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# PHYSICS

# 2014

# Trial Examination

**(2 hours 30 minutes)**

***Motion in one and two dimensions***
***Electronics and photonics***
***Electric power***
***Interactions of light and matter***
***Materials and their use in structures***
***Sound***

**(Note: Use the formula/data sheets supplied by VCAA)**

## SECTION A – Core studies (128 marks)

### Instructions for Section A

Answer all questions in this section.
You should take the value of $g$ to be 10 m $s^{-2}$.
Appropriate working should be shown in questions worth more than 1 mark.
Diagrams are not drawn to scale unless stated otherwise.

### Area of study – Motion in one and two dimensions

### Question 1

A helicopter carrying a 1500 kg load on a 5.00 m long cable speeds up horizontally in a straight line. The mass of the helicopter is 5000 kg. Air resistance on the load is 2660 N. The cable makes an angle of 30° with the vertical.

Source: flickr

a. Determine the tension in the cable. 2 marks

N

b. Determine the net force on the load. 2 marks

N

c. Determine the net force on the helicopter. 2 marks

N

Now the helicopter flies at constant speed in a horizontal circular path of radius 22.5 m. The cable makes the same angle (i.e. 30° ) with the vertical. Air resistance on the load is negligible.

d. Calculate the acceleration of the load. 2 marks

$m\ s^{-2}$

e. Determine the speed of the load. 2 marks

$m\ s^{-1}$

f. Determine the speed of the helicopter. 2 marks

$m\ s^{-1}$

**Question 2**

A vertical circular section of a roller coaster has a radius of 22.5 m (measured from the rider to the centre of the circular section). For safety reason each rider is restrained to the seat by a harness.


a. What is the weight of a 75 kg rider at the highest point of the section? 1 mark

N

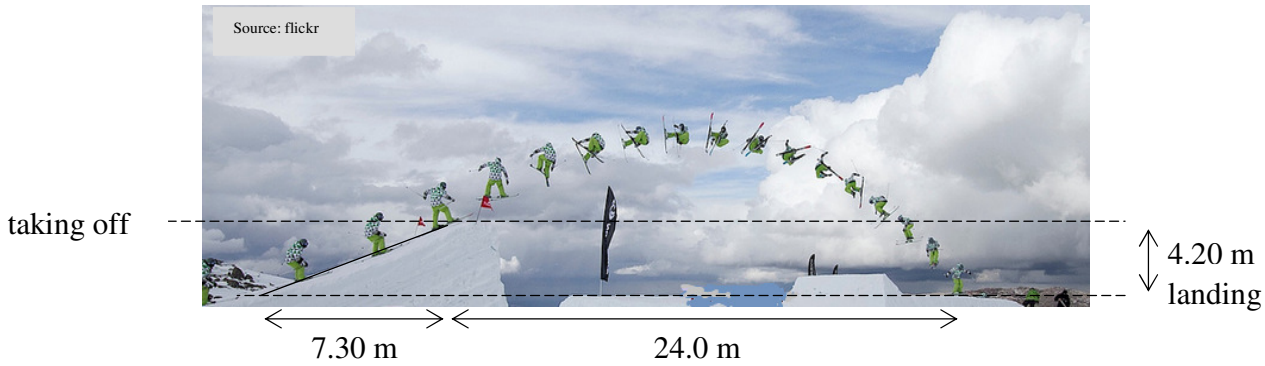
b. The rider feels weightless when the speed of the carriage is 15.0 m $s^{-1}$ at the highest point of the section. Explain the statement with a calculation. 2 marks

c. Find the speed over 15.0 m $s^{-1}$ when the rider's apparent weight is 75 N at the highest point of the section. 2 marks

m $s^{-1}$

**Question 3**

The diagram shows a multiple exposure photograph of a skier taking off from a straight ramp together with some relevant measurements. Ignore air resistance in this question. The time of flight is 1.90 seconds.




a. Show that the speed of the skier at the end of the straight ramp is 14.6 m $s^{-1}$. 3 marks

b. Calculate the maximum height reached by the skier above the landing level. 3 marks

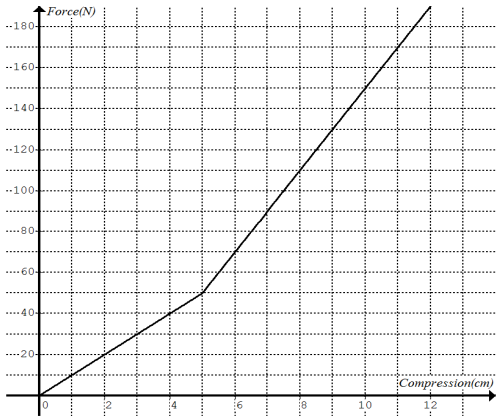
m

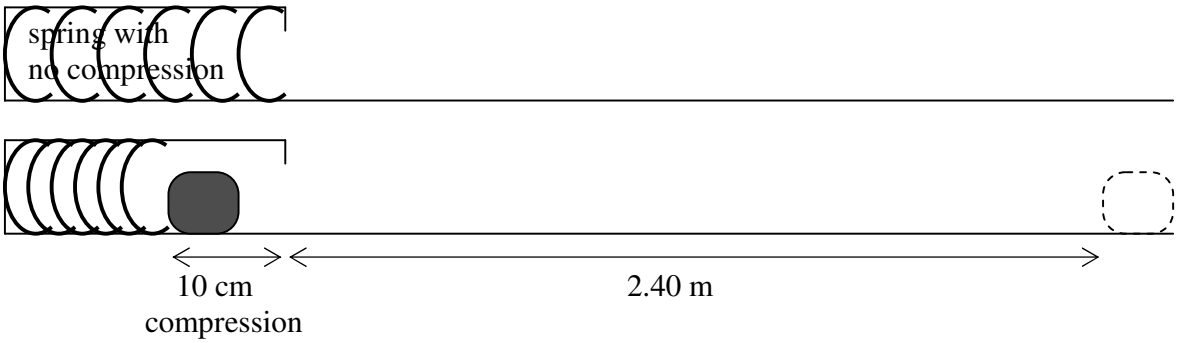
**c.** Calculate the speed of the skier just before landing. 2 marks

m $s^{-1}$

**Question 4**

The force-compression graph of a spring (of negligible mass) is shown below.




A 0.5 kg block is placed next to the spring which is compressed by 10 cm. When the spring is released, it forces the block to slide. The block travels 2.50 m in total in a straight line on a horizontal surface before it stops.

a. Calculate the total amount of heat energy generated when the block comes to a stop. 2 marks

J

b. Calculate the force of friction between the block and the surface. 1 mark

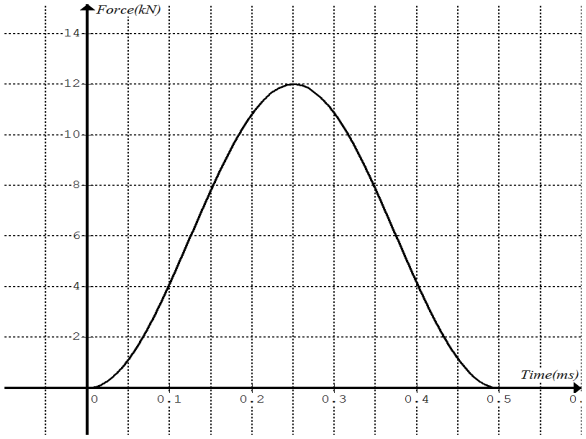
N

c. Calculate the maximum speed of the block. 2 marks

m $s^{-1}$

**Question 5**

The force-time graph of a club hitting a 46 grams golf ball is shown in the following graph where time is measured in ms, and force is on the golf ball and in kN.





a. Determine the momentum of the golf ball just after the hit. The ball was at rest before the hit. 2 marks

kg m $s^{-1}$

b. Find the speed of the golf ball just after the hit. 1 mark

m $s^{-1}$

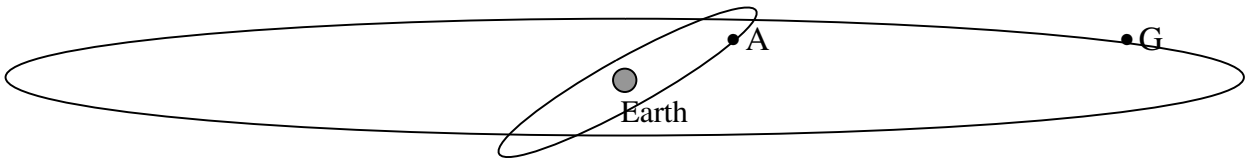
c. What is the average force on the club head when it is in contact with the golf ball? 1 mark

N

d. Explain why the law of conservation of momentum is/is not applicable in this collision. 1 mark

**Question 6**

Satellites G and A are in circular orbits around planet Earth. Satellite G is a geostationary satellite. Satellite A has an orbital radius which is a quarter of the orbital radius of satellite G.




a. Calculate the value of the ratio $\frac{T_G}{T_A}$ where $T_G$ and $T_A$ are the periods of satellites G and A respectively.

2 marks

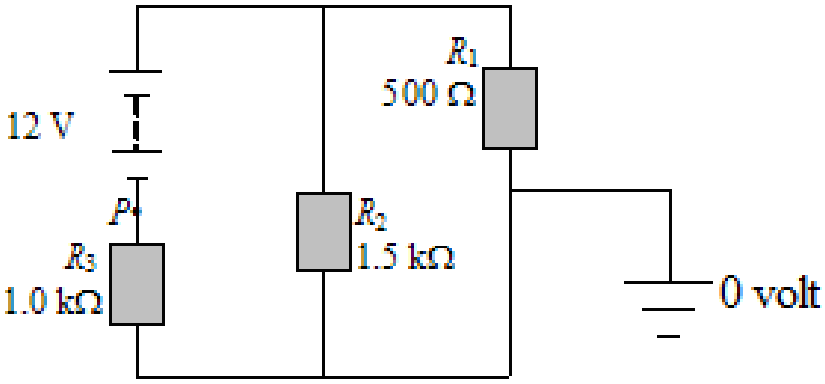
b. Calculate the value of the ratio $\frac{g_A}{g_G}$ where $g_A$ is the gravitational field of planet Earth at A, and $g_G$ is the gravitational field of planet Earth at G. 2 marks

c. A second geostationary satellite twice as massive as G is to be placed in orbit. Compare the orbital radius of the second geostationary satellite with the orbital radius of G. 1 mark

**Area of study – Electronics and photonics**

**Question 7**

The following circuit consists of a battery supplying a constant voltage of 12 V, and three ohmic resistors $R_1$, $R_2$ and $R_3$. Assume that the battery has zero internal resistance.




a. What is the effective resistance of the circuit? 2 marks

k Ω

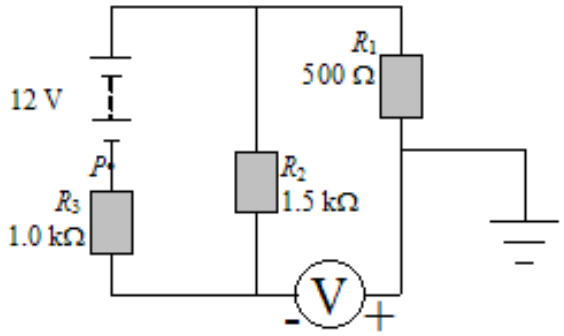
b. What is the electric potential at point *P*? 2 marks

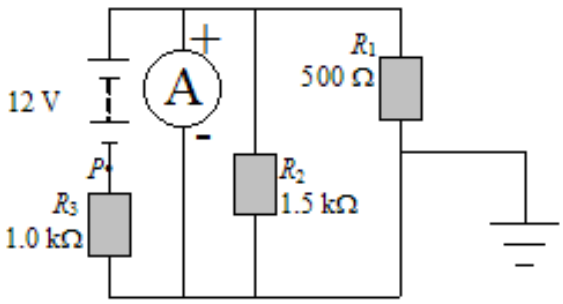
V

c. Determine the total power of the circuit. 2 marks

W

A voltmeter and an ammeter were *incorrectly* connected to the circuit by a student as shown in the following diagrams.




d. What is the reading on the voltmeter?

1 mark

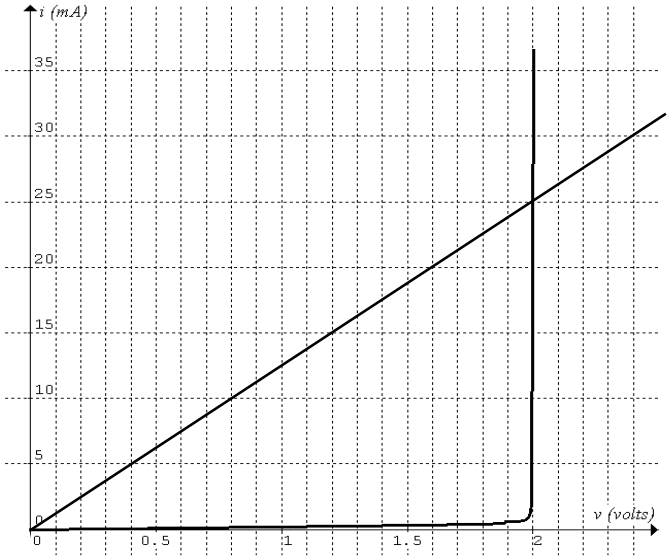
V

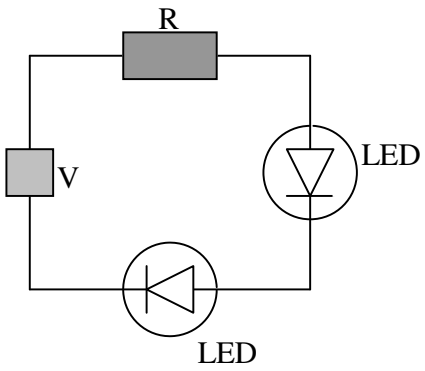
e. What is the reading on the ammeter? 1 mark

mA

**Question 8**

The following graphs show the *i*-*v* characteristics of a LED and an ohmic resistor, R.
A student connects two such LEDs and the resistor in series with a variable voltage source V.
The circuit is shown below.



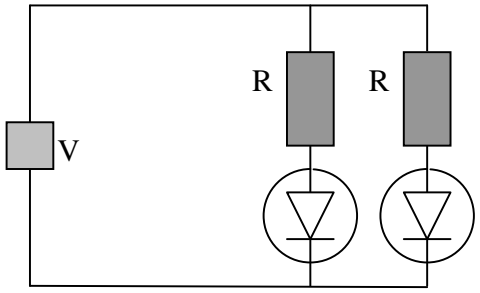

a. What is the resistance of resistor R? 1 mark

Ω

b. Determine the current through the LEDs when the variable voltage source V is set at 6.0 volts, and the LEDs are in conduction mode. 2 marks

mA

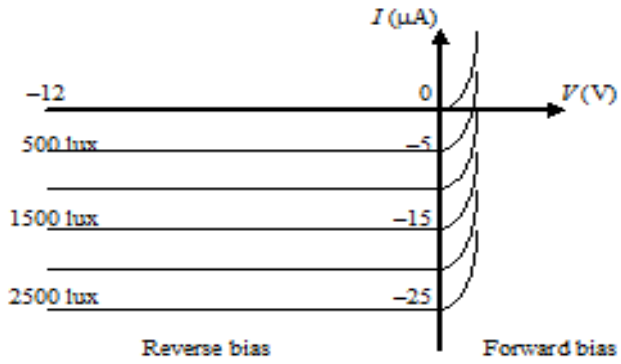
c. Now the two LEDs are connected in parallel. The voltage source V is kept at 6.0 V. Two ***new*** identical ohmic resistors are chosen to give the LEDs the same brightness as in part b. Find the resistance of each resistor.
2 marks

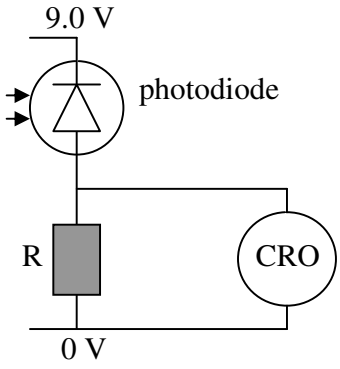



Ω

**Question 9**

Light is directed at a photodiode which is in series with an ohmic resistor R of 200 kΩ. The voltage across R is monitored with a CRO as shown in the circuit diagram below.
The following I-V graph shows the characteristics of the photodiode at different illuminating light intensities.



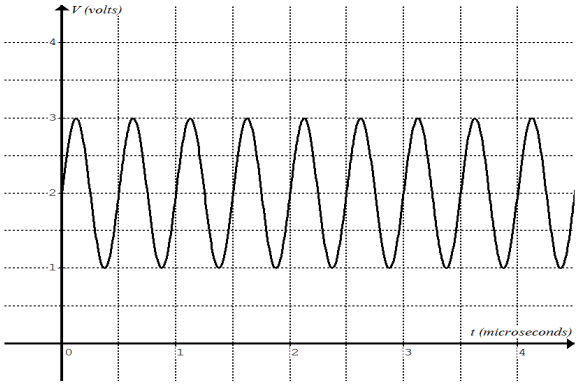

When a photodiode is in reverse bias, its conducting current is directly proportional to light intensity.

a. Calculate the voltage shown on the CRO when light of 2000 lux intensity is directed at the photodiode.

2 marks

V

An intensity modulated beam of light is directed at the photodiode. The voltage variation on the CRO is shown below, where $V$ is in volts and $t$ is in $10^{-6}$ s.




b. Calculate the frequency of the intensity modulation in the light beam. 2 marks

Hz

c. Calculate the amplitude of the variation in the light intensity. 2 marks

lux

**Question 10**

The input signal to a voltage amplifier is shown in Fig. 1, and the voltage transfer graph of the voltage amplifier is shown in Fig. 2.

Fig. 1

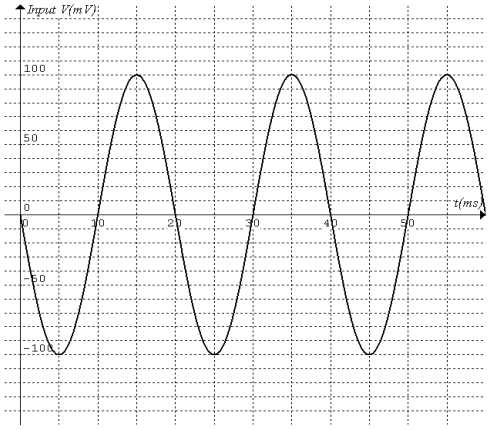
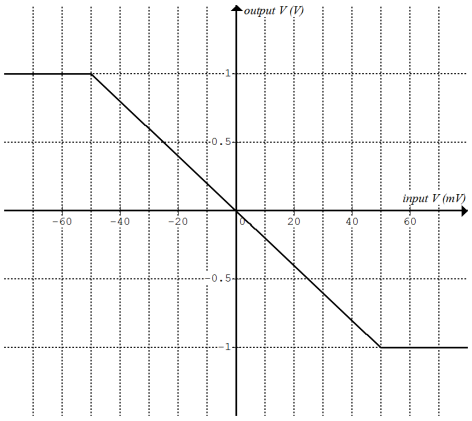



Fig. 2




a. Calculate the signed voltage gain of the voltage amplifier. 2 marks

b. What is period of the output signal? 1 mark

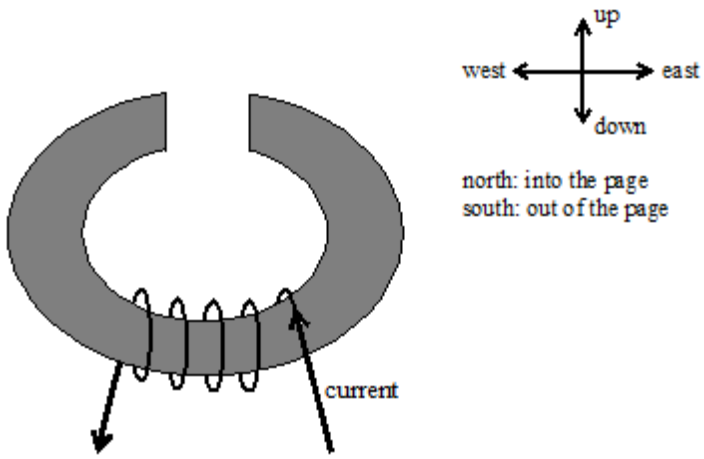
s

c. The input signal passes through the voltage amplifier and a second identical voltage amplifier in tandem. Sketch accurate graph of the output voltage of the second amplifier as a function of *t* (show scales on both axes). 2 marks

**Area of study – Electric power**

**Question 11**

The following diagram shows a horse-shoe electromagnet positioned vertically in the east-west direction as shown in the following diagram. The magnitude of the magnetic field generated between the poles is ***four times*** the magnitude of the magnetic field of the earth.
The earth's magnetic field is $4.00\times10^{-5}$ tesla and it is horizontal.




a. Label the magnetic north pole of the electromagnet as N on the above diagram 1 mark

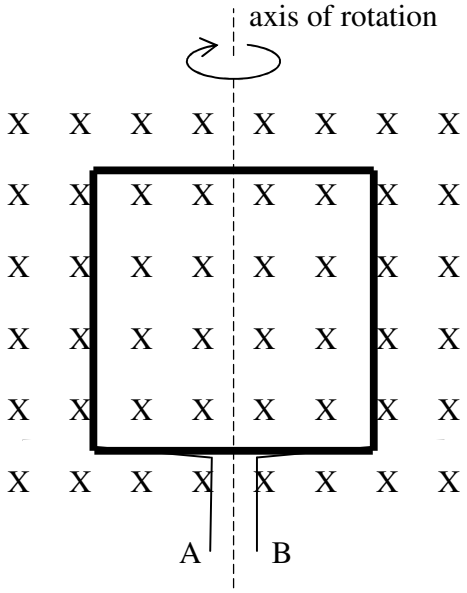
b. Calculate the magnitude of the combined magnetic field of the earth and the electromagnet at the midpoint between the poles of the electromagnet. 2 marks

T

c. Determine the direction (compass bearing) of the combined magnetic field. 2 marks

**Question 12**

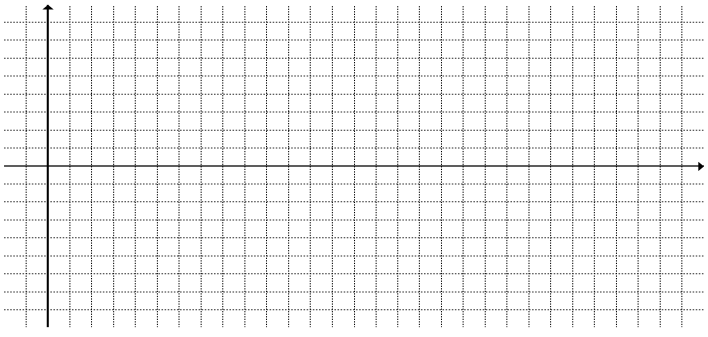
A square coil has 5 turns of insulated conducting wire.
The side length of the square coil is 10 cm.
It is made to rotate mechanically at a frequency of 50 Hz in the clockwise direction (viewed above the axis of rotation.
The coil is placed in a uniform magnetic field of 0.50 T.
Initially (at $t = 0$) the magnetic field is perpendicular to the plane of the coil (into the page) as shown below.




a. Calculate the maximum magnetic flux through the coil during its rotation. 2 marks

wb

b. Draw a graph showing the variation of magnetic flux with time for two rotations from $t = 0$. Show scales on both axes. 2 marks



c. Calculate the maximum value of the average induced emf possible during the rotation of the coil. 2 marks

V

d. State the direction of the induced current in the coil, from A to B, or from B to A, immediately after $t = 0$. Refer to the first diagram on page 15.

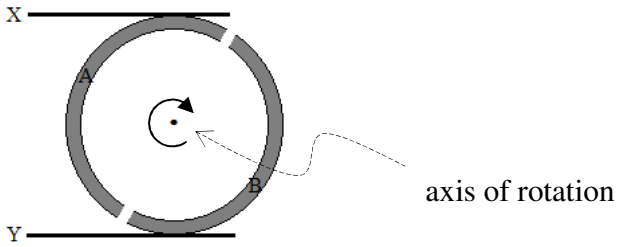
1 mark

e. Name the law and explain how to use it to answer part d. 3 marks

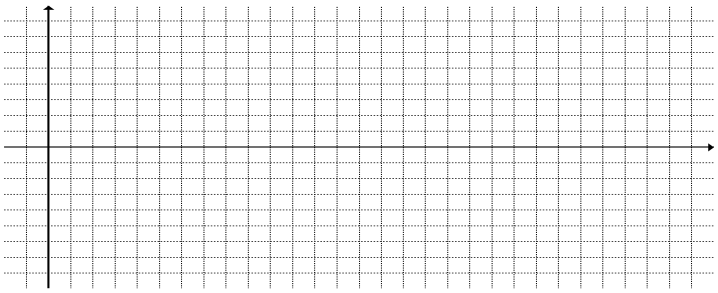
f. State the direction of the induced current in the coil, from A to B, or from B to A, immediately after $t = 0$ if the rotation of the coil is ***anticlockwise*** instead of clockwise. Refer to the first diagram on page 15.

1 mark

Now a split-ring commutator is connected to terminals A and B of the coil. The diagram below shows the split-ring at time $t > 0$. X and Y are conducting brushes touching the half-rings. The direction of rotation is as shown.




g. Sketch a graph showing the variation of *the potential at* X *(relative to the potential at* Y*)* with *time* for two rotations from $t = 0$. Show scales on the time axis only. 2 marks



h. Instead of rotating the coil mechanically, now it is made to rotate by connecting brush X to the positive terminal, and brush Y to the negative terminal of a battery. Describe and explain the direction of rotation of the coil. Use the split-ring diagram as the viewing reference in describing directions.

3 marks

**Question 13**

A laboratory power pack supplies 12 V AC only.
It is connected to a 240 V power point.
It has a step-down transformer inside.
$N_p$ is the number of turns in the primary coil and $N_s$ in the secondary coil.

a. What is the value of the ratio $N_p : N_s$ of the transformer? 1 mark

b. What is the peak to peak voltage output of the power pack? 1 mark

V

Now a light globe (rated 8 watts 12 V) is connected to the power pack.

c. What is the rms current through the light globe? 1 mark

A

d. What is the average input power to the power pack, assuming that it has an efficiency of 90%? 1 mark

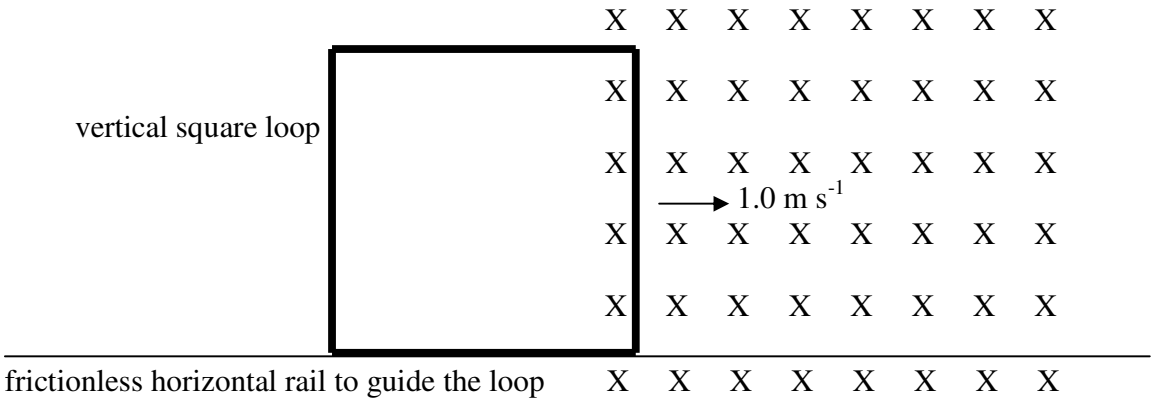
W

e. What is the rms current (2 significant figures) in the primary coil of the transformer in the power pack? 1 mark

A

**Question 14**

A square coil has 20 turns of insulated conducting wire with the two ends joined to form a closed circuit.
The side length of the square coil is 0.50 m. The total resistance of the coil is 5.0 Ω.
The loop is pushed into a uniform magnetic field of 0.50 T at a constant speed of 1.0 m $s^{-1}$ along the rail guide.




a. Calculate the rate of change in magnetic flux through the square loop. 2 marks

wb $s^{-1}$

b. Calculate the magnitude of the induced emf in the square loop. 1 mark

V

c. Calculate the induced current in the square loop. 1 mark

A

d. Calculate the force required to push the square loop into the magnetic field at 1.0 m $s^{-1}$. 2 marks

N

e. Determine the force required to keep the square loop moving at 1.0 m $s^{-1}$ when it is completely inside the magnetic field. 1 mark

N

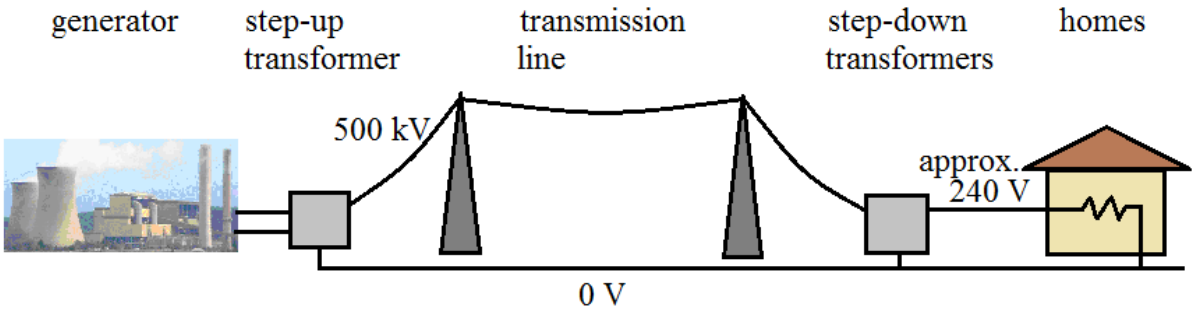
**Question 15**

The Yallourn brown coal power station is located in the Latrobe Valley, 150 km east of Melbourne. Every hour 2400 tonnes of brown coal is used to boil water into superheated steam to drive four turbine generators. Each generator has an average capacity of 380 megawatts of electricity supplying 500 thousand homes.

a. Use the provided values to calculate the average energy consumption (kilowatt-hour) by a Victorian home in an hour. 2 marks

kwh

The following diagram shows a simplified version of the transmission and distribution of power to Victorian homes. At a particular time of the day the generator produces 400 megawatts (Mw) of electricity.
The total resistance of the transmission line is 8.00 Ω.




b. At the power station end of the transmission line the voltage is 500 kV. Calculate the voltage (3 significant figures) at the other end of the transmission line.

2 marks

kV

c. Calculate the % power loss in the transmission line. 2 marks

%

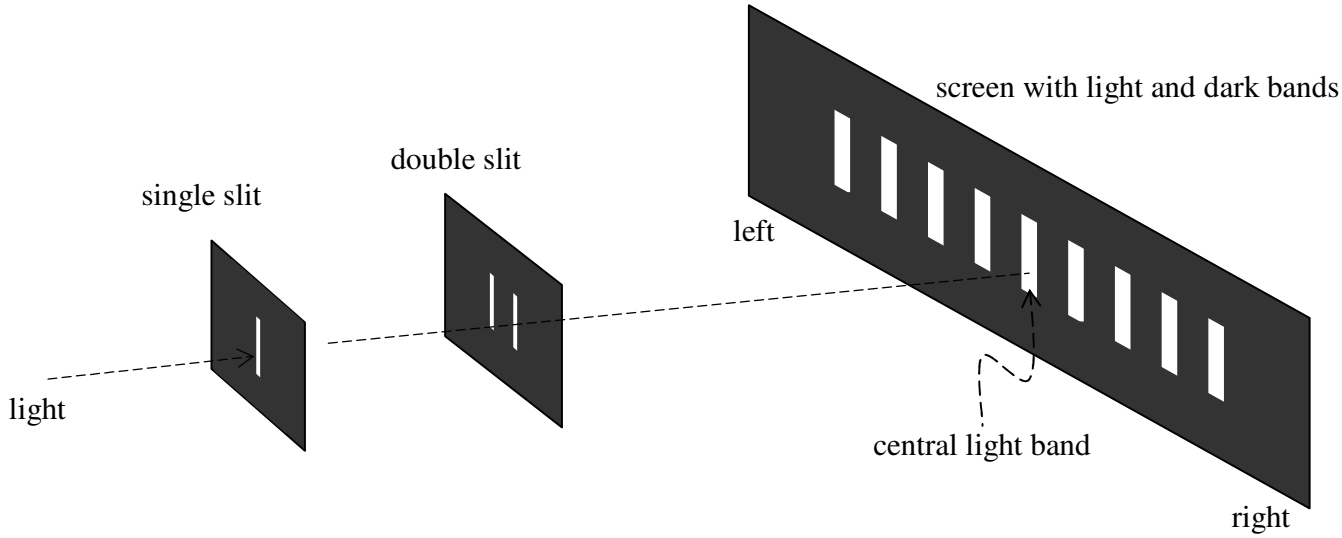
d. The frequency of rotation of the generator is 50 Hz delivering 400 Mw output. What is its frequency of rotation when its output is 200 Mw? 1 mark

Hz

**Area of study – Interactions of light and matter**

**Question 16**

The following diagram illustrates the setup of Young's double slit experiment.
Let $\lambda$ metres be the wavelength of light used in the experiment.




a. Briefly explain the use of the single slit. 1 mark

b. Use the wave model to explain the formation of the dark bands. 2 marks

c. Briefly describe two ways to increase the spacing between two adjacent light bands. 2 marks

d. The difference in distances from a dark band to the two slits is $1.58\times10^{-6}$ m. The difference in distances from an ***adjacent*** dark band is $1.13\times10^{-6}$ m. Calculate the wavelength $\lambda$ of the light used in the experiment.
2 marks

| | m |
|---|---|

**Question 17**

The sky appears blue on a clear day.

Explain this phenomenon in terms of diffraction of light and the ratio $\frac{\lambda}{w}$.

The size of particles in the air is about 900 nm.
The range of wavelengths of the visible light spectrum is 400 nm to 800 nm approximately.

3 marks

**Question 18**

Light of 250 nm wavelength is directed at a metal surface. The work function of the metal is 3.70 eV.

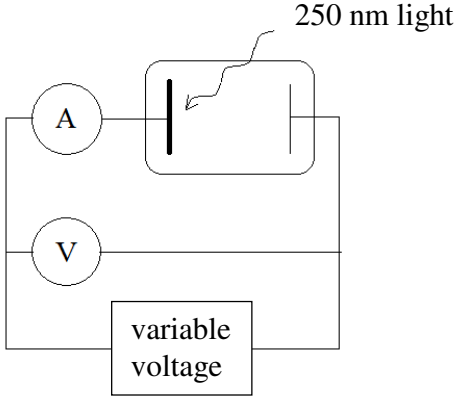
a. Calculate the maximum kinetic energy of the electrons emitted from the metal. 2 marks

eV

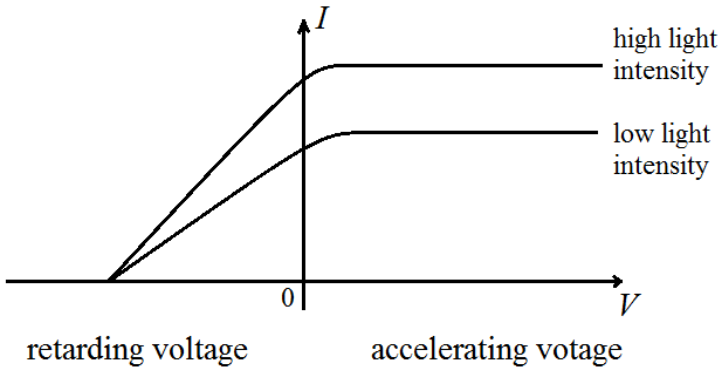
b. Calculate the maximum wavelength of light used on the metal for emission of electrons to occur. 2 marks

nm

The following setup is used to investigate the kinetic energy of the electrons emitted from the metal.
Ultra-violet light of 250 nm wavelength is directed at the metal surface throughout the experiment. An ammeter, A, and a voltmeter, V, are used to measure the current *I* and voltage *V* respectively.



The investigation is repeated using the same ultra-violet light at a higher light intensity.
The results are presented graphically below.




Use the photon model to explain the observations in parts c, d, e and f.

c. Current remains constant for both light intensities when accelerating voltage is applied. 1 mark

d. Current is higher for high light intensity than for low light intensity. 1 mark

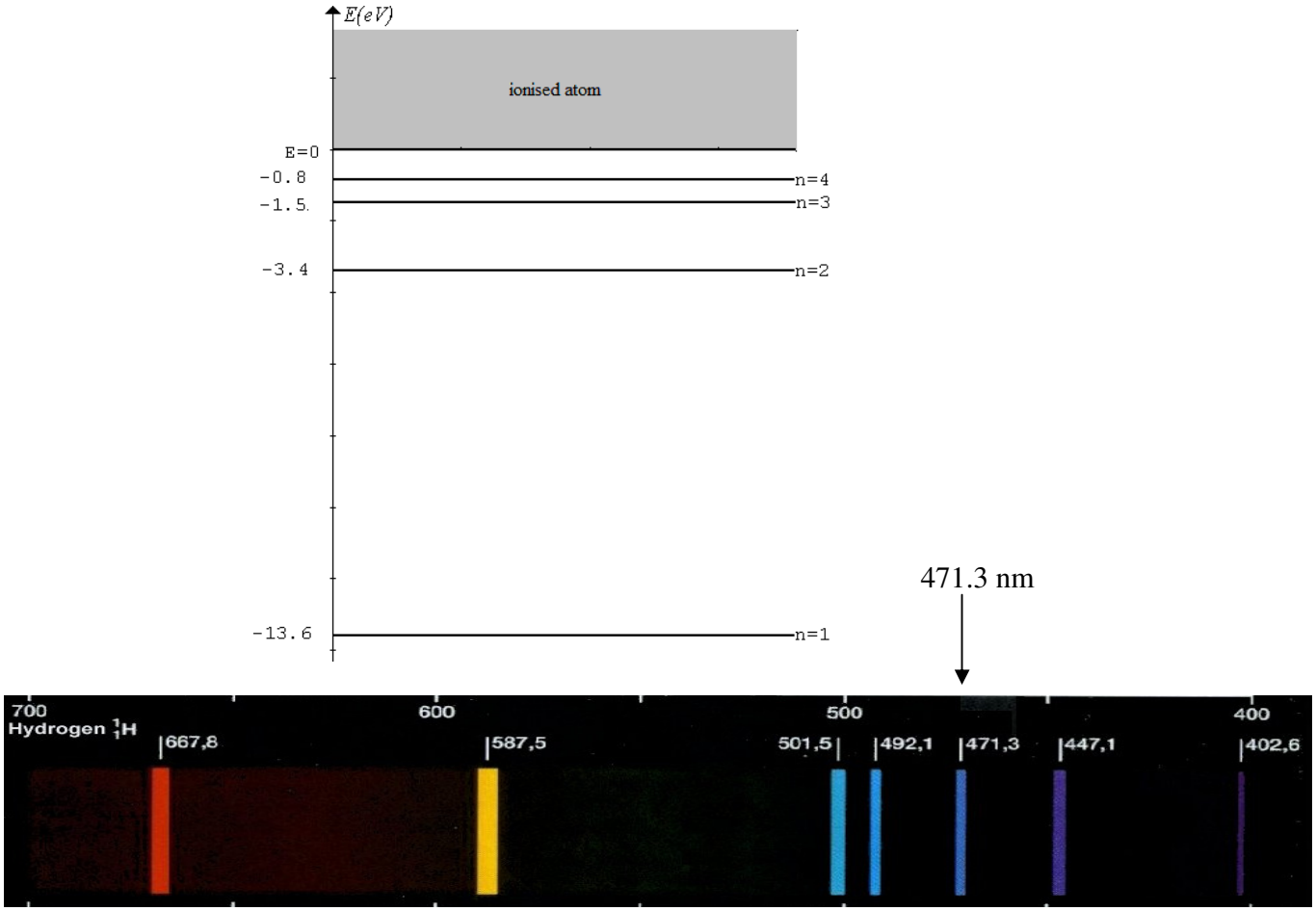
e. Current decreases as retarding voltage increases. 1 mark

f. Both graphs (high and low light intensities) have the same retarding voltage for zero current. 1 mark

g. Name one important change to the results if light of a shorter wavelength is used in the experiment. 1 mark

**Question 19**

An energy-level diagram ( $n = 1$ to $4$ ) for the hydrogen atom and its emission spectrum are shown below.




a. Explain with a calculation the appearance of 471.3 nm spectral line in the spectrum of hydrogen. 3 marks

b. Light with 471.3 nm wavelength is used to produce a diffraction pattern in an experiment. A beam of electrons is also used in the diffraction experiment. Calculate the electron momentum required to produce a similar diffraction pattern. 2 marks

kg m $s^{-1}$

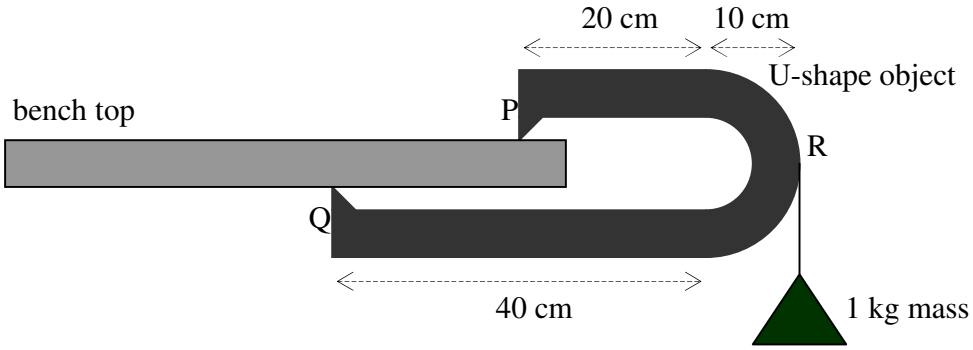
## SECTION B

Select **one** Detailed study and answer **all** questions within that Detailed study.
Choose the response that is **correct** for the question.
A correct answer scores 2, an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.

### Detailed study 2 – Materials and their use in structures

*Use the following information to answer Questions 1, 2 and 3*

A rigid U-shape object has a mass of 2 kg. A 1-kg mass is attached to it at point R. It is supported at points P and Q by a bench top, and it is in equilibrium. The centre of mass of the U-shape object is at a horizontal distance of 15 cm from R.




**Question 1**

The force (newtons) exerted by the U-shape object on the bench top at point Q is

A. 10

B. 15

C. 20

D. 30

**Question 2**

The force (newtons) exerted by the bench top on the U-shape object at point P is

A. 30

B. 40

C. 50

D. 60

**Question 3**

The upper (20 cm section) and the lower (40 cm section) arms of the U-shape object are

A. both under tensile stress

B. both under compressive stress

C. under compressive stress and tensile stress respectively

D. under tensile stress and compressive stress respectively

*Use the following information to answer Questions 4, 5 and 6*

| **Material** | **Young's modulus** (GPa) | **Elastic limit** (MPa) | **Tensile strength** (MPa) | **Compressive strength** (MPa) | **Breaking strength** (MPa) |
|---|---|---|---|---|---|
| Cast iron | - | 200 | 200 | 650 | - |
| Steel | 200 | 450 | 600 | 600 | - |
| Al alloy | 80 | 240 | 300 | - | 260 |
| Concrete | 18 | 4 | 4 | 20 | - |
| Glass | 70 | 100 | 100 | - | - |
| Wood (pine) | 15 | 35 | 40 | 35 | - |

**Question 4**

Using only the values provided in the table, a brittle material which is the strongest in compression is

A. glass

B. concrete

C. cast iron

D. pine wood

**Question 5**

Using only the values provided in the table, the stress (MPa) required in breaking Al alloy is

A. 240

B. 260

C. 300

D. 80000

**Question 6**

A tensile stress of 70 MPa is applied to the glass shown in the table. The resulting strain (%) is closest to

A. 0.0001%

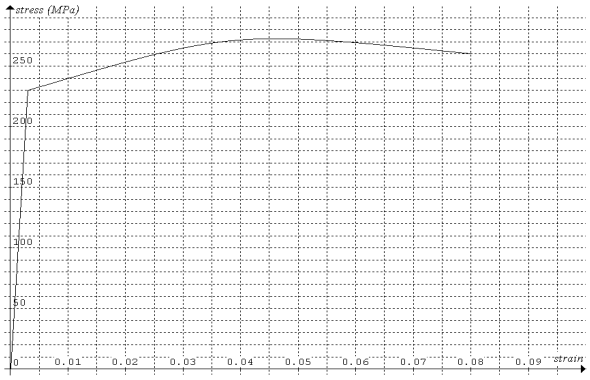
B. 0.001%

C. 0.01%

D. 0.1%

*Use the following information to answer Questions 7 and 8*

The stress-strain graph for a material up to the breaking point is shown below.




**Question 7**

The value of Young's modulus (GPa) is closest to

A. 100

B. 10

C. 1

D. 0.1

**Question 8**

The strain energy (MJ) of 0.5 $m^3$ of the material near the breaking point is closest to

A. 20

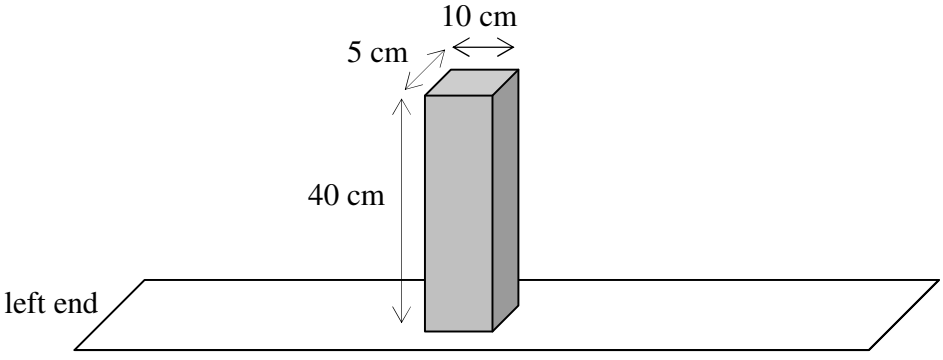
B. 10

C. 2

D. 1

**Question 9**

A rectangular block of uniform density rests on a rough horizontal board. Slowly the board is lifted at the left end. The block does not slide down the board.




The maximum angle (degrees) that the board makes with the horizontal plane before the block topples over is closest to

A. 7.5

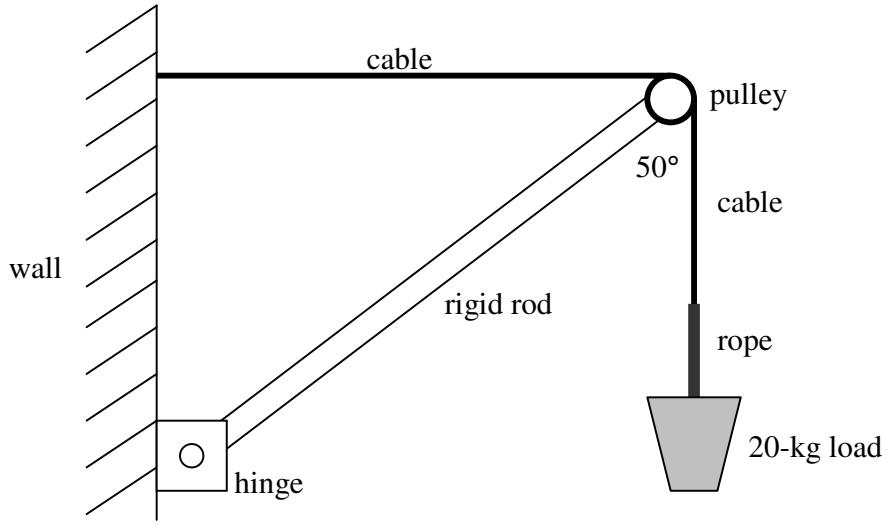
B. 15

C. 22

D. 22.5

*Use the following information to answer Questions 10, 11 and 12*

A 2.8-m long rigid rod has a uniform cross-sectional area of 10 $cm^2$.
It is hinged to a vertical wall at one end, and makes a 50° angle with the vertical.
A cable passes over a smooth pulley at the other end of the rod.
The cable is fastened to the wall and supports a 20-kg load through a rope.
The radius of the rope is greater than the radius of the cable.
Assume that the cable and the rope **do not have** mass.
The system (shown below) is in equilibrium.




**Question 10** The tension in the rope

A. equals to the tension in the cable

B. is greater than the tension in the cable

C. is less than the tension in the cable

D. is not determinable

**Question 11** The stress in the rope

A. equals to the stress in the cable

B. is greater than the stress in the cable

C. is less than the stress in the cable

D. depends on its length

**Question 12** The stress (MPa) in the rigid rod is closest to

A. 0.1

B. 0.3

C. 14

D. 28

**Detailed study 6 – Sound  Circle the best choice in each question**

*Use the following information to answer Questions 1, 2, 3 and 4*

A small source of sound is suspended in the air with the closest obstacle 100 m away. The sound power of the source is 1.0 watt. The frequency of the sound is 1100 Hz. The speed of sound is 342 m $s^{-1}$. Surface area of a sphere of radius $r$ is $4\pi r^2$.

**Question 1**

The wavelength (in m) of the 1100 Hz sound is closest to

A. 0.2

B. 0.3

C. 0.4

D. 0.5

**Question 2**

The speed (m $s^{-1}$) of a 550 Hz sound is closest to

A. 680

B. 340

C. 170

D. 85

**Question 3**

The intensity (W $m^{-2}$) of the sound at 5.0 m from the source is closest to

A. $1\times10^{-3}$

B. $2\times10^{-3}$

C. $3\times10^{-3}$

D. $1\times10^{-2}$

**Question 4**

At a *further* distance of 5 m from the same source, the sound intensity level (dB) will

A. decrease by about 0.3 dB

B. decrease by about 3 dB

C. decrease to a quarter of the original level

D. decrease by about 6 dB

*Use the following information to answer Questions 5 and 6*

A stretched wire fixed at both ends is 2.5 metres long. Its frequency of vibration is 62 Hz.

**Question 5**

At $20°\,C$ air temperature, the speed ($m\ s^{-1}$) in the air of the sound wave generated by the vibrating wire is closest to

A. 155

B. 195

C. 345

D. 690

**Question 6**

A possible speed ($m\ s^{-1}$) of the travelling wave in the vibrating wire is

A. 155

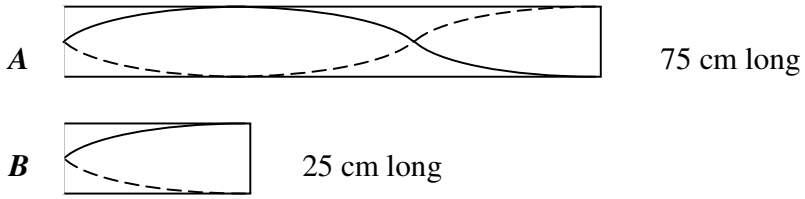
B. 195

C. 345

D. 690

*Use the following information to answer Questions 7 and 8*

Closed pipe ***A*** is 3 times the length of closed pipe ***B***.
The pressure variation patterns of the pipes are shown below.




**Question 7**

Which of the following statements is correct?

A. The sound from ***A*** has a higher pitch than the sound from ***B***.

B. The sound from ***A*** has a lower pitch than the sound from ***B***.

C. The sound from ***A*** has the same pitch as the sound from ***B***.

D. The sound from ***A*** is louder than the sound from ***B***.

**Question 8**

Which of the following statements is correct?

A. The sound speed in ***A*** is 3 times the sound speed in ***B***.

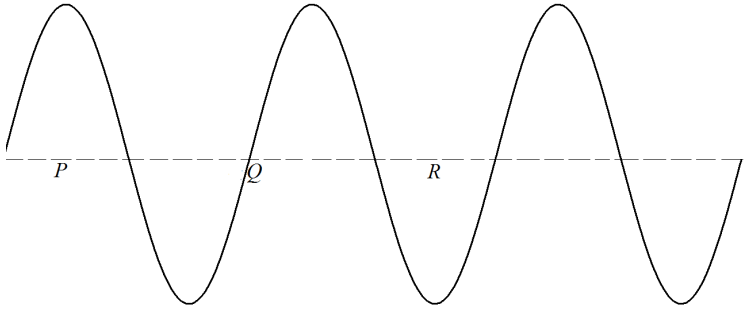
B. The sound speed in ***A*** is a third of the sound speed in ***B***.

C. The sound speed in ***A*** is the same as the sound speed in ***B***.

D. The sound wave in ***A*** has greater amplitude than the sound wave in ***B***.

**Question 9**

The diagram represents a photograph of a periodic transverse wave travelling in a rope to the *right*.
Three positions are marked as *P*, *Q* and *R*.




Which of the following statements is correct?

A. There is a displacement node at position *Q*.

B. There is an air pressure antinode at position *P*.

C. There is a rarefaction at position *R*.

D. The particles in the rope near position *Q* moves downwards.

**Question 10**

A speaker box has a tweeter, a mid-range speaker and a woofer. The diameter of the woofer is much larger than that of the tweeter so that

A. the speaker box produces less interference of the sound waves

B. the speaker box produces more interference of the sound waves

C. the speaker box produces more directional sound

D. the speaker box spreads all sound frequencies evenly in all directions.

**Question 11**

A sound waves passes by an obstacle. The extent of diffraction of the sound wave increases when

A. the width of the obstacle increases

B. the wavelength of the sound wave decreases

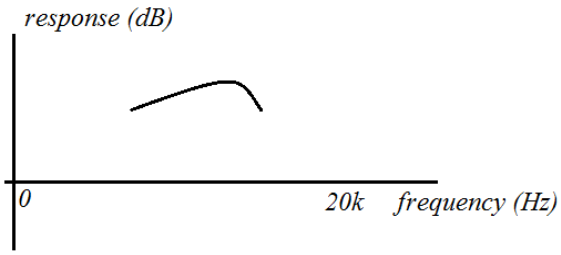
C. the value of the ratio $\frac{wavelength\ of\ the\ sound\ wave}{width\ of\ the\ obstacle}$ increases

D. the value of the ratio $\frac{wavelength\ of\ the\ sound\ wave}{width\ of\ the\ obstacle}$ decreases

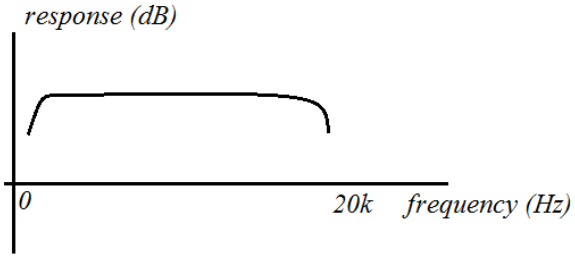
**Question 12**

The frequency response graphs of four microphones are shown below. Which one is the most suitable for musical concerts?

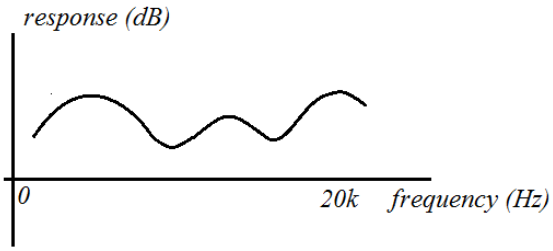
A.



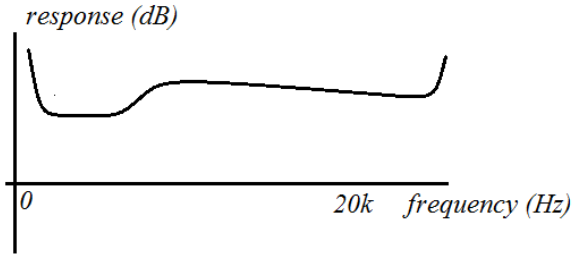

B.




C.




D.




## End of examination