$$t = 5\ \text{s}$$

3.1.5 2 times (twice)

3.1.6 Area = distance

$h = \frac{1}{2}(5-2)(30)$ e.c.o 3.1.4

$= 45$ m

OR $v_f^2 = v_i^2 + 2a\Delta x$

$30^2 = 0 + 2(9{,}8)\Delta x = 45\text{m}$

OR $\Delta x = v_i t + \frac{1}{2} a t^2$

$= 0 + \frac{1}{2}(9{,}8)(5-2)^2 = 45$ m

3.2 Say $x$ meter in 1st second, then $x + 1{,}1$ meter in first 2 seconds:

$x + 1{,}1 = \frac{1}{2}a(2)^2$ and $x + 3{,}3 = \frac{1}{2}a(3)^2$ in first 3 seconds

$x = 2a - 1{,}1$ $x = 4{,}5a - 3{,}3$

thus $2a - 1{,}1 = 4{,}5a - 3{,}3$

$$2{,}5a = 2{,}2$$
$$a = 0{,}88\ \text{m}\cdot\text{s}^{-2}$$

$$x = 2(0{,}88) - 1{,}1$$
$$= 1{,}76 - 1{,}1$$
$$= 0{,}66\ \text{m}$$

## QUESTION 4 NEWTON

4.1 4.1.1 The two boxes are made of different material.

4.1.2 100 N

4.1.3 When object A exerts a force on object B, object B **simultaneously** exerts an oppositely directed force of equal magnitude on object A

4.1.4 $F_{Q\ on\ P} - F_f = ma$
$F_{P\ on\ Q} = 12(0,2) + 40$ ($F_{Q\ on\ P} = F_{P\ on\ Q}$)
$= 42{,}4$ N to the right

4.2 4.2.1 mass
on same surface / same friction **OR**
Same distance, same person taking time to calculate.

4.2.2 So that **only** the independent variable will influence the change in the dependent variable.

4.2.3 Applied force

4.2.4 The graph uses the applied force, but acceleration is calculated with the resultant force
All the values of $F_A$ must be smaller due to the magnitude of $F_f$ that must be subtracted
This will shift the line back through the origin OR
This causes line to pass through bigger value, thus crossing x-axis.

4.2.5

$$\underset{\substack{\downarrow\\ a}}{y} = m\underset{\substack{\downarrow\\ F}}{x} + c$$

$$F = ma$$

$$a = \frac{1}{m}F$$

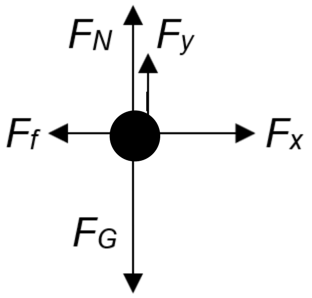
$$\text{gradient} = \frac{1}{m}$$

4.3 No, it is not correct

- The force of the truck on the car = the force of the car on the truck according to Newton's third law of motion
- More damage to the car is due to the crumple zone of the car or softer metal.
- Mass of the truck does not independently influence the force the car will experience (only increase momentum which is not a force)

## QUESTION 5 MOMENTUM, WORK, ENERGY & POWER

5.1 5.1.1




$F_N$ = normal force $F_f$ =friction
$F_y$ = *y*-component of applied force **OR**
***F_APPLIED*** **at an angle**
$F_x$ = *x*-component of applied force
$F_G$ = gravitational force/weight
Relative arrow lengths $F_N$ and $F_G$

5.1.2 The work done by a net force on an object is equal to the change in the kinetic energy of the object

5.1.3
$$\begin{aligned} W_f &= F_f \Delta x \\ &= \mu_k F_N \Delta x \\ &= (0,3)[(15)(9,8) - F_A \sin 20°]\ (4)\cos 180° \\ &= -1,2[147 - F_A(0,342)] \\ &= -176,4 + 0,41\,F_A \end{aligned}$$

$$(F_N + F_y = F_G$$
$$F_N = (15)(9,8) - F_A \sin 20°)$$

5.1.4
$$\begin{aligned} W &= W_f + W_X \\ &= (-176,4 + 0,041\,F_A)\ + (F_A \cos 20° \cdot 4\cos 0°) \\ 0 &= -176,4 + 0,041\,F_A + 3,76\ F_A \\ -3,80\ F_A &= -176,4 \\ F_A &= 46,4\ \text{N} \end{aligned}$$

5.2 5.2.1 The total linear momentum of an isolated system remains constant

5.2.2
$$\begin{aligned} p_{before} &= p_{after} \\ (1,5)(3) + 0\ &= (1,5)(2) + (0,55)(v) \\ 4,5 - 3,0 &= 0,55\ v \\ v &= 2,73\ \text{m}\cdot\text{s}^{-1} \end{aligned}$$

5.2.3
$$\begin{aligned} F\Delta t &= \Delta p \\ F(0,02) &= 1,5(2-3) \\ F &= -75,0\ N \quad \text{(ball on truck)} \\ F &= 75,0\ N \quad \text{right (truck on ball)} \end{aligned}$$

5.2.4
$$\begin{aligned} E_{mech\ before} &= E_{mech\ after} \\ \frac{1}{2}(0,55)(2,73)^2 + 0\ &= (0,55)(9,8)h + 0 \\ 2,05 &= 5,39h \\ h &= 0,38\ \text{m} \end{aligned}$$

## QUESTION 6 FIELDS

6.1 $E = \dfrac{kQ}{r^2}$

$= \dfrac{(9\times10^9)(6\times10^{-3})}{(0{,}025)^2}$

$= 8{,}64\times10^{10}\ \text{N}\cdot\text{C}^{-1}$

6.2 6.2.1
- The negatively charged ball's electrons will repel the electrons in the neutral ball
- This $e^-$ will move to the other side of the neutral ball, far away from the neg ball
- The pos side will be closest to the neg ball and thus attraction occurs

6.2.2 The moment they touch, electrons move over from negative ball to positive side of the other ball until the two balls have the same charge.

6.2.3 1 $e^-$ has a charge of $-1{,}6\times10^{-19}$ C
? $e^-$ has a charge of $-2\times10^{-6}$ C

$2\times10^{-6} \div 1{,}6\times10^{-19} = 1{,}25\times10^{13}$ electrons

6.3 6.3.1 $F_{P\ on}\ Q = \dfrac{kQ_1Q_2}{r^2}$

$= \dfrac{(9\times10^9)(3\times10^{-9})(2\times10^{-9})}{(0{,}2)^2}$

$= 1{,}35\times10^{-6}$ N, right

$F_{R\ on}Q = \dfrac{(9\times10^9)(4\times10^{-9})(2\times10^{-9})}{(0{,}3)^2}$

$= 8{,}00\times10^{-7}$ N, right $(0{,}8\times10^{-6}$ N)

$F_R = 0{,}8\times10^{-6} + 1{,}35\times10^{-6} = 2{,}15\times10^{-6}$, right

6.3.2 Left

## QUESTION 7 ELECTRIC CIRCUITS

7.1 Current through a conductor is directly proportional to the potential difference across the conductor at constant temperature

7.2 7.2.1 $\frac{1}{R} = \frac{1}{6} + \frac{1}{3}$

$R_p = 2\ \Omega$

$R_T = 2 + 1 + r$

$Emf = IR_T$

$12 = 3\ R_T$

$R_T = 4\ \Omega$

$3 + r_i = 4$

$r_i = 1\ \Omega$

OR

$Emf = I(r_i + \text{Re})$

$12 = 3(r_i + 3)$

$r_i = 1\ \Omega$

7.2.2 $V_1 = Emf - V_i$

$= 12 - (3)(1)$

$= 9\ \text{V}$

OR R$_{ext}$ = V/I

(2+1) = V /3

V = 9V

7.2.3 $V_2 = IR_p$

$= (3)(2)$

$= 6\ \text{V}$

**OR** $V = IR$

$= (3)(2)$

$= 6\ \text{V}$

**OR** $V_2 = V_{ext} - V$

$= 9 - 3 = 6\ \text{V}$ **OR**

$\boldsymbol{V_2 = (12 - 3) - 3 = 6\ \text{V}}$

7.2.4 $W = \frac{V^2 t}{R}$

$= \frac{(6)^2(120)}{(3)}$

$= 1\,440\ \text{J}$

**OR** $W = I^2 Rt$

$= (2)^2(3)(120)$

$= 1\,440\ \text{J}$

E = W (both correct)

7.3 7.3.1 current is the rate of flow of charge

7.3.2 20 joules of energy can be transferred by every coulomb charge that flows

7.3.3 *P* = *VI*

150 = 20 *I*

*I* = 7,5 A

7.3.4 Voltmeter

To keep same current in X + Y, it must have very high resistance

7.3.5 Current will decrease as the resistance will increase

Internal voltage will decrease

Internal resistance *r* will not change as it is the same battery

## QUESTION 8 ELECTRODYNAMICS

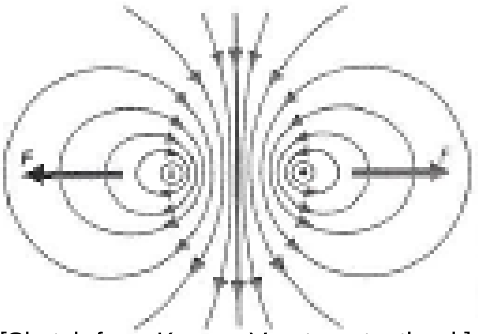
8.1 8.1.1 The induced current flows in a direction so as to set up a magnetic field to oppose the change in magnetic flux.

8.1.2 The emf induced is directly proportional to the rate of change of magnetic flux (flux linkage).
As the magnet moves in or moves out of the coil, there is a change in the magnetic flux linkage with the coil, causing an emf.

8.1.3 south

8.1.4
- As the magnet falls to the ground, it will accelerate due to gravity
- The change in magnetic flux is slower at the top and faster at the bottom
- Emf is directly proportional to the rate of change of the magnetic flux

8.2


[Sketch from Ken-en Verstaan textbook]

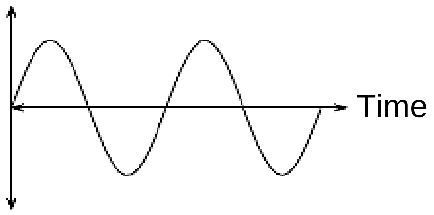
| |
|---|
| Arrow directions |
| Increase in density between the two |
| Decrease in density on outside |
| Force between them bigger than on outside, pushing them apart |

8.3 8.3.1 Electrical energy to kinetic energy.

8.3.2 Split ring (commutator)

8.3.3
- Half a ring will connect side one of the coil with the positive/ negative side of the battery causing it to experience a force downwards/upwards
- The force gradually decreases as the coil moves from the horizontal to vertical position as the linkage deceases
- Momentum carries it past the lowest/highest point when the coil then connects to the other half circle which is connected to the negative/positive side of the battery
- This causes the current to flow in the opposite direction of side one of the coil so that it experiences a force in the opposite direction to move a full circle

8.3.4 current (arbitrary units)



## QUESTION 9 PHOTONS AND ELECTRONS

9.1 $$E = \frac{hc}{\lambda}$$
$$= \frac{(6,6\times10^{-34})(3\times10^{8})}{(3,4\times10^{-8})}$$
$$= 5,82\times10^{-18}\ \text{J}$$

9.2 9.2.1 Threshold frequency ($f_o$) is *the minimum frequency of incident radiation at which electrons will be emitted from a particular metal*

9.2.2 $$E_0 = hf_0$$
$$3,5\times10^{-19} = \left(6,6\times10^{-34}\right)f_0$$
$$f_0 = 5,30\times10^{14}\ \text{Hz}$$

9.3 9.3.1
- Every element's atoms have specific energy differences between the levels that can only be found in that element
- When electrons drop from one level to another and the energy is released, light of specific energy, and therefore frequency, is released
- A colour line is connected to the specific frequency of light released

9.3.2 $eV = 3,4\times1,6\times10^{-19} = 5,44\times10^{-19}$ J

9.4 $$E_k = E - W$$
$$= hf - W$$
$$y = mx + c$$

$$\text{Gradient} = \frac{(3,4-1,4)\times10^{-19}\ \text{J}}{(12-9)\times10^{14}\ \text{s}^{-1}}$$

(use any coordinates exactly on line – far apart)
(11,2 ; 3) (10,6 ; 2,5) (9,6 ; 1,8) (7,8 ; 0,6) (7,1 ; 0,2)

$$h = 0,66\times10^{-33}$$
$$= 6,6\times10^{-34}\ \text{J}\cdot\text{s}$$

**Total: 200 marks**