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GRADE 12 EXAMINATION

JUNE 2023

PHYSICAL SCIENCES: PAPER I

Time: 2 hours

130 marks

Examiner: K Mari

Moderator: J Morrison-Young

NAME																	
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PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 20 pages, and a Data Sheet of 2 pages. Please check that your question paper is complete.
2. Read the questions carefully.
3. Answer ALL the questions.
4. Use the data and formulae whenever necessary.
5. Show your working in all calculations.
6. Units need not be included in the working calculations, but appropriate units should be shown in the answer.
7. Answers must be expressed in decimal format, not left as proper fractions.
8. Where appropriate, express answers to TWO decimal places.
9. It is in your own interest to write legibly and to present your work neatly.

Question 1

Answer these questions on the multiple-choice answer sheet below. Make a cross (X) in the box corresponding to the letter that you consider to be correct.

A	B	☒	D
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Here the option C has been marked as an example.

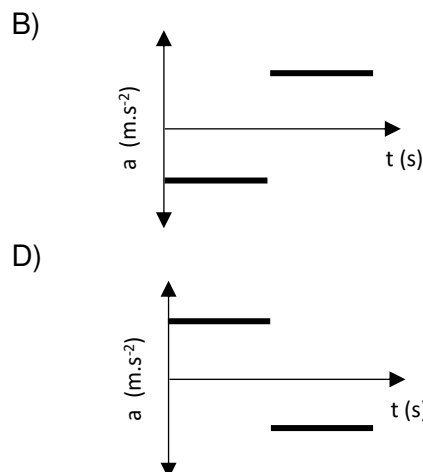
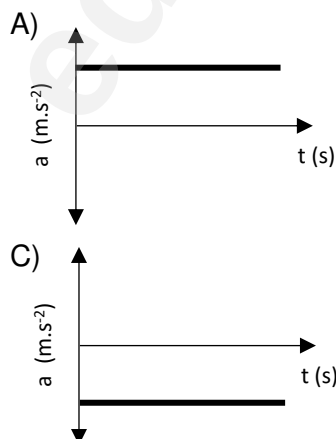
1.1	A	B	C	D
1.2	A	B	C	D
1.3	A	B	C	D
1.4	A	B	C	D
1.5	A	B	C	D
1.6	A	B	C	D
1.7	A	B	C	D

- 1.1 Linear momentum is defined as the product of the mass and velocity of the object $p = mv$. This formula consists of:

- A) one vector quantity and two scalar quantities
- B) two vector quantities and one scalar quantity
- C) three vector quantities
- D) three scalar quantities

- 1.2 A ball is thrown vertically upwards and caught on the way down. Which graph best shows the relationship between acceleration and time for the entire motion of the ball?

Ignore air friction and take upwards as the positive direction.



- 1.3 Newton's third law concerns the forces of interaction between two bodies. Which of the following statements relating to the third law is **NOT** correct?
- A) The two forces must act on different bodies.
 - B) The two forces are always in opposite directions.
 - C) The two forces are at all times equal in magnitude.
 - D) The two forces are equal and opposite so the bodies are in equilibrium.

- 1.4 Consider the following ideal pulley system in which the rollers are frictionless.



Which of the following statements are correct regarding the tension in the rope?

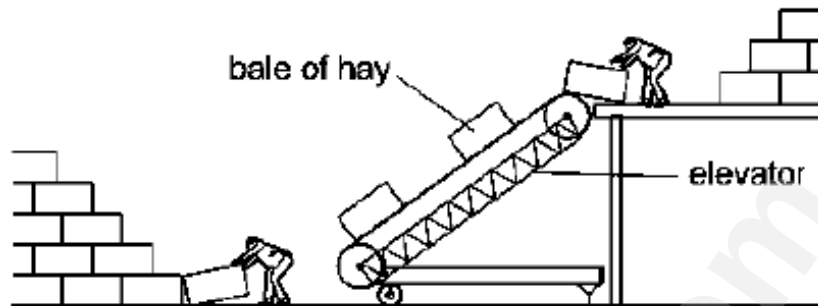
I – the tension in the rope is 39,2 N when the system is at rest

II – the tension in the rope decreases when the block on the right is moving downwards at a constant velocity

III – if one of the masses was replaced with an 8 kg mass the tension in the rope would double

- A) I and II
 - B) II and III
 - C) II only
 - D) I only
- 1.5 A net force F is applied to two stationary objects P and Q. The mass of P is triple that of Q. The rate of change of momentum of P is Y . What will the rate of change of momentum of Q be?
- A) $0,5 Y$
 - B) Y
 - C) $3 Y$
 - D) $0,33 Y$

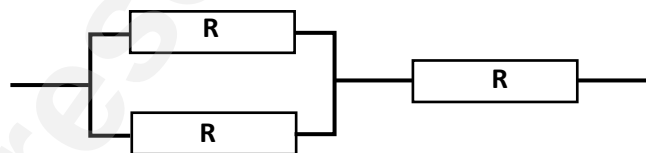
- 1.6 An electric motor runs a conveyor belt which lifts bales of hay as shown in the diagram below. All the bales of hay have the same mass.



An hour before sunset, the speed of the motor is increased so that more bales are lifted per hour.

	Work done in lifting each bale	Useful power output of the motor
A	Remains the same	Increases
B	Increases	Increases
C	Decreases	Decreases
D	Remains the same	Decreases

- 1.7 The diagram below shows how three resistors, each with resistance R , are connected in a certain electric circuit. Which one of the following expressions best represents the total resistance for the three resistors?



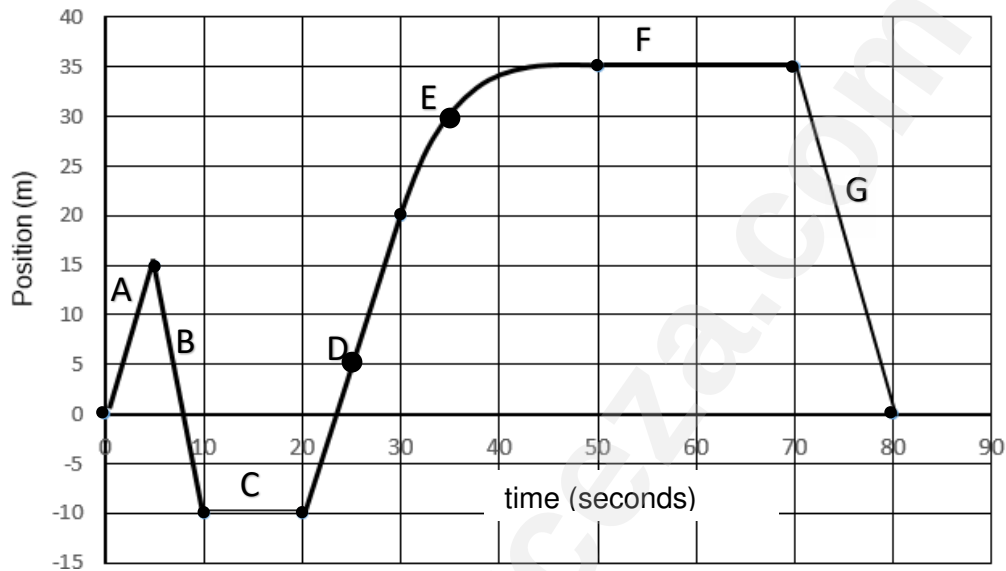
- A) $\frac{3}{2} R$ B) $\frac{2}{3} R$
 C) $3 R$ D) $2 R$

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Question 2

A camera on a straight rail is used to assist in televising a game of World Cup rugby. The camera is initially positioned at the half-way line of the field, and it can move North or South as directed by the cameraman.

The graph below shows the position of the camera on the rail during the 80 minutes of play. **North** is taken as the positive direction.



2.1 Describe the speed and the direction of the camera during the following sections.

2.1.1 E (2)

2.1.2 G (2)

2.2 Define the term *velocity*. (2)

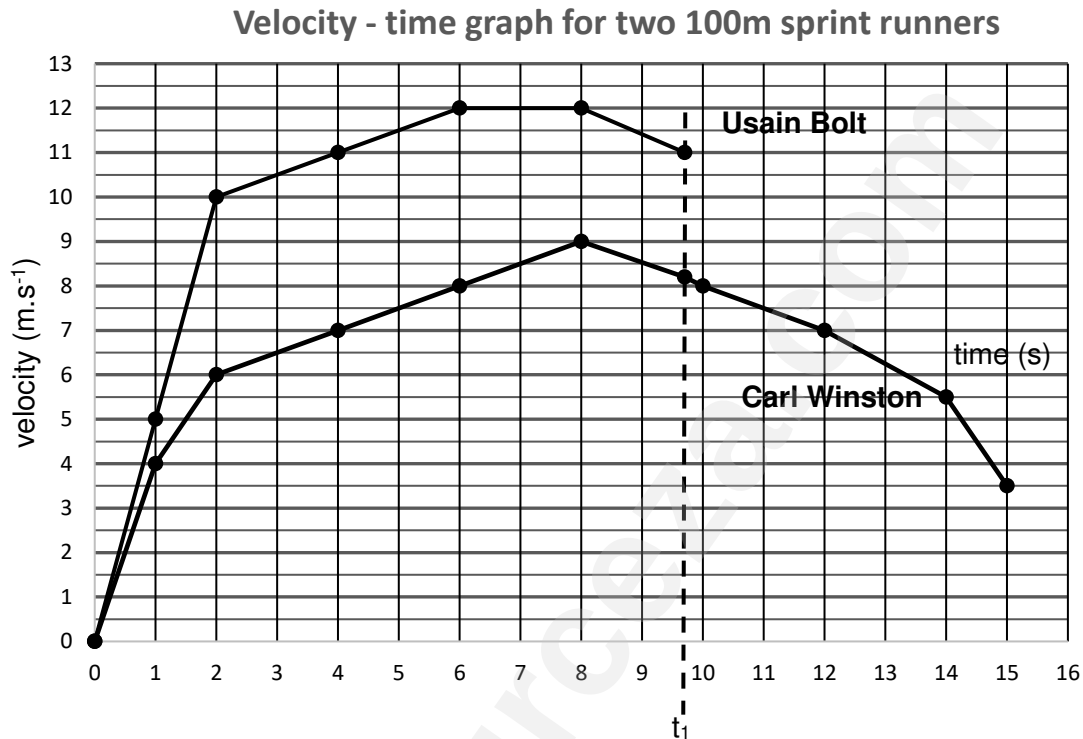
2.3 Calculate the magnitude of velocity of the camera at D. (2)

2.4 Calculate the magnitude of the acceleration between D and E. (3)

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Question 3

- 3.1 Below are two simplified velocity-time graphs showing the velocity of two runners, Usain Bolt and Carl Winston, for the duration of a 100m sprint race.



- 3.1.1 During which time interval did the runners have the same acceleration? (2)

- 3.1.2 Which runner won the race? Give a reason for your answer. (2)

- 3.1.3 Did one of the runners pass the other at any time? If so, state the time at which this occurred. (2)

3.1.4 The running plan of a sprinter has four stages:

Stage I : Drive (maximum acceleration)

Stage II: Transition (lower acceleration but increasing speed)

Stage III: Maximum speed reached

Stage IV: Maximum speed maintained to the end of the race.

In which of these stages did Usain Bolt's performance not follow the running plan? Explain your answer. (2)

3.1.5. What feature, other than the starting point, of the two graphs is identical? Explain your answer. No calculations are required. (2)

3.1.6. Given that Usain Bolt ran 54 m in the first 6 seconds of the race, perform a calculation to determine the time t_1 (to one decimal place). (5)

- 3.2 In another race, Usain Bolt lost a 100 m sprint against his old school friend Leroy “the bullet” Johnson (who rode his bicycle). Sports analysts described the race as follows:

Usain Bolt accelerated at a constant rate, from rest, to reach a maximum velocity of $12,5 \text{ m.s}^{-1}$ as he reached the 25 m mark (after running the first 25 m). He maintained this speed for the remainder of the race.

Leroy Johnson accelerated at 3 m.s^{-2} , from rest, for a time of 4 s, then at 2 m.s^{-2} for a time of 1 s before maintaining a constant speed for the remainder of the race.

- 3.2.1 Calculate the time Usain Bolt took to run the first 25 m. (3)

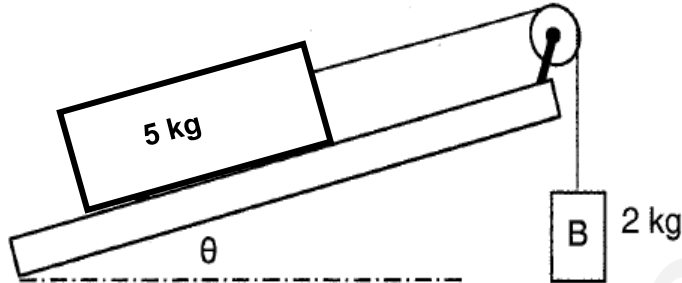
- 3.2.2 Calculate the magnitude of the maximum velocity reached by Leroy Johnson in this race. (5)

- 3.2.3 Calculate the distance Leroy Johnson cycled before reaching his maximum velocity. (6)

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Question 4

- 4.1 A box is placed on a **frictionless** surface as shown in the diagram below. It is connected to a 2 kg weight by a string which passes over a frictionless pulley. The surface is inclined such that the box barely remains stationary.



- 4.1.1 State *Newton's second law*. (3)

Calculate:

- 4.1.2 The tension in the string when the system is stationary. (2)

- 4.1.3 The value of θ when the system is stationary. (2)

The slope is adjusted such that θ is reduced to 10° .

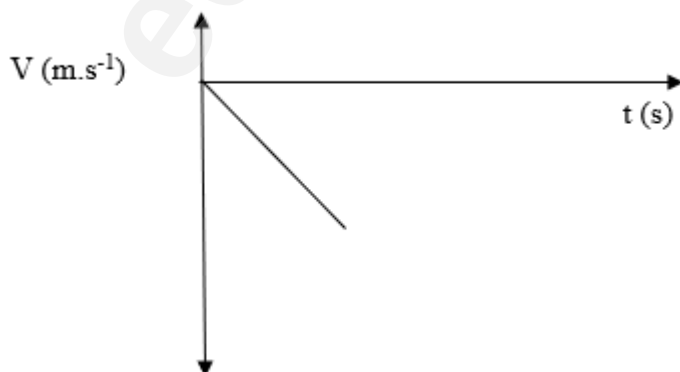
4.1.4 What will happen to the box? Answer only REMAIN STATIONARY/
ACCELERATE UP THE SLOPE/ACCELERATE DOWN THE SLOPE. (2)

4.1.5 Calculate the acceleration of the system when $\theta = 10^\circ$. (5)

4.2 A crane in a harbour is holding a 400 kg crate at a height of 30 m above the water, waiting for a cargo ship to arrive. Before the ship has arrived the rope snaps and the crate falls into the water. The graph of the velocity of the crate vs time from the time the rope snaps until the crate hits the water is shown below.

Down is taken as **negative**.

Air resistance can be ignored.



4.2.1 Define the term *acceleration*. (2)

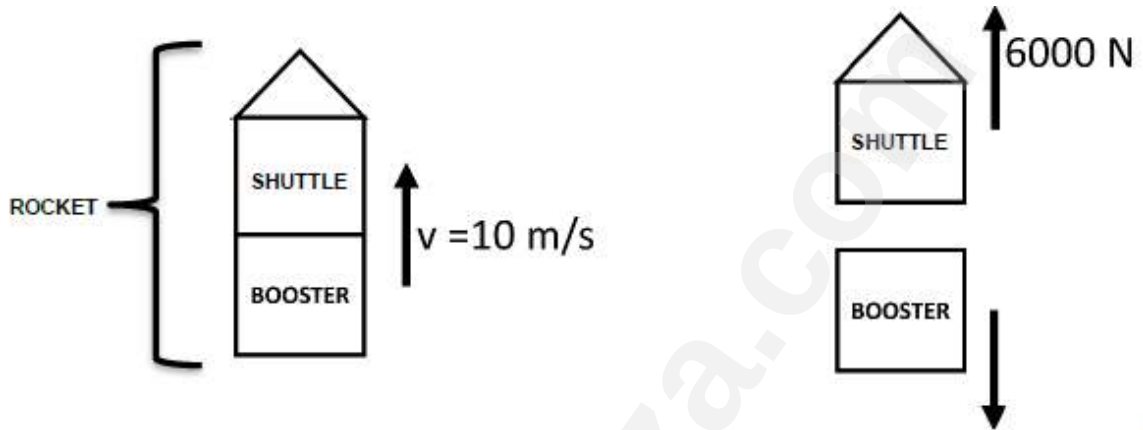
4.2.2 State, without doing any calculations, the value of the gradient of the graph. (2)

4.2.3 Calculate the speed with which the crate hits the water. (3)

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Question 5

At a point after launch, a rocket, consisting of a booster and shuttle, is 3 km above the ground. The rocket has an upward velocity of 10 m.s^{-1} at this point. A booster rocket is fired downward, resulting in a net force of 6000 N being exerted upward on the shuttle.



The booster is fired over a period of 2,5 seconds.

5.1 Define the term *impulse*. (2)

5.2 If the mass of the shuttle is 2000 kg, calculate the velocity of the shuttle immediately after the booster is fired. (5)

In space, an astronaut of mass 75 kg and carrying a pack of mass 25 kg, accidentally separates from the space shuttle. The space shuttle is now at a distance of 15 m from the astronaut.

The astronaut knows that the only way to get back to the shuttle is to push away his pack, which he does.

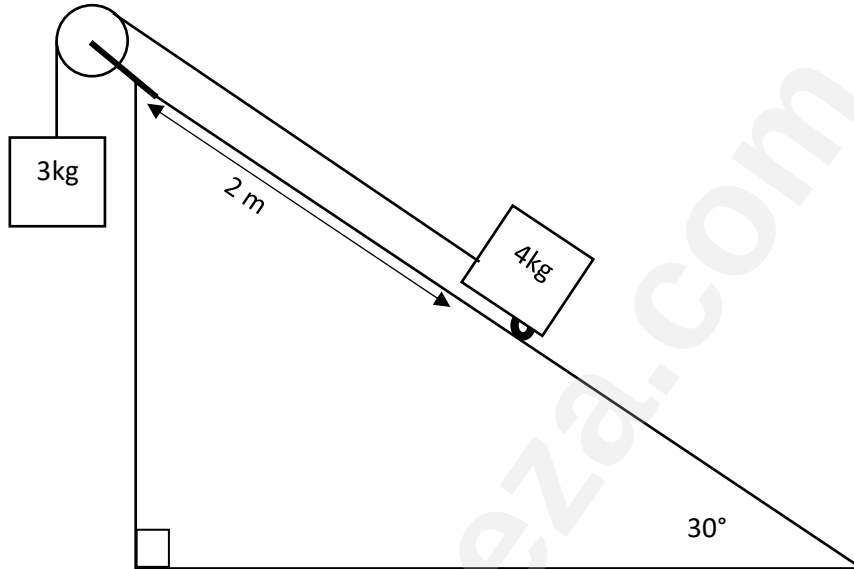
- 5.3 Calculate the magnitude of the velocity at which the astronaut moves after the push if he gets back to the shuttle in 30 seconds. (3)

- 5.4 State the *law of conservation of linear momentum*. (2)

- 5.5 Determine the magnitude and the direction of the velocity of the pack (relative to the shuttle) after the astronaut's push that returns him to the shuttle in 30 seconds. (5)

Question 6

In the diagram shown below, ignore all frictional effects. Consider the string attaching the mass block and the trolley to be inextensible and to have negligible mass.



The system is initially held stationary. When the suspended 3 kg mass is released, it falls and accelerates the 4 kg trolley 2 m up the slope.

- 6.1 Calculate the component of the force of gravity acting on the trolley parallel to the slope ($F_{g//}$). (2)
- 6.2 Prove that the vertical rise in height of the trolley is equal to 1 m. (2)
- 6.3 Calculate the gain in potential energy of the trolley. (3)

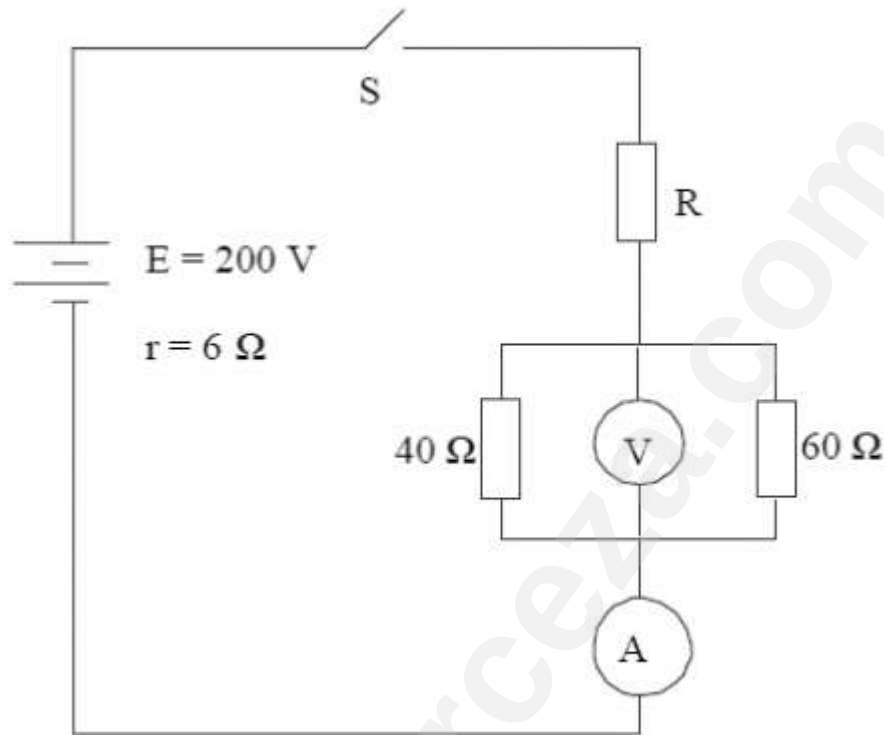
6.4 Calculate the total work done on the trolley by the string. (3)

6.5 State the *Work-Energy theorem*. (2)

6.6 Make use of the Work-Energy theorem to calculate the speed of the trolley after travelling the 2 m up the ramp. (5)

Question 7

In the circuit below the voltmeter V has a very high resistance and the ammeter A has a very low resistance. The emf of the power supply is 200 V and its internal resistance is $6\ \Omega$.



The $40\ \Omega$ resistor gives off **15 000 J** of energy in **50s** when the switch S is closed.

7.1 State *Ohm's law*. (2)

7.2 Calculate the reading on voltmeter V. (4)

7.3 Calculate the current in the $60\ \Omega$ resistor. (3)

7.4 Calculate the reading on ammeter A. (3)

7.5 Calculate the resistance of R. (5)

The $40\ \Omega$ resistor above is, in fact, a small electric heater.

7.6 If electricity costs R2,43 per kWh, how much does it cost to leave this heater switched on for 2 hours? (4)

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EXAMINATION DATA SHEET FOR THE PHYSICAL SCIENCES (PHYSICS)

TABLE 1 PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Acceleration due to gravity	g	$9,8 \text{ m}\cdot\text{s}^{-2}$
Speed of light in a vacuum	c	$3,0 \times 10^8 \text{ m}\cdot\text{s}^{-1}$
Universal gravitational constant	G	$6,7 \times 10^{-11} \text{ N}\cdot\text{m}^2\cdot\text{kg}^{-2}$
Coulomb's constant	k	$9,0 \times 10^9 \text{ N}\cdot\text{m}^2\cdot\text{C}^{-2}$
Magnitude of charge on electron	e	$1,6 \times 10^{-19} \text{ C}$
Mass of an electron	m_e	$9,1 \times 10^{-31} \text{ kg}$
Planck's constant	h	$6,6 \times 10^{-34} \text{ J}\cdot\text{s}$
1 electron volt	eV	$1,6 \times 10^{-19} \text{ J}$

TABLE 2 PHYSICS FORMULAE

MOTION

$v = u + at$ or $v_f = v_i + a\Delta t$	$s = \left(\frac{v+u}{2}\right)t$ or $\Delta x = \left(\frac{v_f+v_i}{2}\right)\Delta t$
$v^2 = u^2 + 2as$ or $v_f^2 = v_i^2 + 2a\Delta x$	$s = ut + \frac{1}{2}at^2$ or $\Delta x = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$

FORCE AND MOMENTUM

$F_{net} = ma$	$F_{net} = \frac{\Delta p}{\Delta t}$ or $F_{net}\Delta t = m\Delta v$	$J = \Delta p = mv - mu$ or $J = \Delta p = mv_f - mv_i$
$p = mv$	$F_g = mg$	$F_{fs}^{max} = \mu_s F_N$ $F_{fk} = \mu_k F_N$

WORK, ENERGY AND POWER

$W = Fs$ or $W = F\Delta x$ or $W = F\Delta x \cos\theta$	$P = \frac{W}{t}$	$P = Fv$
$E_p = mgh$	$E_k = \frac{1}{2}mv^2$	$W_{net} = \Delta E_K$
efficiency = $\frac{\text{power}_{out}}{\text{power}_{in}} \times 100$		

GRAVITATIONAL AND ELECTRIC FIELDS

$F = G \frac{m_1 m_2}{r^2}$	$g = \frac{F}{m}$	$g = G \frac{M}{r^2}$
$F = k \frac{q_1 q_2}{r^2}$	$E = \frac{F}{q}$	$E = \frac{kQ}{r^2}$

ELECTRIC CIRCUITS

$I = \frac{q}{t}$	$V = \frac{W}{q}$
$R = \frac{V}{I}$	$emf = I(R_{ext} + r)$ or $emf = V_{load} + V_{internal\ resistance}$
$R_s = R_1 + R_2 + \dots$	$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$
$P = \frac{W}{t} \quad \text{or} \quad W = Pt$	
$W = VIt \quad \text{or} \quad W = I^2 R t \quad \text{or} \quad W = \frac{V^2}{R} t$	
$P = VI \quad \text{or} \quad P = I^2 R \quad \text{or} \quad P = \frac{V^2}{R}$	

ELECTRODYNAMICS

$\Phi = BA \cos \theta$	$emf = - \frac{N \Delta \Phi}{\Delta t}$	$F = IB \ell \sin \theta$
$V_p I_p = V_s I_s$	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$	

PHOTONS AND ELECTRONS

$c = f \lambda$		$E = hf$ or $E = \frac{hc}{\lambda}$	
$E = W_0 + E_{K(\max)}$	$W_0 = hf_0$	$E_{K(\max)} = \frac{1}{2} m v_{\max}^2$	