<u>HIGHER PHYSICS EXAM – 2003</u>
<u>WORKED SOLUTIONS</u>

Q1. To answer this question you must know what a vector is.

A vector is a quantity that requires magnitude and direction to be stated in order to convey their full meaning.

You should know some common scalar and vector quantities as given below:

SCALAR	VECTOR
Speed	Velocity
Distance	Displacement
Time	Acceleration
Mass	Force
Energy	Momentum
Power	Impulse

Not all vectors and scalars are given above, and this table on its own does not answer the question.

The two quantities that are vectors are weight and momentum, as these quantities should have a direction stated to convey the full meaning of the measurement.

D

Q2. Inspection of each pair of graphs and application of your knowledge should leave you with the correct answer.

GRAPH A

DESCRIPTION GRAPH 1
1. Velocity increases at a steady rate with time.

EXPECTED GRAPH 2
   - For a steady increase in velocity, there should be a constant acceleration.

DESCRIPTION GRAPH 2
2. The rate of acceleration increases with time.

EXPECTED GRAPH 1
   - If the rate of acceleration increases, the velocity would increase at a greater rate the longer the vehicle is travelling (exponential type increase in velocity).

GRAPH B

1. The graph shows a vehicle with constant velocity.
   - A vehicle with constant velocity, has no acceleration.
2. The graph shows a vehicle travelling with a constant acceleration.
   - A vehicle with constant acceleration should see a steady increase in velocity.

GRAPH C

1. Velocity decreases with time.
   - A vehicle with decreasing velocity should have a constant deceleration.
2. Constant acceleration.
   - A vehicle with constant acceleration should see a steady increase in velocity.

GRAPH D

1. Velocity decreases with time.
   - A vehicle with decreasing velocity should have a constant deceleration.
2. Increasing negative deceleration.
   - Increase in velocity in the opposite direction (increasing negative deceleration with exponential form).

GRAPH E

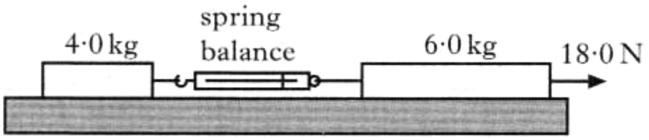
1. Velocity decreases with time.
   - A vehicle with decreasing velocity should have a constant deceleration.
2. Constant negative acceleration (deceleration).
   - Constant and steady deceleration.

Above are statements, which describe the graphs, and a statement to say what the other graph should show.

E

The only pair of graphs that agree with one another is the last option.

Q3. The whole system illustrated below will move with the same acceleration.



The force applied to the whole system is 18N, however it comprises of two different masses.

Newton's 2nd Law is:

$$F = ma$$

As we are considering two different masses we can re-write this as:

$$F = m_1 a + m_2 a$$
$$18 = 6a + 4a$$
$$18 = 10a$$
$$a = \frac{18}{10}$$
$$a = 1.8ms^{-2}$$

The small block produces a drag force of:

$F = ?$

$m = 4kg$

$a = 1.8ms^{-2}$

$$F = ma$$
$$F = 4 \times 1.8$$
$$F = 7.2N$$

A

The drag force of 7.2N is the reading on the spring balance.

Q4. The loss of kinetic energy is calculated by finding the difference in energy before and after the deceleration.

BEFORE DECELERATION

$E_K = ?$

$m = 1000kg$

$v = 40ms^{-1}$

$$E_K = \frac{1}{2}mv^2$$
$$= \frac{1}{2} \times 1000 \times 40$$
$$E_K = 800kJ$$

AFTER DECELERATION

$E_K = ?$

$m = 1000kg$

$v = 10ms^{-1}$

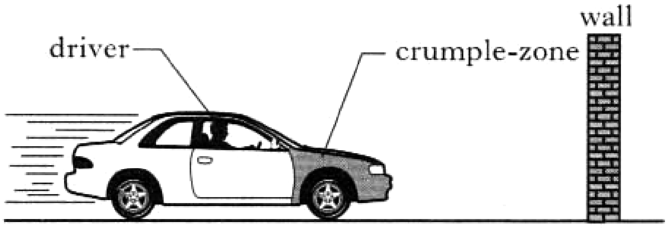
$$E_K = \frac{1}{2}mv^2$$
$$= \frac{1}{2} \times 1000 \times 10$$
$$E_K = 50kJ$$

D

So the loss in kinetic energy is: loss = 800kJ - 50kJ = 750kJ

Q5. Cars are designed with "crumple-zones" to make the car safer for the passengers travelling in the car.

With this in mind, you should read each of the statements and decide which makes the car safer.



A decrease the driver's change in momentum per second.
The longer it takes for the change in momentum to take place the better. A car stopping experiences a change in momentum, because it does it safely over a period of 10s or so you are not at any risk.

B increase the driver's change in momentum per second.
An increase in the change in momentum per second is dangerous!!! Think of a car having to do an emergency stop if you weren't wearing your seatbelt in comparison with stopping over a large distance.

C decrease the driver's final velocity.
Crashing will result in the final velocity being zero. There is not any change that can be made to the final velocity.

D increase the driver's total change in momentum.
The change in momentum will be the same regardless of the crumple zone. The total change in momentum is due to the initial and final velocities.

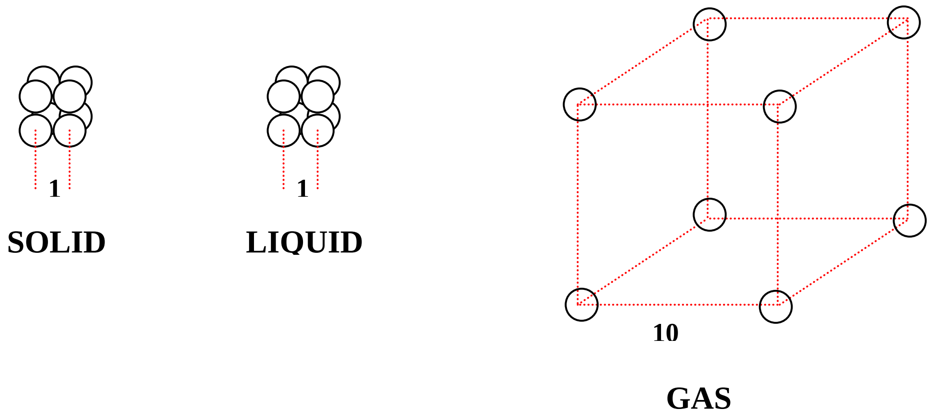
E decrease the driver's total change in momentum.
The change in momentum will be the same regardless of the crumple zone. The total change in momentum is due to the initial and final velocities.

A

The crumple zone increases the time taken for the cars velocity to reach zero. This increased time means the change in momentum per second is less.

Q6. When a liquid changes state to become a gas, or vice-versa, the change in volume is by a factor of 1000.

This is shown and explained below, considering the particle arrangement between solids, liquids and gases.



In the gas the particles are about 10 times as far apart as those in a solid or liquid.

This means that the same mass of gas will have a volume approximately, $10 \times 10 \times 10 = 1000$ times that of the solid or liquid.

C

As the fixed mass of gas condenses to form a liquid, the increase in density is 1000 times and the decrease in spacing is 10 times, as illustrated above.

Q7. You are asked to consider the change in the pressure, volume and mass of the gas in the cylinder.

Firstly, consider the pressure of the gas in the cylinder. As gas is released from the cylinder, the pressure will decrease.

The volume of gas in the cylinder will be unchanged, as the gas will occupy most of the volume at all times, even as some of the gas is released.

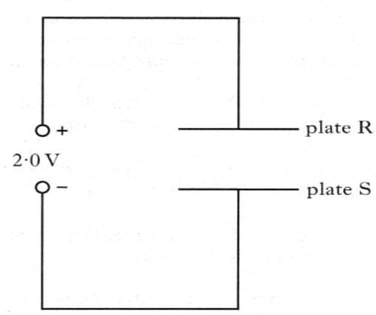
The mass of gas in the cylinder will obviously decrease as gas is released.

E

Q8. An electron moving from plate R to plate S gains electrical potential energy in accordance with the relationship:

$$E_W = QV$$

The given circuit shown below, states the voltage applied to the circuit:



The final piece of information is the charge on the electron, which is given in the data sheet.

The gain in electrical potential energy is:

$E = ?$

$Q = 1.60 \times 10^{-19}\, C$

$V = 2.0V$

$$E = QV$$

$$E = \left(1.60 \times 10^{-19}\right) \times (2)$$

$$E = 3.2 \times 10^{-19}\, J$$

C

Q9. When dealing with a problem involving internal resistance, Ohm's Law has the form:

$$\varepsilon = IR + Ir$$

The resistance of resistor R is:

$\varepsilon = 8V$

$I = 4A$

$R = ?$

$r = 0.20\Omega$

$$\varepsilon = IR + Ir$$

$$\varepsilon = I(R + r)$$

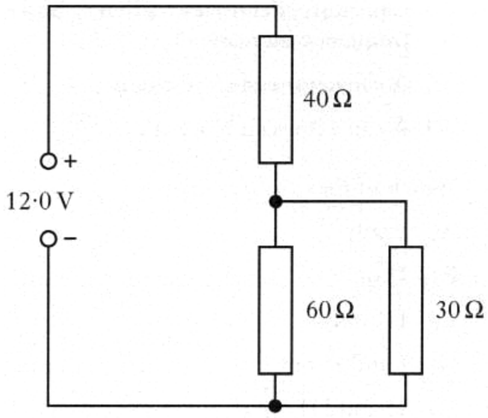
$$R + r = \frac{\varepsilon}{I}$$

$$R = \frac{\varepsilon}{I} - r$$

$$R = \frac{8}{4} - 0.2 = 1.8\Omega$$

B

Q10. This problem is a combination of resistors in parallel and resistors in series.



Consider the two resistors in parallel, the 30Ω and 60Ω resistors:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$\frac{1}{R_T} = \frac{1}{30} + \frac{1}{60}$$
$$R_T = 20\Omega$$

Combining these two resistors leaves two resistors in series with the values 40Ω and 20Ω.

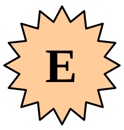
This is essentially a voltage divider circuit where the ratio is 2:1.

The potential difference across the 40Ω resistor is 8V.

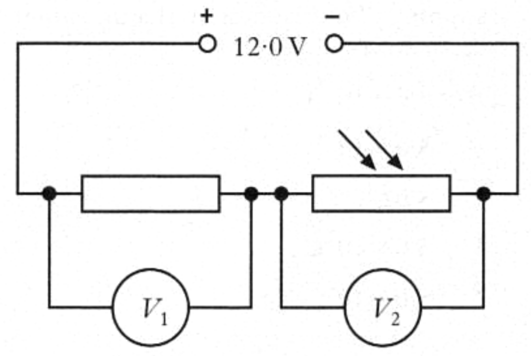
The potential difference across the 20Ω resistor is 4V.

The potential difference across the 60Ω resistor is equal to the potential across the 30Ω resistor when they are connected in parallel to one another

Two resistors in parallel are known as a current divider circuit. Combine the two resistors as shown and then find the potential across them.



Q11. As the light intensity on the LDR reduces, the value of resistance decreases.



This circuit has two resistors in series, which is a voltage divider circuit.

As the resistance of the LDR decreases, the voltage on V_2 increases.

Since V_2 increases, to keep the balance V_1 decreases.

Always keep in mind:

D

$$V_T = V_1 + V_2$$

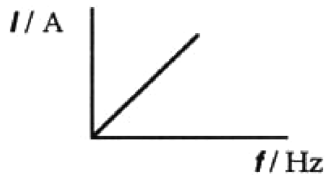
Q12. Never the easiest questions, but you must read each statement and apply your knowledge of physics to conclude whether it is true or not.

STATEMENT I - "the current in a circuit containing a capacitor decreases when the supply frequency increases."

You should be aware that as the frequency of the supply is increased, the current through the capacitor increases.

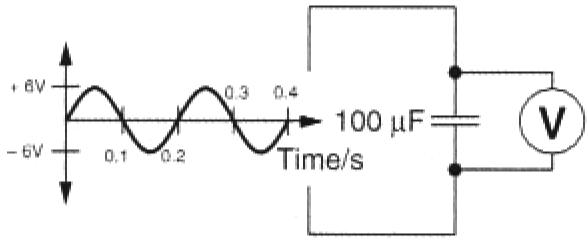
The current through a capacitor in an AC circuit is directly proportional to the frequency of the supply.

This relationship is shown in the graph below:



The above is explained by the theory that follows.

Consider the following circuit where a continuously alternating voltage supply is connected across a capacitor.



As there is no resistor in the above circuit, the voltage across the capacitor follows instantly the voltage set by the power supply.

In this instance, the voltage across the capacitor after 0.05s is 6V.

The charge stored on the $100\mu F$ capacitor is found from:

$Q = ?$	$Q = CV$
$C = 100\mu F = 100 \times 10^{-6} F$	$Q = (100 \times 10^{-6})(6)$
$V = 6V$	$Q = 600 \times 10^{-6} C$

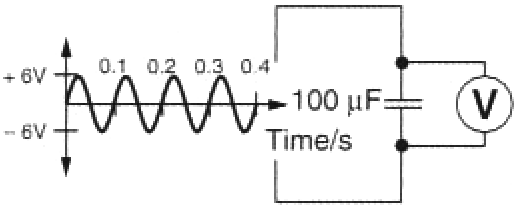
After a further 0.05s the voltage across the capacitor will be 0V and so this means that the capacitor has given up its entire charge of $600 \times 10^{-6} C$.

A current will be detected on an ammeter if connected into the circuit because of this movement of charge.

The current at any instant during the discharge varies, but the average current during the 0.05s can be found from:

$$average\,current = \frac{total\ charge}{time}$$
$$= \frac{600 \times 10^{-6}}{0.05}$$
$$= 0.012A$$
$$= 12mA$$

Now consider an alternating source with the same peak voltage of 6V but the frequency of the source having doubled.



The charge stored is given as before:

$Q = ?$
$C = 100\mu F = 100 \times 10^{-6} F$
$V = 6V$

$Q = CV$
$Q = (100 \times 10^{-6})(6)$
$Q = 600 \times 10^{-6} C$

In this case though, the capacitor will discharge not in 0.05s but rather in half that time, 0.025s.

The current at any instant during the discharge will vary, but the average current is calculated to be:

$$average\,current = \frac{total\ charge}{time}$$
$$= \frac{600 \times 10^{-6}}{0.025}$$
$$= 0.024A$$
$$= 24mA$$

Doubling the frequency has doubled the current in the circuit.

The current in the circuit is directly proportional to the frequency of the supply.

STATEMENT II - "a capacitor can store charge."

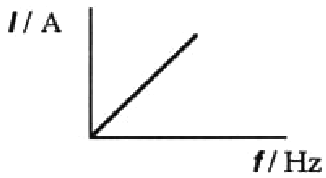
The term capacitor refers to the capacity of charge that a capacitor can store.

You simply must know a capacitor stores charge.

STATEMENT III - "a capacitor can block d.c."

A direct current has zero frequency.

If the frequency is zero, the current through the capacitor must be zero according to the graph below:



If there is no current flow, then the capacitor is said to block direct current.

E

Statements II and III are correct.

Q13. The simplest way to answer these questions is recall the appropriate equation.

Firstly, you must decide what quantity is measured in Farads.

The Farad is the unit of capacitance and has the equation:

$$Q = CV$$

C

A rearrangement of this equation gives:

$$C = \frac{Q}{V}$$

FARAD (C)

COULOMB (Q) **per** **VOLT** (V)

Q14. The charge stored in a capacitor is defined by the relationship:

$$Q = CV$$

The maximum charge stored is:

$Q = ?$

$C = 10\mu F = 10\times 10^{-6} F$

$V = 50V$

$Q = CV$

$Q = (10\times 10^{-6})\times 50$

$Q = 5\times 10^{-4} C$

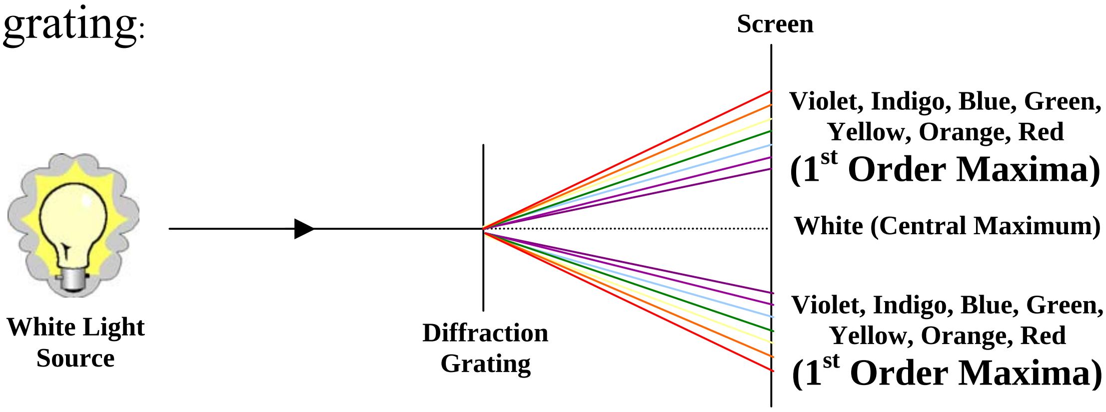
B

Q15. When light is passed through a diffraction grating, what happens to the distance between the areas of constructive interference when:

- The screen is moved further away from the source.
- Light of a greater wavelength is used.
- Distance between slits increases.

As the screen is moved further away from the diffraction grating, the distance between the areas of constructive interference increases.

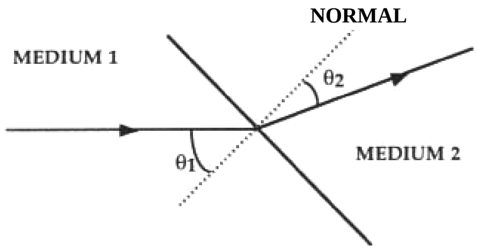
Increasing the wavelength of light passed through the grating increases the distance between constructive interference areas. This is illustrated below where white light, which is made up of light of various wavelengths, is passed through a grating:



Increasing the distance between the slits of the grating reduces the distance between the areas of constructive interference.

B

Q16. A ray of light will bend closer towards the normal when passing from a material to another with a higher refractive index.



If a ray of light passes from a material to another with the same refractive index, there is no deviation in direction.

As the ray of light travels from air to material P, the ray bends towards the normal, indicating it enters a material with a greater refractive index than that of air.

The ray of light from P to Q does not change direction, so both materials have the same refractive index.

As the light ray travels from Q to R, the ray bends towards the normal, indicating that R has a greater refractive index.

Lastly, the ray of light bends away from the normal going from R to air, indicating that the air is of a much lower refractive index than R.

B

Q17. To recall the units of measurement, you can recall an equation for light intensity:

$$I = \frac{P}{A}$$

WATTS (P)

per

METRE SQUARED (A)

To express the unit Watt in another form, recall a second equation:

$$P = \frac{E}{t}$$

JOULE (E)

per

SECOND (t)

D

This is written as: Intensity $\equiv$ W m^{-1} $\equiv$ J s^{-1} m^{-2}.

Q18. This question is relating to the photoelectric effect.

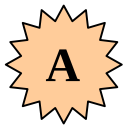
The frequency of the light remains the same whilst the intensity of the light is doubled.

The rate at which electrons are ejected is dependent upon the distance from the source of light. Since the intensity has doubled, this means the source has moved much closer to the metal.

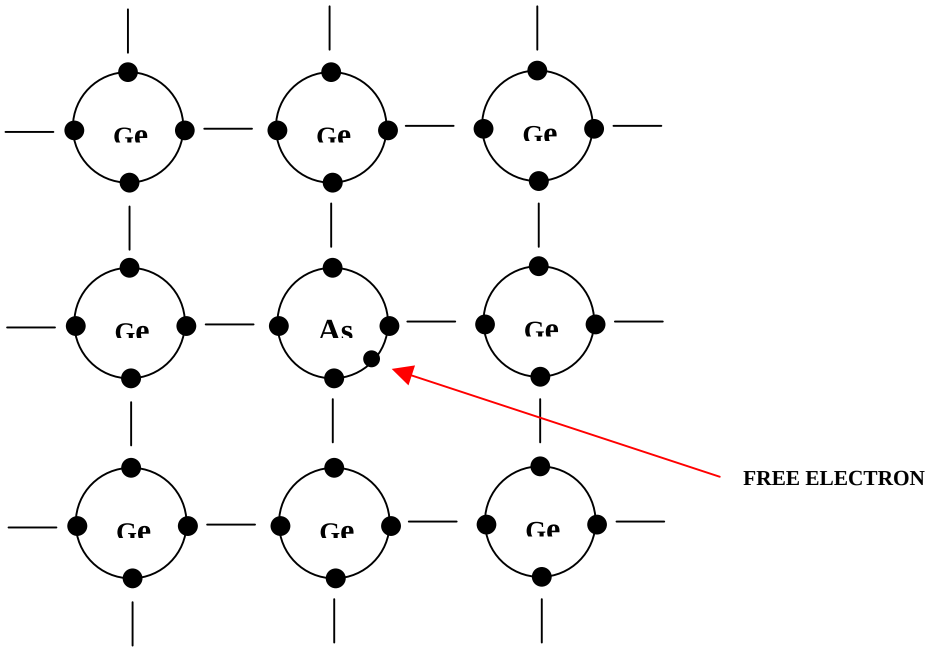
It is sensible to conclude that twice as many electrons are ejected from the surface.

The speed at which the electrons are ejected and the kinetic energy they posses are governed by the energy input into the system from the light source.

Since the work function of the metal has not been altered, there is no "extra" energy, so no change to the speed or kinetic energy of the ejected electrons.



Q19. A sample of an n-type semiconductor material is illustrated below:



When such a sample as illustrated is connected across a power supply, the free electrons in the material flow towards the positive end of the supply.

As the electrons transfer charge, and they are negatively charged, you can conclude that most charge carriers are negative.

In both, n-type and p-type semiconductors, the materials are electrically neutral overall.

As shown, impurity atoms with 5-outer electrons are added to a material in the process of n-type doping, as this leaves free electrons so that current flows.

Statements I and III are correct. **E**

Q20. Try not to confuse the two processes known as nuclear fission and nuclear fusion.

Nuclear fission is the process where one large nucleus is split into two smaller nuclei with the release of several neutrons.

A