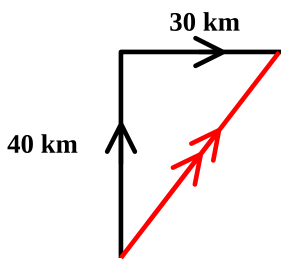
HIGHER PHYSICS EXAM – 2005
WORKED SOLUTIONS

Q1. You must be able to distinguish between the different terms used, displacement, average speed and average velocity.

Given the diagram shown below:



You should be able to add in the resultant displacement vector as shown in the above diagram in red:

To calculate the displacement from the above diagram, you simply use Pythagoras Theorem for a right-angled triangle:

$$s^2 = 40^2 + 30^2$$
$$= 1600 + 900$$
$$s = \sqrt{2500}$$
$$s = 50km$$

When asked to calculate the average speed over the whole journey, where speed is a scalar, the distance travelled is given by adding the individual distances together.

$$d = 30km + 40km$$
$$= 70km$$
$$t = 2h$$
$$\bar{v} = ?$$

$$\bar{v} = \frac{d}{t}$$
$$= \frac{70}{2}$$
$$\bar{v} = 35kmh^{-1}$$

To calculate the average velocity, where velocity is a vector, the displacement is used:

$$s = 50km \qquad t = 2h \qquad \bar{v} = ?$$

$$\bar{v} = \frac{s}{t} = \frac{50}{2}$$

$$\bar{v} = 25kmh^{-1}$$

Comparing these results with the table given, the correct answer is: **A**

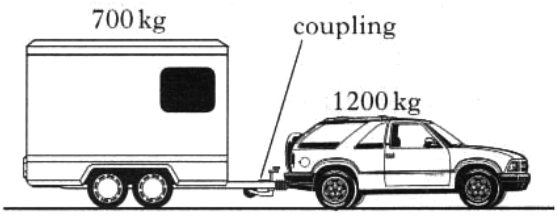
Q2. Acceleration is defined as:

Acceleration: the rate of change of velocity with time.

In this instance, where the acceleration is $3ms^{-2}$, this means that the velocity of the object increases by $3ms^{-1}$ every second.

So this means the answer is: E

Q3. The tension in the coupling is due to the drag-force the horsebox places on the coupling.



The force created by the horsebox is given by using the relationship:

$$F = ma$$

Make a note of the information given and do the calculation:

$F = ?$ $\quad$ $F = ma$

$m = 700kg$ $\quad$ $F = 700 \times 2$

$a = 2ms^{-2}$ $\quad$ $F = 1400N$

So from the multiple-choice the answer is: **C**

Q4. You should be aware of the two types of collisions that can take place, elastic and inelastic.

The following you should know about each type of collision:

ELASTIC COLLISION	**INELASTIC COLLISION**
The following are conserved: • Momentum • Kinetic Energy • Total Energy.	The following are conserved: • Momentum • Total Energy. The following are not conserved: • Kinetic Energy

Since there are numerical values given in the question, we can calculate the required data and compare with the rows given in the table.

Start with momentum – momentum is always conserved.

To show this is the case, you can do the following:

$$\textit{total momentum before} = \textit{total momentum after}$$
$$m_1v_1 + m_2v_2 = m_1v_1 + m_2v_2$$
$$(2\times10)+(10\times0)=(2\times(-5))+(10\times3)$$
$$20 = -10 + 30$$
$$20 = 20$$

Kinetic energy may or may not be conserved, so we must check this using the values given.

BEFORE:

$$E_K = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(2)(10)$$
$$E_K = 10J$$

AFTER:

$$E_K = \frac{1}{2}m_1{v_1}^2 + \frac{1}{2}m_2{v_2}^2$$
$$= \frac{1}{2}(2)(-5)^2 + \frac{1}{2}(10)(3)^2$$
$$= 25J + 45J$$
$$= 70J$$

In this instance, kinetic energy is not conserved.

To summarise then:

- Momentum is conserved
- Kinetic energy is not conserved.

This allows you to conclude that the collision must be inelastic.

From the options, this tells you your answer is: **B**

Q5. The average force exerted on the ball by the club can be calculated using the equation for impulse:

$$Ft = mv - mu$$

Writing down the data given in the question and performing the calculation gives:

$$F = ?$$
$$t = 0.1s$$
$$m = 5\times10^{-2}kg$$
$$v = 80ms^{-1}$$
$$u = 0ms^{-1}$$

$$Ft = mv - mu$$
$$F = \frac{mv}{t} - 0$$
$$F = \frac{mv}{t}$$
$$F = \frac{(5\times10^{-2})\times(80)}{0.1}$$
$$F = 40N$$

The answer from the options given is: **E**

Q6. You must know the relationship between the Kelvin and Celsius temperature scales:

A temperature change of 1°C is the same as a change of 1K.

So a temperature change from -20°C to 70°C represents a change in temperature of:

$$\Delta T = 70°C - (-20°C)$$
$$= 70°C + 90°C$$
$$\Delta T = 90°C$$

So the change in temperature in Kelvin is $\Delta T = 90K$.

So the answer from the choices given is: **B**

Q7. You must know the definition of a volt in order to answer this question.

One volt is one joule per coulomb.

This is obtained from the following relationship:

$$E = QV$$

If you re-arrange the above equation you get:

$$E = QV$$
$$V = \frac{E}{Q}$$

This allows you to choose the answer as: **C**

Q8. An electron moving parallel to an electric field will gain kinetic energy equal to the work done.

The amount of kinetic energy is given by:

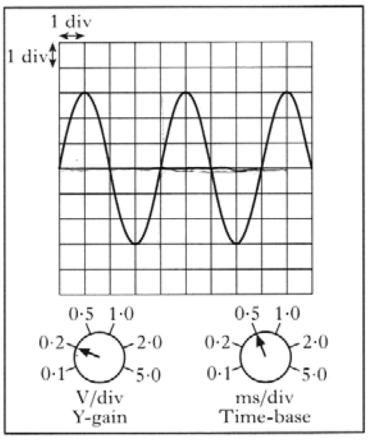
$$E_K = QV$$

So the data given allows you to calculate the kinetic energy to be:

$$E_k = ?$$
$$Q = 2mC = 2 \times 10^{-3} C$$
$$V = 5000V$$

$$E_K = QV$$
$$= (2 \times 10^{-3})(5000)$$
$$E_K = 10J$$

Q9. Given the following diagram of an oscilloscope you are asked for the frequency of the signal.



Obviously you must know what is meant by frequency, so recall the definition to be:

> The frequency of a signal is the number of waves to pass a particular point is one second.

From the dial you can see that each division along the *x*-axis represents 0.5ms.

The period of the wave is defined as:

> The period of a wave is the time taken for one complete wave to pass a point.

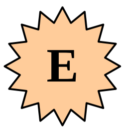
From the oscilloscope screen, the time taken for one complete wave to pass a point is 2*ms*.

Period and frequency are related by the expression:

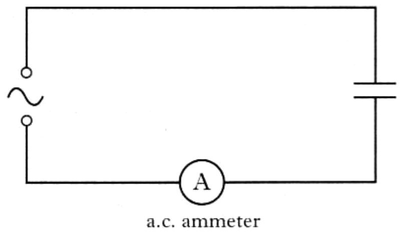
$$f = \frac{1}{T}$$

Which gives:

$$f = \frac{1}{T} = \frac{1}{2 \times 10^{-3}} = 500 Hz$$



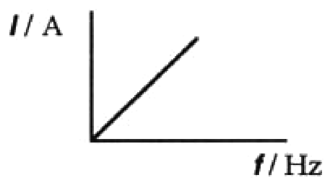
Q10. Given that a capacitor is connected to an alternating supply, as shown in the diagram below, you are asked to predict what will happen to the reading on the AC ammeter.



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

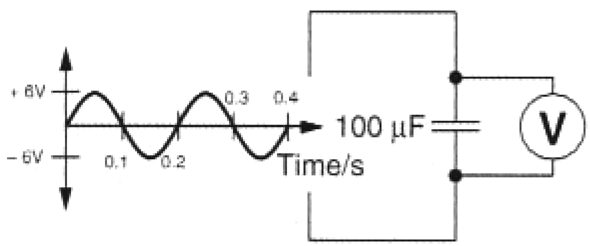
The current through a capacitor in an AC circuit is directly proportional to the frequency of the supply.

The following graph represents this:



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:

$$Q = ? \qquad C = 100\mu F = 100\times10^{-6}F \qquad V = 6V$$

$$Q = CV$$
$$Q = (100\times10^{-6})(6)$$
$$Q = 600\times10^{-6}C$$

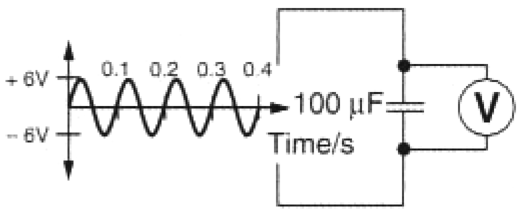
After a further 0.05s the voltage across the capacitor will be 0V and so this means that the capacitor has given up its entire charge of $600\times10^{-6}C$.

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:

$$average\ current = \frac{total\ charge}{time}$$
$$= \frac{600\times10^{-6}}{0.05}$$
$$= 0.012A$$
$$= 12mA$$

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:

$$Q = ? \qquad C = 100\mu F = 100\times10^{-6}F \qquad V = 6V$$

$$Q = CV$$
$$Q = (100\times10^{-6})(6)$$
$$Q = 600\times10^{-6}C$$

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:

$$\begin{aligned} \textit{average current} &= \frac{\textit{total charge}}{\textit{time}} \\ &= \frac{600 \times 10^{-6}}{0.025} \\ &= 0.024A \\ &= 24mA \end{aligned}$$

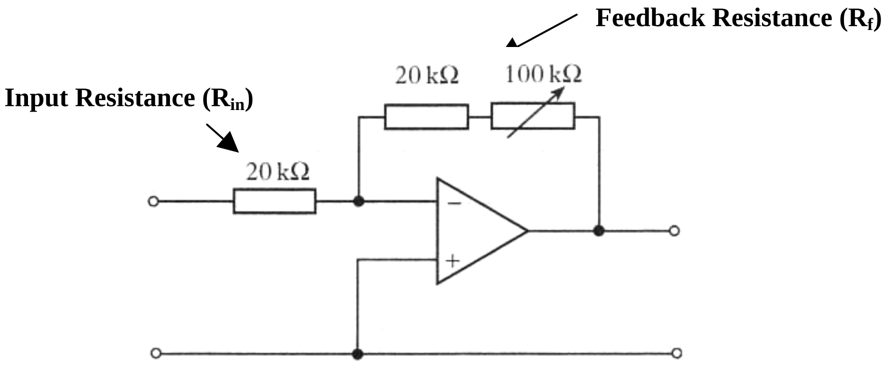
Doubling the **frequency** has **doubled** the **current** in the circuit.

The **same amount of charge** has **left the capacitor** in **half the time**.

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

This means our answer is: **C**

Q11. If you adjust the resistance of the variable resistor to zero, then effectively you are left with the $20k\Omega$ resistor.



The feedback resistance is the $20k\Omega$ resistor plus the variable resistor.

The input resistance is the $20k\Omega$ resistor on its own.

The voltage gain of an amplifier is given by the ratio:

$$gain = \frac{R_f}{R_{in}}$$

For the circuit shown in the diagram, when the variable resistor is set to zero the voltage gain of the amplifier is:

$$gain = \frac{R_f}{R_{in}}$$
$$= \frac{20k\Omega}{20k\Omega}$$
$$gain = 1$$

Where the variable resistor is set to a maximum resistance of $100k\Omega$, the effective feedback resistance is:

$$R_f = 20k\Omega + 100k\Omega$$

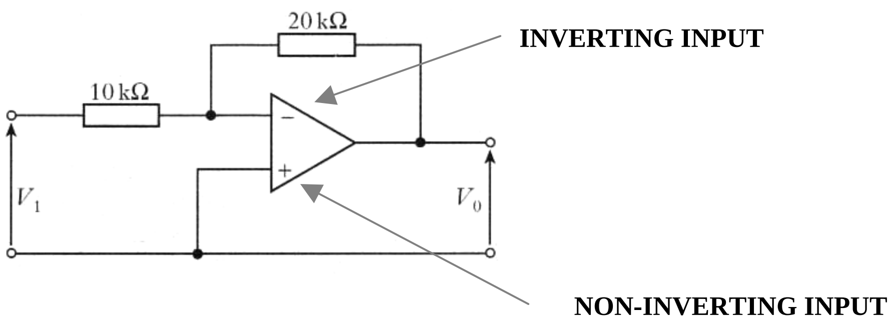
So when the variable resistor is set to a maximum value of $100k\Omega$, the voltage gain of the amplifier is:

$$gain = \frac{R_f}{R_{in}}$$
$$= \frac{120k\Omega}{20k\Omega}$$
$$gain = 6$$

The voltage gain can be altered from one to six.

This gives an answer of: **E**

Q12. Given the diagram shown below, you should be able to spot that amplifier is in the inverting mode.

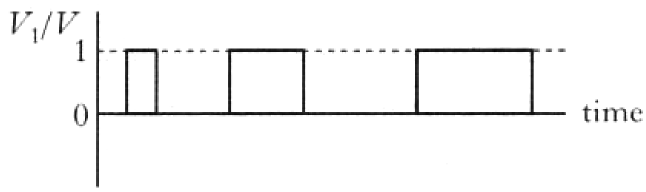


The following steps help you identify that the amplifier is inverting:

- The non-inverting input is joined directly to the $0V$ line.
- Part of the output signal is fed back via resistor R_f to the inverting input.
- The input signal is also connected to the inverting input via the resistor R_{in}.

Only when all of these conditions are satisfied is the op-amp circuit an inverting amplifier.

As you now know the circuit is an inverting amplifier, you know that the output will be an inversion of the input given below.



Where the input signal peaks, the output signal will trough.

The maximum input voltage is 1V. The maximum output voltage is dependent on the gain of the amplifier.

The **gain of an amplifier** is given by the ratio:

$$gain = \frac{R_f}{R_{in}}$$

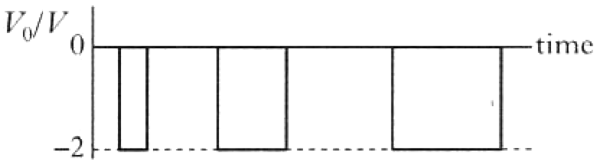
The gain of the amplifier given in the question is therefore:

$$\begin{aligned} gain &= \frac{R_f}{R_{in}} \\ &= \frac{20k\Omega}{10k\Omega} \\ gain &= 2 \end{aligned}$$

So the maximum output voltage will be magnitude of 2.

From inspection of the graphs you should spot that the following graph is the one that represents:

- Correct voltage gain
- Inverted from input.



Choosing from the options, the answer is: **C**

Q13. You must know that the **light intensity and distance from a point source** are related by the expression:

$$I \propto \frac{1}{d^2}$$

Since the this expression is valid, by re-arranging the relationship we obtain

$$Id^2 = constant$$

So the correct answer is: **B**

Q14. Despite the speed of the microwaves decreasing, the frequency of the microwave signal remains constant.

Consider passing red light through a glass prism where the beam of light is refracted.

The direction that the beam of red light is travelling in changes, and the speed of the light will change.

The colour of the light stays the same.

If the colour of light is the same, then the frequency of the light must be the same.

The answer from the choices given is: **B**

Q15. To spot the relationship between frequency and wavelength of photons of electromagnetic radiation, you must know that a photon travels with a speed equal to the speed of light, $3 \times 10^8 ms^{-1}$.

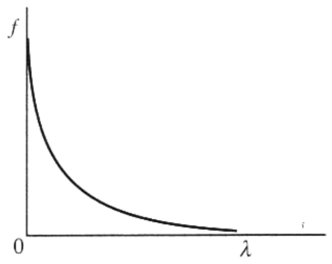
Consider the following equation:

$$v = f\lambda$$

Since the speed v is a constant value, if f increases, λ must decrease.

Similarly, if f decreases, λ must increase.

This relationship described, is represented on a graph as illustrated below:



The correct answer from the given options is shown above and is: **A**

Q16. The key point in the wording of the question is, "liquid and solid have the same refractive index."

If the solid and liquid have the same refractive index there is no change between the two media.

The ray of light travelling from the liquid to the solid of equal refractive index will have:

- The same speed.
- The same wavelength.

The correct answer is: **A**

Q17. You should know the relationship between the intensity, power and the area to fully understand.

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

P = **power (W)**

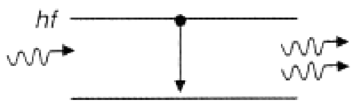
A = **area ($\mathbf{m^2}$)**

The units or measurement of intensity is therefore given to be watts per square metre, Wm^{-2}.

The correct answer is: **D**

Q18. Stimulated emission occurs when an incident photon of the correct energy causes an electron in the excited state to drop down to a lower energy.

A second photon of the same energy is emitted.



Stimulated emission

The incident radiation (or photon) and emitted radiation are in-phase and travel in the same direction.

The correct answer is: **D**

Q19. You have to know what particles are released during alpha and beta decay and this will allow you to work to the original element started with.

An alpha particle is released during alpha decay, which is a helium nucleus. A helium nucleus is written as:

$$^{4}_{2}He$$

An example of alpha decay is given below:

$$^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}He$$

A high-energy electron is released from the nucleus during beta decay because a neutron has changed into a proton and an electron.

As a result of this decay, the nucleus has one less neutron but one extra proton. The result is the atomic number increases by one, but the mass remains the same.

The high energy electron that is released, can be represented by:

$$^{0}_{-1}e$$

An example of beta decay is given below:

$$^{1}_{0}n \rightarrow \, ^{1}_{1}p + \, ^{0}_{-1}e$$

Given the following radioactive decay in the question, you should simply work backwards.

$$^{P}_{Q}\mathrm{Bi} \xrightarrow[\text{decay}]{\beta} \, ^{R}_{S}\mathrm{Po} \xrightarrow[\text{decay}]{\alpha} \, ^{208}_{82}\mathrm{Pb}$$

Start with the final product, which is a result of an alpha decay:

$$^{208}_{82}Pb + ^{4}_{2}He \rightarrow ^{212}_{84}Po$$

The polonium nucleus is as a result of beta decay, so working backwards gives:

$$^{212}_{84}Po + ^{0}_{-1}e \rightarrow ^{212}_{83}Bi$$

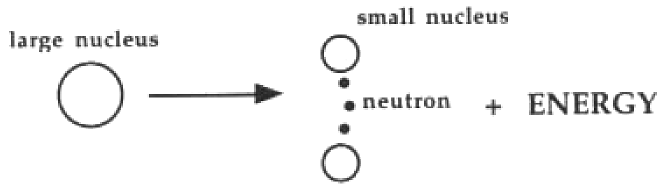
So the values calculated are:

$$P = 212$$
$$Q = 83$$
$$R = 212$$
$$S = 84$$

The correct answer from the table of choices is: **B**

Q20. The two main nuclear processes are nuclear fission and nuclear fusion. You must be able to distinguish between the two processes to attempt the question.

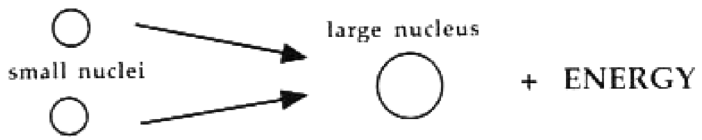
Nuclear fission is illustrated in the following diagram:



In stimulated or induced emission, an incident neutron hits the large nucleus causing it to undergo fission.

Fission is illustrated above where a large nucleus is split into two nuclei of smaller mass releasing several neutrons.

Nuclear fission is where two small nuclei combine to form one large nucleus as illustrated below:



The nuclear equation given is shown:

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + ^{1}_{0}n + ^{1}_{0}n + ^{1}_{0}n$$

This illustrates a nucleus and a neutron present before the reaction, with the product of the reaction being 2 nuclei of smaller mass plus several neutrons released.

This shows that the type of reaction is stimulated or induced nuclear fission.

The correct answer from the example listed is: **D**