	Office use only	
Name:	Motion:	/40
Teacher:	Fields & electricity:	/40
	TOTAL:	**/80**

Melbourne High School

HONOUR THE WORK

Solutions

SMD / EMS

VCE Physics Unit 3

Motion, Fields & Electricity

SACs 2017

Reading time: 15 minutes
Writing time: 80 minutes

Total Possible Score: 80 marks

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, up to two pages (one A4 sheet) of pre-written notes (typed or handwritten) and one approved scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper, CAS/graphics calculator, mobile phones, iPads and/or any other unauthorised electronic devices.

Materials Supplied
This Question and Answer booklet, with detachable formula sheet at end of booklet.

Instructions
- Detach the formula sheet at the end of the booklet during reading time.
- Write your name and that of your teacher in the spaces provided.
- Answer all questions in this book where indicated.
- **Always** show your working where spaces are provided and always place your answer(s) in the boxes provided.
- All written answers must be in comprehensible English.

Instructions for Section
Answer all questions for Area of Study in this section of the paper.

Area of Study -Motion

Figure 1 shows Joe traveling on an up escalator that is moving with a speed of 1.5 m s^{-1}. Mary is on a parallel escalator that is moving down with a speed of 1.5 m s^{-1}.

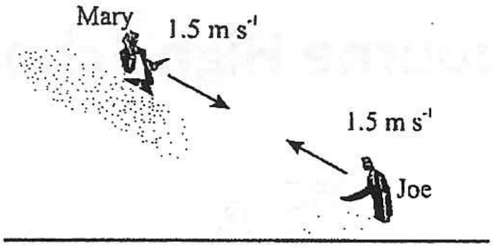


Figure 1

Question 1
Calculate the speed of Mary relative to Joe.

Galilean velocity addition $\Rightarrow$ speed required $= (1.5 + 1.5)\ ms^{-1}$ • M1 (soi)
$= 3.0\ ms^{-1}$. [M1, A1]

| 3.0 m s^{-1} | • A1

2 marks

When standing on the moving escalator Joe is carried to the top in a time of 60 s. The next day, the escalator has stalled. Joe walks up the stalled escalator and reaches the top in a time of 90 s.

Question 2
Calculate the time it would take Joe to walk up the moving escalator to the top.

Length of escalator $= L = 1.5\ ms^{-1} \times 60 s = 90\ m$.
Joe's walking speed $= V_s = \frac{L}{90s} = \frac{90m}{90s} = 1.0\ ms^{-1}$. • M1
• A1
Joe's speed on moving escalator relative to ground $= V_{Esc} + V_s = 2.5\ ms^{-1}$. [M1, A2]

| 36 s | • A1 So time required $= \frac{L}{V_{Esc}+V_s} = \frac{90m}{2.5ms^{-1}} = 36\ s$.

3 marks

Eric stands motionless on a set of bathroom scales and notes the reading as 300 N. He then crouches down and suddenly jumps up. Jason, who is watching, notes that the reading on the bathroom scales momentarily increases to 400 N when Eric jumps up.

Question 3
Calculate the magnitude of Eric's maximum acceleration as he jumps up.

Eric's weight is 300 N (by Newton I). His mass is $\frac{300 N}{9.8 N kg^{-1}} \simeq 30.6\ kg$ • B1

Hence: 400 N, 300 N, $a = \frac{\Sigma F}{m} \approx \frac{100\ N}{30.6\ kg} \simeq 3.27\ ms^{-2}$.

• B1 ($\Sigma F = 100 N$). [B2, A1]

| 3.27 m s^{-2} | • A1

3 marks

8

Ashleigh drove her car of mass 900 kg along a straight horizontal road with a speed of 20 m s^{-1}. She applied the brakes and slowed down to a speed of 5.0 m s^{-1} in 10 s.
Ignore effects due to friction.

Figure 2

Question 4
Calculate the magnitude of the braking force that acted on the car.

$$|a| = \frac{|\Delta v|}{\Delta t} = \frac{15\ \text{m s}^{-1}}{10\ \text{s}} = \underline{1.5\ \text{m s}^{-2}}. \quad \bullet \text{B1}$$

$$\text{So } |\Sigma F| = m|a| = 900\ \text{kg} \times 1.5\ \text{m s}^{-2} = 1350\ \text{N}.$$

Since the only horizontal force is the braking force, the braking force is 1350 N.

1350 N	• A1

[B1, A1]

2 marks

Figure 3 shows a mass of 0.10 kg that is attached to a hanging mass of 0.90 kg by a cord. The table is frictionless and the small mass rotates in a circular path.

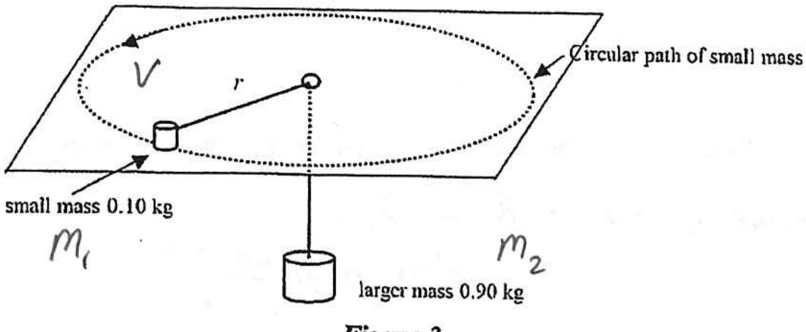


Figure 3

Question 5
Calculate the speed of rotation, in m s^{-1}, of the 0.10 kg mass which will keep the 0.90 kg mass at rest, if the radius of rotation, r, is 0.80 m.

$$\frac{m_1 v^2}{r} = m_2 g, \quad \bullet \text{M1 (equating centrip. force \& weight)}$$

$$v = \sqrt{\frac{m_2}{m_1} r g} = \sqrt{70.56\ \text{m}^2\text{s}^{-2}} = 8.4\ \text{m s}^{-1}.$$

8.4 m s^{-1}	• A1

[M1, A1]

2 marks

4

Questions 6 - 7 refer to the following information.
During a game of rugby, a football is kicked off with an initial speed of 18 m s $^{-1}$ at an angle of 45^0 to the horizontal playing field. A receiver on the goal line 50 m away in the direction of the kick begins running to meet the ball at the instant it is kicked as shown in Figure 4.

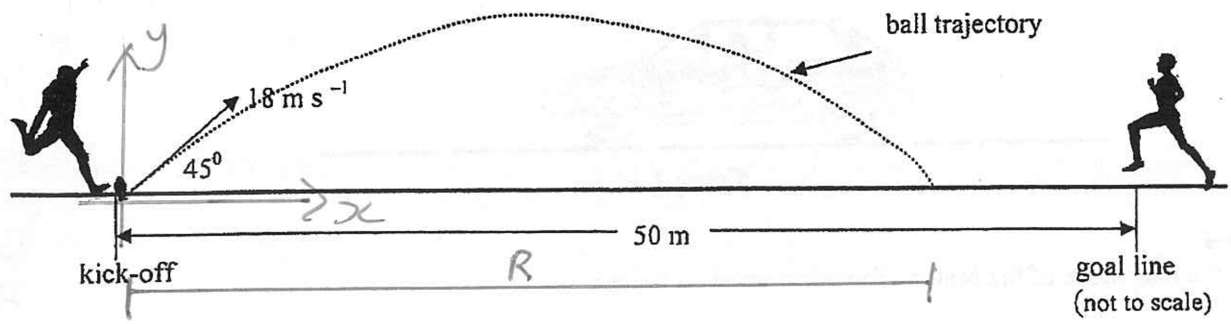


Figure 4

Question 6
Calculate the time the ball is in the air if it isn't caught.

With the natural choice of axes and the usual symbols:

$$u_y = u \sin\theta = 18\ ms^{-1} \times \sin 45^\circ = 9\sqrt{2}\ ms^{-1}.$$ • B1 (initial vertical velocity, soi)

By symmetry, $V_y = -9\sqrt{2}\ ms^{-1}$ when the ball hits the ground.

So $\Delta t = \dfrac{2u_y}{g} = \dfrac{18\sqrt{2}\ ms^{-1}}{9.8\ ms^{-2}} \approx 2.5975 \approx 2.6\ s.$

| 2.6 s | • A1

[B1, A1]

2 marks

Question 7
Calculate the minimum average speed of the receiver if he is to catch the ball before it hits the ground.

Horizontal distance travelled by ball $= R = u_x \Delta t$

$$= (u\cos\theta)\left(\frac{2u\sin\theta}{g}\right)$$

$$= \frac{u^2 \sin(2\theta)}{g}$$

$$= \frac{(18\ ms^{-1})^2 \times 1}{9.8\ ms^{-2}}$$

$$\approx 33.06\ m$$ • B1 (soi)

| 6.5 m s $^{-1}$ | • A1

[B1, M1, A1]

3 marks

Person must run at at least $\dfrac{50m - R}{\Delta t}$ • M1 $= \dfrac{50m}{\Delta t} - u_x$

$$= \frac{25\ g\ m}{u_y} - u_x$$

$$\approx 19.249\ ms^{-1} - 9\sqrt{2}\ ms^{-1}$$

$$\approx 6.521\ ms^{-1}.$$

* On this page deduct 1 mark if final answers are not correct to the number of sig figs to which they are stated. e.g. '6.54 ms^{-1}' loses a mark.

5

Questions 8 - 9 refer to the following information.
An elevator filled with passengers has a total mass of 2500 kg as shown in Figure 5 . The cable snaps when the elevator is at rest at the first floor of a building. At this instant the bottom of the elevator is 3.0 m above the top of a cushioning spring. The spring is compressed by 0.50 m in bringing the elevator to rest initially. Ignore the mass of the spring in this question.

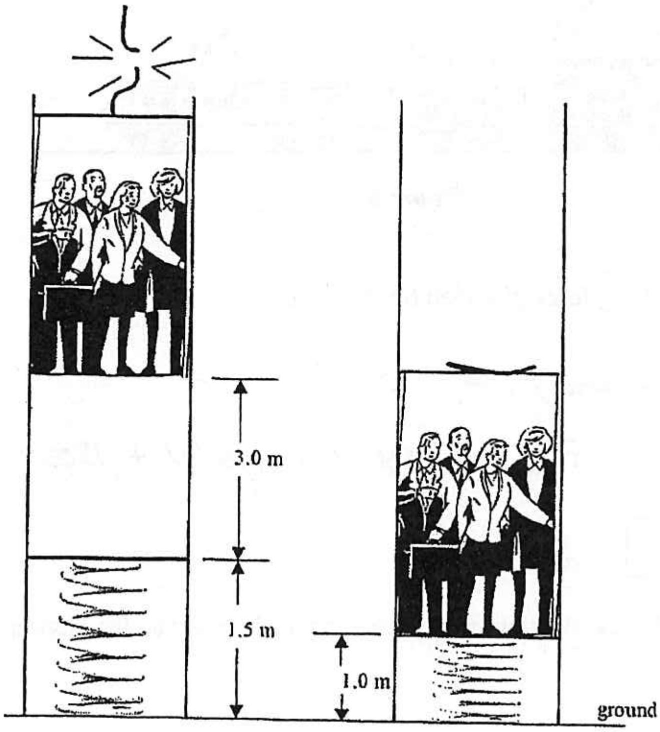


Figure 5

Question 8
Calculate the speed of the elevator as it first makes contact.

$v^2 = 2g\Delta h$,

$v = \sqrt{2g\Delta h} = \underline{\sqrt{2 \times 9.8\,ms^{-2} \times 3.0m}}$ • M1

$= \sqrt{58.8\,m^2s^{-2}} \approx 7.668 \approx 7.7\,ms^{-1}$. [M1, A1]

$\boxed{7.7\,\mathrm{m\,s^{-1}}}$ • A1

2 marks

Question 9
Calculate the spring constant of the spring.

$\Delta PE_{spring} = \underbrace{|\Delta KE|}_{\text{during contact}} + \underbrace{|\Delta GPE|}_{\text{during contact}}$ because of the signs in this situation.

Since in Q8 we effectively used conservation of energy for the 3 m drop, it's simpler (and more accurate) to write: $\Delta PE_{spring} = |\Delta GPE_{total}|$,

[M2, A1]

$\boxed{6.86 \times 10^5\ \mathrm{N\,m^{-1}}}$ • A1 (not conseq) $\frac{1}{2}k(0.5m)^2 = \underline{2500\,kg \times g \times 3.5\,m}$, 3 marks

(= 85 750 J)

$k = 686\,000\ N\,m^{-1}$.

- M1 : Using conservation of energy
- M1 : Realising that GPE still changes as the spring is being compressed

✗ Final A1 is not consequential on Q8.

5

5

Questions 10 - 12 refer to the following information.
Figure 6 shows a train with an engine, a coal truck and carriage travelling at constant velocity along a straight, horizontal section of track. The mass of the engine is 20.0 tonnes and the mass of each of the other two parts is 10.0 tonnes.
At this constant velocity the resistance force (due to frictional forces and air resistance) on the engine is 2000 N and the carriage and coal truck experience a resistance force of 1500 N each.

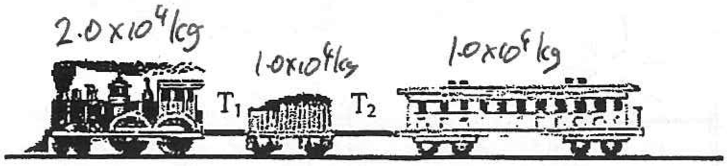


Figure 6

Question 10
Calculate the magnitude of the driving force provided by the engine.

F_{driv} + (three resistance forces) = 0,
$F_{driv} = 2000\,N + 1500\,N + 1500\,N = 5000\,N.$ } • M1

5 000 N	• A1

2 marks [M1, A1]

While still on the same section of track, the train is required to speed up and so the engine driving force is increased to 2.5×10^4 N.

Question 11
Calculate the acceleration of the train during this process. Assume that the resistance forces have not changed.

$$a = \frac{1}{m}\Sigma F = \frac{2.5\times10^4\,N - 0.5\times10^4\,N}{4.0\times10^4\,kg}$$ • M1
$$= 0.50\ ms^{-2}.$$

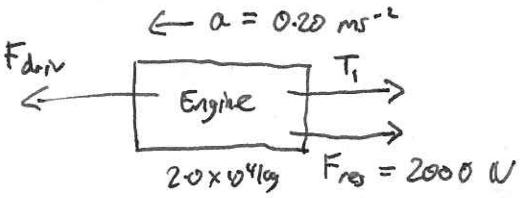
(Allow incorrect powers of 10. Do not award if forces on, or masses of, parts of the train are missing.)

$0.50\ m\,s^{-2}$	• A1

[M1, A1] 2 marks

During another part of the journey the train is accelerating at $0.20\ m\,s^{-2}$ along a straight, level section of track.

Question 12
Calculate the magnitude of the tension (T_1) in the coupling between the engine and the coal truck during this acceleration. (Assume that the resistance forces remain the same as before).



By a calculation similar to that in Q11,
$F_{driv} = 1.3\times10^4\,N.$

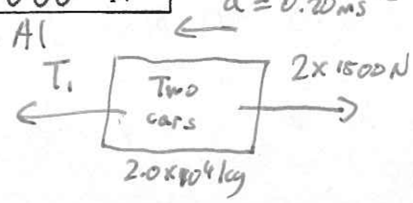
Hence: $F_{driv} - T_1 - 2000N = 2.0\times10^4\,kg \times 0.20\,ms^{-2}$,
$\Rightarrow T_1 = 7000\ N$ [M2, A1]

• M1: Evidence (eg. diagram) that student distinguishes between tension, resistances, & "net force"
• M1: Correct values of quantities used

7000 N

• A1

Alternative:



$T_1 - 3000\,N = 2.0\times10^4\,kg \times 0.20\,ms^{-2}$
$\Rightarrow T_1 = 7000\ N$

3 marks

7

Questions 13 - 14 refer to the following information.

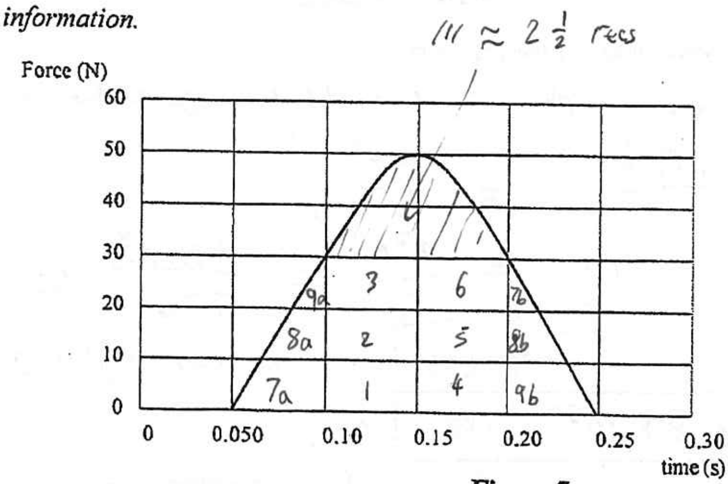


Figure 7

Anne throws a volleyball of mass 0.20 kg vertically into the air to serve. She strikes the ball with her hand at the instant the ball is motionless in the air. The force exerted by her hand on the ball varies with time as shown in Figure 7.

Question 13

Estimate the impulse of the force exerted by Anne's hand on the ball.

Impulse = area under F-t graph ≈ $11\frac{1}{2}$ rectangles × 0.5 Ns rectangle^{-1}

≈ 5.75 Ns

[M1, A1]

| 5.75 Ns | • A1

2 marks

• M1: evidence of attempt to find area

Question 14

Calculate the speed of the ball immediately after impact with Anne's hand.

Ignoring gravity, $\Delta p = 5.75\ Ns \Rightarrow mv = 5.75\ Ns$,

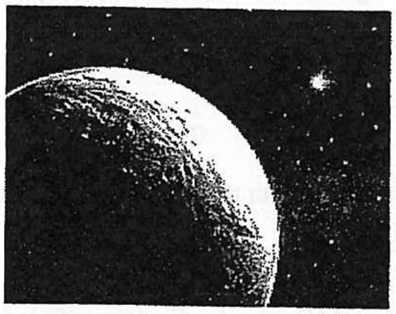
$v = \frac{5.75\ Ns}{0.20\ kg} = 28.75\ ms^{-1}$

[M1, A1]

| 29 m s^{-1} | • A1

2 marks

Questions 15 - 18 refer to the following information.



One of the more than 200 extra-solar planets discovered recently revolves in a circular path around a star, (HR 7291, found in the constellation Sagittarius), at a distance of 7.7×10^9 m (between centres). The period of the planet is 3.09 days.

Question 15

Calculate the orbital velocity, in m s^{-1}, of the planet.

$V = \frac{2\pi r}{T} = \frac{2\pi \times 7.7 \times 10^9\ m}{3.09\ day \times 86400\ s\ day^{-1}} \approx 1.812 \times 10^5\ ms^{-1}$

• M1 (allow incorrect units)

[M1, A1]

| 1.8×10^5 m s^{-1} | • A1

2 marks

6

M : mass of star

m : mass of planet

Question 16
Calculate the mass, in kg, of the parent star.

Grav force on planet = centripetal force required for uniform circ. motion,

$$\frac{GMm}{r^2} = \frac{mv^2}{r},$$

$$\underbrace{M = \frac{v^2 r}{G}} = \frac{4\pi^2 r^3}{T^2 G} \approx 3.79 \times 10^{30} \text{ kg}$$

• M1 (equate forces and cancel m) (using $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2})

$\boxed{3.8 \times 10^{30} \text{ kg}}$ • A1 (not consequential)

[M1, A1]

2 marks

The mass of the planet revolving around star HR 7291 is 1.6×10^{26} kg.

Question 17
Calculate the magnitude of the gravitational force of attraction between the planet and star HR 7291.

$$|F_{grav}| = |F_{cent}| = \frac{mv^2}{r} = \frac{1.6 \times 10^{26} \text{ kg} \times (\text{Q15 ans})^2}{7.7 \times 10^9 \text{ m}} \quad \text{• M1}$$

$$\approx 6.824 \times 10^{26} \text{ N}$$

or $|F_{grav}| = \frac{GMm}{r^2}$

$$= \frac{G \times (\text{Q16 ans}) \times 1.6 \times 10^{26} \text{ kg}}{(7.7 \times 10^9 \text{ m})^2} \approx \ldots$$

$\boxed{6.8 \times 10^{26} \text{ N}}$ • C1

Conseq on Q15 or Q16, as required.

[M1, C1]

2 marks

Question 18
How would the surface temperature of this planet compare with that of the Earth's surface temperature, **assuming the star is like the Sun?**

Higher temperature (because it is closer).

1 mark

• B1 ('About 5 times the temperature, to zeroth order.' Too much to ask for for 1 mark.)

(BOTE calculation: $r_{exoplanet} \approx 25.7$ light-sec. $r_{\oplus} \approx 500$ light-sec.

So $\frac{r_{exo}}{r_{\oplus}} \approx 0.05$.

• $E_{received} \propto \frac{1}{r^2}$.

END OF AREA OF STUDY

• Both $E_{received}$ & $E_{radiated\ away}$ are proportional to (radius of planet)^2.

$E_{received} \propto \pi a^2$, $E_{radiated\ away} \propto 4\pi a^2$ where a = radius of planet.

• $E_{rad\ away} \propto T^4$. Hence $\frac{r_{exo}}{r_{\oplus}} \approx 0.05 \Rightarrow \frac{E_{exo}}{E_{\oplus}} \approx 400 \Rightarrow \frac{T_{exo}}{T_{\oplus}} \approx 4.5$.

• $E_{received} = E_{rad\ away}$ for thermal equilib.

Instructions for Section .
Answer all questions for Area of study in this section of the paper.

Area of study – Electricity and Fields

Questions 1 and 2 refer to the following information.

Figure 1 shows a wire of length 0.12 m carrying an electric current of 2.0 A in a uniform magnetic field of strength 0.90 T and perpendicular to the field. A magnetic force causes the wire to move.

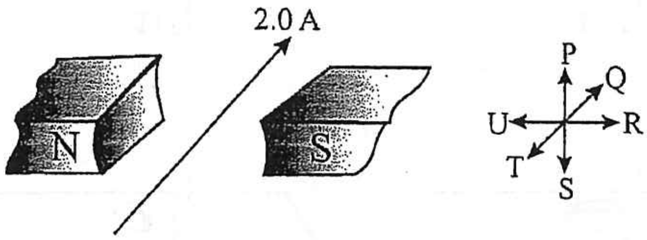


Figure 1

Question 1

Calculate the magnitude of the force on the wire. Assume all of the wire is in the magnetic field.

$$F = BIl = \underbrace{0.9 \times 2 \times 0.12}_{(1)} = 0.216\,N$$

$\boxed{0.22 \text{ N}}$ (1)

2 marks

Question 2

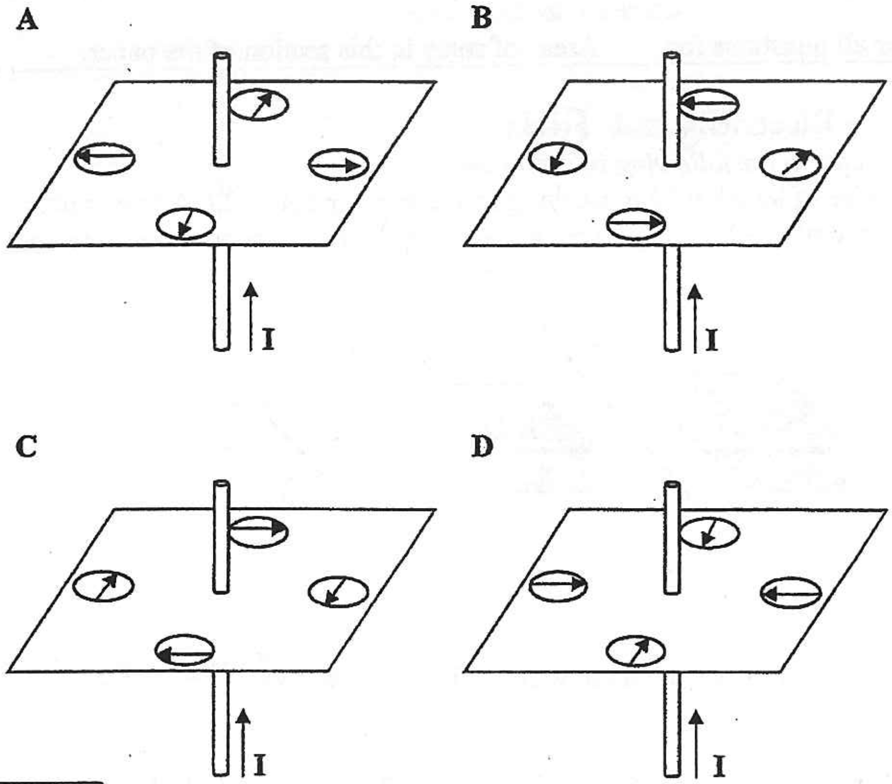
Which one of the directions, P – U, shown in **Figure 2** indicates the direction of the force on the wire when the current flows.

$\boxed{S}$ (1)

1 mark

Question 3

Which one of the following diagrams, A - D shown below, best shows the orientation for a set of four compasses placed around a current-carrying wire? The arrows indicate the north pole of the compass needle.



B (2)

2 marks

Questions 4 - 7 refer to the following information.

The diagram shows part of the system used in Victoria for generating electric power and transmitting this power from the generating station to a terminal station.

Power station → Electricity at 24 kV $_{RMS}$ → Step-up transformer → Electricity at 500 kV $_{RMS}$ (*) → Step-down transformer → Electricity at 66 kV $_{RMS}$

(*At beginning of transmission lines.)

Question 4

Which statement below correctly describes the operation of a transformer ?

A. A current flows from one coil through the core to the other coil.
B. An AC voltage across one coil induces an AC voltage across the other coil.
C. A DC voltage across one coil causes a DC voltage in the other coil.
D. An AC voltage in the primary coil is transformed to a DC voltage in the secondary coil.

B (2)

2 marks

The primary coil of the step-up transformer has 1000 turns.

Question 5

Calculate the number of turns in the secondary coil.

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} \quad \therefore N_s = \frac{N_p V_s}{V_p} = \frac{1000 \times 500 \times 10^3}{24 \times 10^3} \text{ (1)}$$

$$= 2.1 \times 10^4 \text{ turns}$$

$\boxed{2.1 \times 10^4 \text{ turns}}$ (1)

2 marks

One generator at the power station produces of 530 MW of power.

Question 6

Calculate the magnitude of the RMS current in the secondary coil of the step-up transformer. The transformer is considered to be ideal.

$P_{primary} = P_{secondary}$ (ideal transformers)

$$\therefore I_s = \frac{P_s}{V_s} = \frac{530 \times 10^6}{500 \times 10^3} \text{ (1)} = 1060 \text{ A}$$

$\boxed{1.1 \times 10^3 \text{ A}}$ (1)

2 marks

The electric power is transmitted over a considerable distance to a step-down transformer. There is a power loss of 5.0 % due to heating of the transmission cables.

Question 7

Calculate the RMS voltage of the primary coil of the step-down transformer. Answer in kilovolts.

If power loss = 5%, power available at primary of step-down transformer $= 95\% \times 530 \times 10^6$ W

$= 5.035 \times 10^8$ W (1)

$$\therefore V_{p,\text{ step-down}} = \frac{P}{I} = \frac{5.035 \times 10^8}{1060} = 4.75 \times 10^5 \text{ V}$$

$\boxed{475 \text{ kV}}$ (1)

2 marks

Questions 8 and 9 refer to the following information.

Figure 3 shows a transformer used in the home which converts mains 240 V $_{RMS}$ electricity to 12 V $_{RMS}$ to power a set of 100 identical Christmas lights wired in parallel. Assume zero power loss in this system.

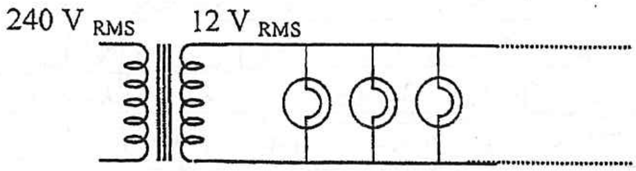


Figure 3

Question 8

Calculate the peak voltage across the secondary coil of the transformer.

$V_{peak} = V_{rms} \times \sqrt{2} = \underbrace{12 \times \sqrt{2}}_{(1)} = 16.97\,V$

17 V	(1)

2 marks

The primary circuit draws **120** W_{RMS} of power.

Question 9

Calculate the resistance, in ohms, of one of the Christmas lights.

$P_{sec} = P_{PRI} = 120\,W_{rms}$

$\therefore P_{lamp} = \frac{120}{100} = \underbrace{1.2\,W_{rms}}_{(1)} = \frac{V^2}{R_{lamp}} = \frac{12^2}{R_{lamp}}$

$\therefore R_{lamp} = \frac{144}{1.2} = 120\,\Omega$

120 Ω

(1)

2 marks

Two solenoids are positioned as shown in **Figure 4** and the switch, S, is closed,

Question 10

Determine the direction of the current that flows through resistor R as the switch closes. Justify your answer.

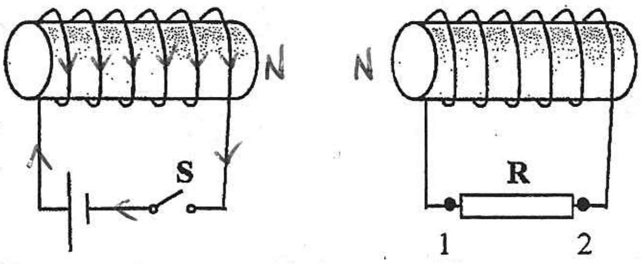


Figure 4

..1.. to ..2....	(1)

As switch S is closed, the current flowing in the left-hand circuit causes a north magnetic pole at the right end of this solenoid (as shown). (1)

(1) To oppose this change in flux, the right-hand solenoid has a current induced that causes a north pole on the left side (as shown). For this to occur, current flows from 1 → 2 through the resistor R.

3 marks

Figure 5 shows a coil of area 1.13×10^{-2} m^2 consisting of 200 loops placed in a 0.35 T magnetic field.
The magnetic field is uniformly changed to 0.25 T in the **opposite** direction in 0.80 s.
(Dots and crosses indicate opposite sense of the magnetic field).

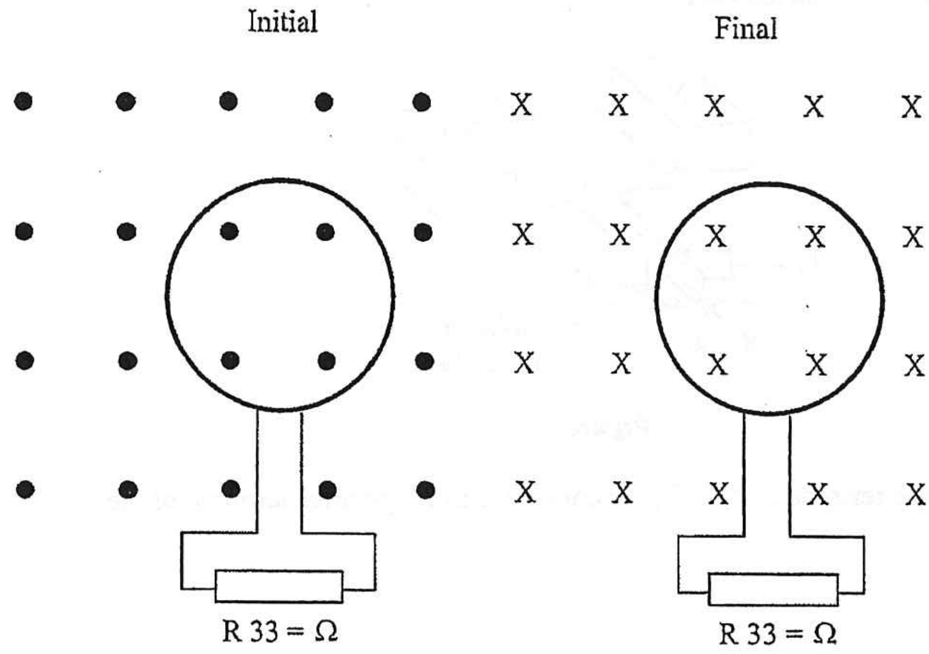


Figure 5

Question 11
Calculate the magnitude of the current in mA, that flows through the 33Ω resistor connected to the coil during this period.
(Ignore the resistance of the coil.)

$$\mathcal{E} = (-)\frac{N\Delta\phi_B}{\Delta t} = \frac{N\Delta B_{\perp}A}{\Delta t} = \frac{200 \times (0.35-(-0.25)) \times 1.13\times10^{-2}}{0.8}$$ (1)

$= 1.695\text{V}$ (1)

$\therefore I = \frac{V}{R} = \frac{1.695}{33} = 0.0513\text{A}$

51 mA (1)

3 marks

Questions 12 – 14 refer to the following information.
Figure 6 shows a model motor which Eric used during an experiment. A coil of wire was connected to a split-ring commutator and placed as shown in the uniform magnetic field. Eric then connected the terminals, T_1 and T_2, to a battery. He observed that the coil began to rotate in a clockwise direction around axis XY.

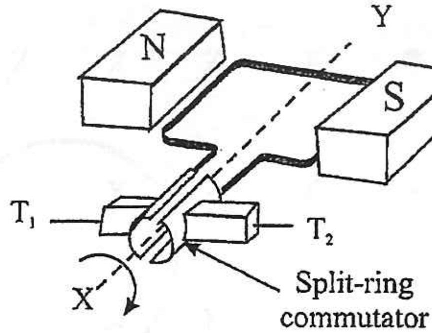


Figure 6

Question 12
Determine which of the terminals, T_1 or T_2, is connected to the *positive* terminal of the battery.

T_2

(2)

2 marks

In order to observe the electromagnetic induction in the coil, Eric removed the battery connections and connected a cathode ray oscilloscope as shown in **Figure 7**. He then slowly rotated the coil around the axis XY in a clockwise direction (as shown).

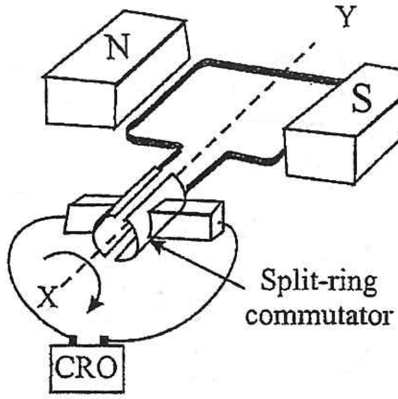
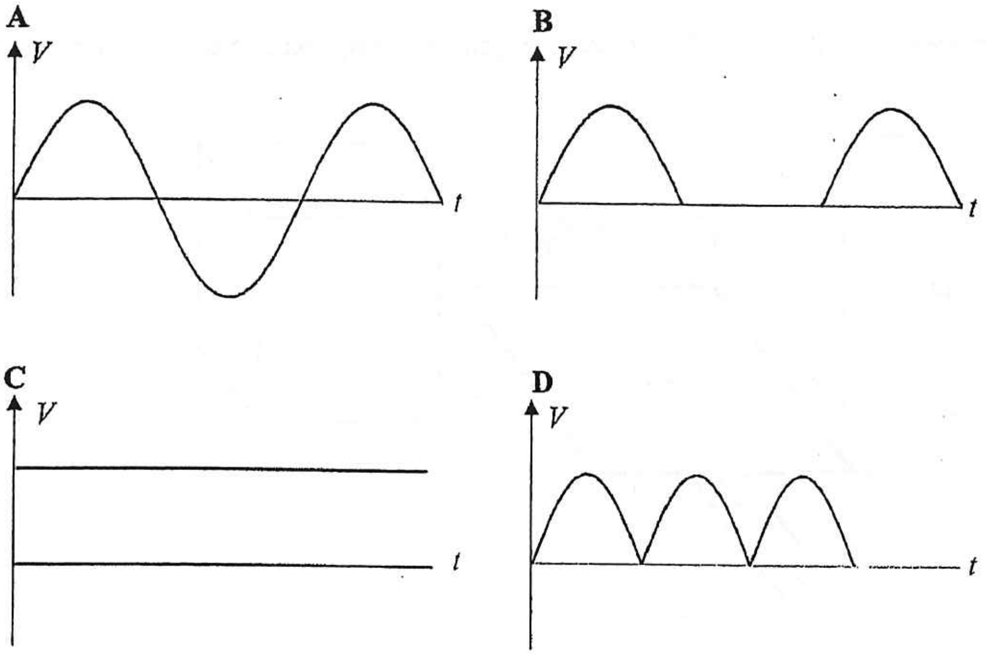


Figure 7

Question 13
Which one of the waveforms below best shows what Eric observed on the C.R.O when the coil was rotated in a clockwise direction as shown in **Figure 7**.



D (2)

2 marks

Question 14
Describe the action of the split-ring commutator in **Figure 6**.

It reverses the direction of the current every half-turn. (1)

This keeps the coil spinning in the same direction. (1)
(NOT with constant torque).

2 marks

if said, -1 mark!

Question 15 to 18 refer to the following information.

Figure 8 shows a simplified electrical generator consisting of a single square coil of wire PQRS placed in a uniform magnetic field of strength 0.60 T. The side length of the square coil is 10 cm.
The coil can be rotated about the axis XY. Louise, a physics ~~students~~, experiments with this coil.

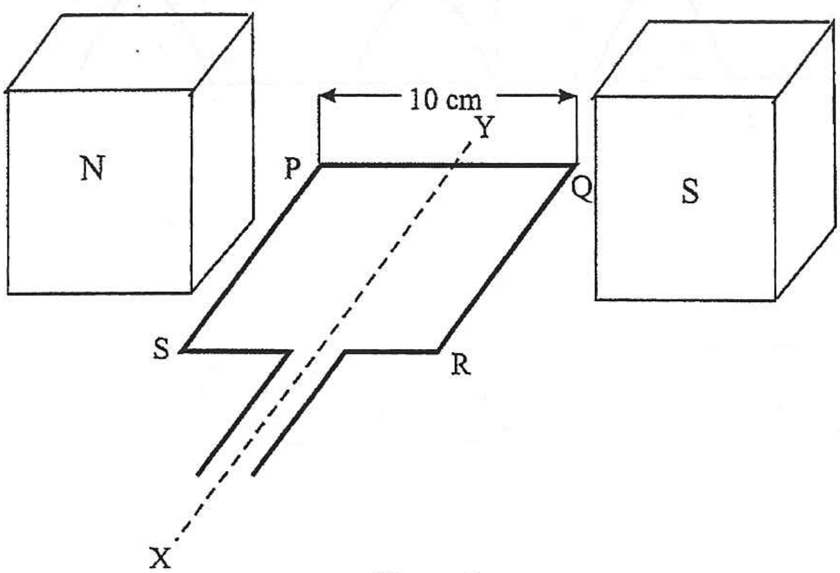


Figure 8

Question 15
Calculate the maximum magnetic flux that can pass through the coil.

$$\phi_B = B_\perp A = 0.6 \times \underset{(1)}{(0.1)^2} = 0.006\,Wb$$

$\boxed{6 \times 10^{-3} \text{ Wb}}$ (1)

2 marks

Figure 9 shows the variation of magnetic flux with time for one complete cycle, of the coil.

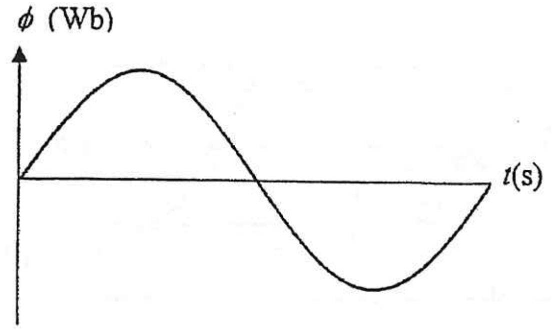
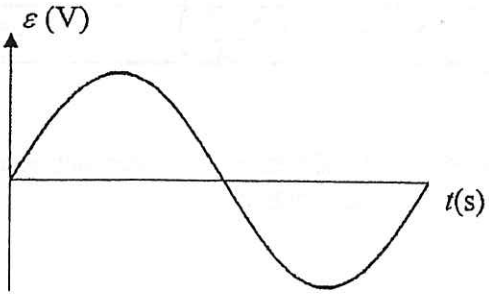


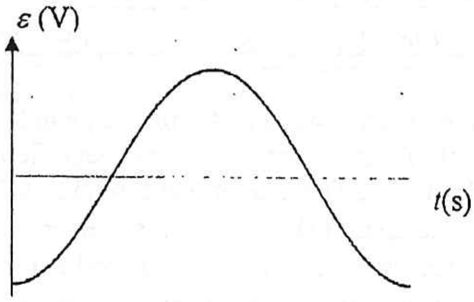
Figure 9

Question 16
From the graphs A – D shown below, choose the alternative that best shows the emf induced in the coil during this cycle.

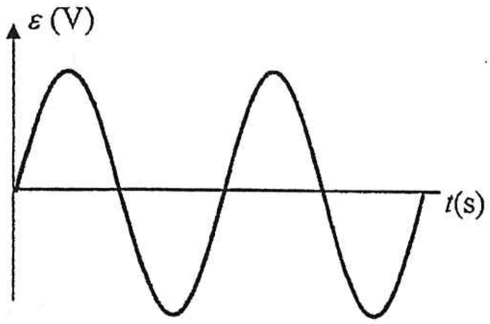
A



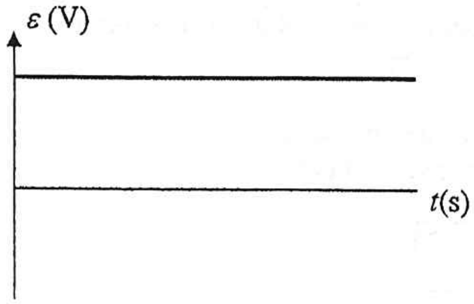
B



C



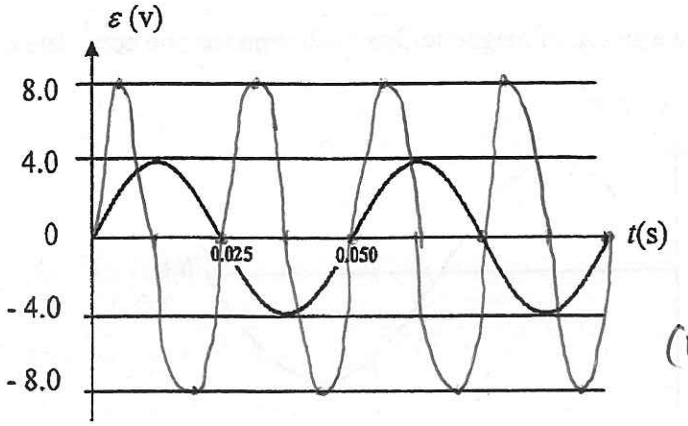
D



B	(2)

2 marks

Figure 10 shows the emf, ε, produced by a coil when it is rotated with a frequency of 20 Hz in a magnetic field.



(1)

Figure 10

Question 17
On **Figure 10** above, draw the corresponding curve for emf induced in the same coil when it is rotated with a frequency of 40 Hz. Justify the shape of the curve that you draw.

By doubling the frequency of rotation:

- Period is halved (1)
- Induced emf is doubled (1) $\left(\varepsilon = \frac{N\Delta\phi}{\Delta t}\right)$

3 marks

Louise wrote the following in her physics notebook.
"When a coil of wire is turned in a magnetic field, a potential difference is induced between the ends of the coil. The size of this potential difference is greater when

- the area of the wire coil is greater.
- the number of turns on the coil is greater.
- the strength of the magnetic field is greater.
- the speed of rotation of the coil is increased.

Question 18
How many of Louise's dot points are correct?
A. None of them.
B. All of them.
C. Only three of them.
D. Only two of them.

$\boxed{B}$ (2)

2 marks

Looking along the axis of rotation from end X, in **Figure 8**, the coil rotated in a clockwise direction.

Question 19
Circle the correct alternative from those listed below.
The induced current will flow in the direction:
from R to Q
from Q to R ← initially. (2)

2 marks

END OF SAC

Physics formulas

Motion and related energy transformations

velocity; acceleration	$v = \frac{\Delta s}{\Delta t}$; $a = \frac{\Delta v}{\Delta t}$
equations for constant acceleration	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $s = vt - \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(v+u)t$
Newton's second law	$\Sigma F = ma$
circular motion	$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
Hooke's law	$F = -k\Delta x$
elastic potential energy	$\frac{1}{2}k(\Delta x)^2$
gravitational potential energy near the surface of Earth	$mg\Delta h$
kinetic energy	$\frac{1}{2}mv^2$
Newton's law of universal gravitation	$F = G\frac{M_1 M_2}{r^2}$
gravitational field	$g = G\frac{M}{r^2}$
impulse	$F\Delta t$
momentum	mv
Lorentz factor	$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$
time dilation	$t = t_o\gamma$
length contraction	$L = \frac{L_o}{\gamma}$
rest energy	$E_{rest} = mc^2$
relativistic total energy	$E_{total} = \gamma mc^2$
relativistic kinetic energy	$E_K = (\gamma - 1)mc^2$

Fields and application of field concepts

electric field between charged plates	$E=\dfrac{V}{d}$
energy transformation of charges in an electric field	$\dfrac{1}{2}mv^2=qV$
field of a point charge	$E=\dfrac{kq}{r^2}$
force on an electric charge	$F=qE$
Coulomb's law	$F=\dfrac{kq_1q_2}{r^2}$
magnetic force on a moving charge	$F=qvB$
magnetic force on a current	$F=IlB$
radius of a charged particle in a magnetic field	$r=\dfrac{mv}{qB}$

Generation and transmission of electricity

voltage; power	$V=RI;\quad P=VI=I^2R$	
resistors in series	$R_T=R_1+R_2$	
resistors in parallel	$\dfrac{1}{R_T}=\dfrac{1}{R_1}+\dfrac{1}{R_2}$	
ideal transformer action	$\dfrac{V_1}{V_2}=\dfrac{N_1}{N_2}=\dfrac{I_2}{I_1}$	
AC voltage and current	$V_{RMS}=\dfrac{1}{\sqrt{2}}V_{peak}$	$I_{RMS}=\dfrac{1}{\sqrt{2}}I_{peak}$
electromagnetic induction	$\text{EMF}:\varepsilon=-N\dfrac{\Delta\Phi}{\Delta t}$	$\text{flux}:\Phi=BA$
transmission losses	$V_{drop}=I_{line}R_{line}$	$P_{loss}=I^2_{line}R_{line}$

Wave concepts

wave equation	$v=f\lambda$
constructive interference	path difference $=n\lambda$
destructive interference	path difference $=\left(n-\dfrac{1}{2}\right)\lambda$
fringe spacing	$\Delta x=\dfrac{\lambda L}{d}$
Snell's law	$n_1\sin\theta_1=n_2\sin\theta_2$
refractive index and wave speed	$n_1v_1=n_2v_2$

The nature of light and matter

photoelectric effect	$E_{K\,max} = hf - W$
photon energy	$E = hf$
photon momentum	$p = \dfrac{h}{\lambda}$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$
Heisenberg's uncertainty principle	$\Delta p_x \Delta x \geq \dfrac{h}{4\pi}$

Data

acceleration due to gravity at Earth's surface	$g = 9.8\ \text{m s}^{-2}$
mass of the electron	$m_e = 9.1 \times 10^{-31}\ \text{kg}$
magnitude of the charge of the electron	$e = 1.6 \times 10^{-19}\ \text{C}$
Planck's constant	$h = 6.63 \times 10^{-34}\ \text{J s}$ $\quad h = 4.14 \times 10^{-15}\ \text{eV s}$
speed of light in a vacuum	$c = 3.0 \times 10^{8}\ \text{m s}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
mass of Earth	$M_E = 5.98 \times 10^{24}\ \text{kg}$
radius of Earth	$R_E = 6.37 \times 10^{6}\ \text{m}$
Coulomb constant (in air)	$k = 8.99 \times 10^{9}\ \text{N m}^2\ \text{c}^{-2}$

Prefixes/Units

p = pico = 10^{-12}	n = nano = 10^{-9}	μ = micro = 10^{-6}	m = milli = 10^{-3}
k = kilo = 10^{3}	M = mega = 10^{6}	G = giga = 10^{9}	t = tonne = 10^{3} kg

END OF FORMULA SHEET