Test 8

Section A – Core short answer questions: 65 marks
Section B – Detailed studies short answer questions: 75 marks
Suggested time: 90 minutes

Section A: Core short answer questions

Specific instructions to students

- Answer **all** questions in the spaces provided.
- For all questions which require a numerical answer you must show all working.
- You should take the value of g to be 10 ms^{-2}.

A parachutist free-falls from a plane travelling in level flight. During the free-fall stage of his motion, the parachutist travels through a vertical distance of 132 m.

QUESTION 1 **2 marks**

Calculate the magnitude of the final vertical velocity of the parachutist at the end of the free-fall stage. Ignore air resistance.

Taking down as positive
vertically, $u = 0$, $a = 10$, $s = 132$, $v = ?$
$v^2 = u^2 + 2as$
$v^2 = 0 + 2 \times 10 \times 132$
$v = 51.38$
Magnitude of vertical velocity = 51.4 ms^{-1}

Answer:

51.4 ms^{-1}

QUESTION 2 **2 marks**

When the parachutist opens his parachute, it slows his rate of descent uniformly to 8.41 ms^{-1} in 4.70 s. Calculate the magnitude of his deceleration during this phase.

Taking down as positive
$v = 8.41$, $u = 51.4$, $t = 4.70$, $a = ?$
$v = u + at$
$8.41 = 51.4 + a \times 4.70$
$a = -9.15$
Magnitude of deceleration = 9.15 ms^{-2}

Answer:

9.15 ms^{-2}

A car of mass 1500 kg is towing a boat and trailer with a combined mass of 1200 kg at a constant speed of 14 ms^{-1} along the highway. Drag forces of 700 N act on the car and drag forces of 400 N act on the boat and trailer.

QUESTION 3 **2 marks**

Calculate the magnitude of the driving force exerted by the car.

$F_{net} = F_{applied} - F_{opposing}$
$0 = F_{driving} - (700 + 400)$
$F_{driving} = 1100$ N

Answer:

1100 N

QUESTION 4 **2 marks**

Calculate the size of the tension force in the coupling between the car and the trailer.

For the forces on the trailer:
$F_{net} = F_{applied} - F_{opposing}$
$0 = T - 400$
$T = 400$ N
Or, for the forces on the car:
$F_{net} = F_{applied} - F_{opposing}$
$0 = 1100 - (700 + T)$
$T = 400$ N

Answer:

400 N

QUESTION 5 **2 marks**

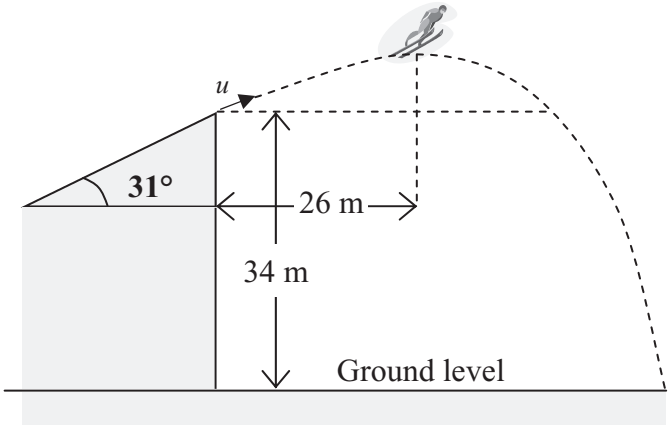
The car, boat and trailer decelerate at a rate of 2 ms^{-2}. How long will it take for them to come to rest?

Taking forwards as positive
$u = 14$, $v = 0$, $a = -2$ (deceleration), $t = ?$
$v = u + at$
$0 = 14 - 2t$
$t = 7s$

Answer:

7 s

A ski jumper makes a ski jump and is in the position shown below, 2 s after leaving the 31° jump ramp. He has travelled 26 m horizontally in this time.



QUESTION 6 **2 marks**

Calculate the magnitude of the skier's horizontal velocity at the instant shown in the diagram. Ignore air resistance.

$v = s \div t$
$= 26 \div 2.0 = 13\ \text{ms}^{-1}$

Answer:

13 ms^{-1}

QUESTION 7 **3 marks**

Calculate the magnitude of the skier's launch velocity (u) from the end of the ramp.

$u_h = u\cos 31°$
$\cos 31° = 13 \div u$
$u = 13 \div \cos 31°$
$= 15.2$ or $15\ \text{ms}^{-1}$

Answer:

15 ms^{-1}

QUESTION 8 **3 marks**

What is the magnitude and direction of the skier's acceleration at the instant shown in the diagram? Justify your answer.

Answers:

Acceleration = 10 ms^{-2}

Direction = downwards

Gravity acts continuously during the skier's motion and is always downwards.

QUESTION 9 **4 marks**

What horizontal distance from the end of the jump ramp will the skier touch down again if the ground level is 34 m below the end of the jump ramp?

Horizontally:
$u = 13$, $v = 13$, $a = 0$, $s = ?$, $t = ?$ not enough information yet
vertically, taking up as positive:
$u = 15.2 \sin 31° = 7.8$, $v = ?$, $a = -10$, $s = -34$, $t = ?$
vertically: $v^2 = u^2 + 2as$
$v^2 = 7.8^2 + 2 \times (-10) \times (-34)$
$v = -27.2\ \text{ms}^{-1}$ (i.e. down)
$v = u + at$
$-27.2 = 7.8 - 10t$
$t = 3.5s$
Horizontally: $s = ut + \frac{1}{2}at^2$
$= 13 \times 3.5$
$= 45.5$ m

Answer:

45.5 m

A waterskier of mass 76 kg is performing a horizontal turn of radius 21 m at a speed of 13.4 ms^{-1}.

QUESTION 10 **2 marks**

What is weight of the waterskier?

$W = mg$
$= 76.0 \times 10$
$= 760$ N

Answer:

760 N

QUESTION 11 **2 marks**

What is the size of the vertical component of the reaction force supplied by water on the waterskier?

$R = W = 760$ N

Answer:

760 N

QUESTION 12 **3 marks**

What is the size and direction of the net force acting on the waterskier?

$F_{net} = mv^2/r = 76 \times 13.4^2 \div 21$
$= 649.8$
Net force = 650 N
Direction = towards the centre

Answer:

Net force = 650 N

Direction = towards the centre

QUESTION 13 **3 marks**

Hence, calculate the size of the total reaction force of water acting on the waterskier.

$R = \sqrt{(760^2 + 650^2)}$
$= 1000$ N

Answer:

1000 N

A satellite is placed into a geosynchronous orbit so that it stays above the same place on the Earth's surface.

QUESTION 14 **4 marks**

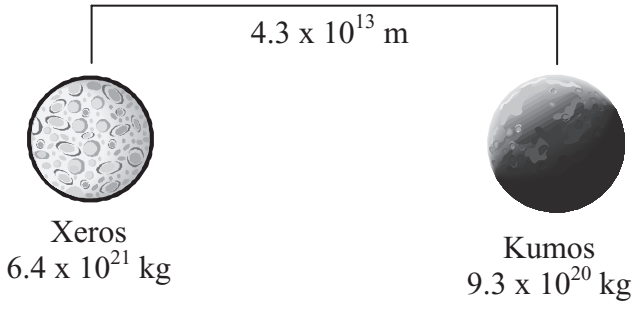
Show that the altitude of such an orbit is 3.6×10^7 m above the Earth's surface.

$4\pi^2 r/T^2 = GM_{Earth}/r^2$
$r^3 = GM_{Earth}T^2/4\pi^2$
$r^3 = (6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 60 \times 60)^2) \div (4\pi^2)$
$r = 4.225 \times 10^7$ m
Altitude $= 4.225 \times 10^7 - R_E$
Altitude $= 4.225 \times 10^7 - 6.4 \times 10^6$
$= 3.6 \times 10^7$ m

Answer:

3.6×10^7 m

Two imaginary planets, Xeros and Kumos, have masses of 6.4×10^{21} kg and 9.3×10^{20} kg respectively. The distance from the centre of Xeros to the centre of Kumos is 4.3×10^{13} m.



QUESTION 15 **2 marks**

Calculate the size of the gravitational force of attraction that Xeros exerts on Kumos.

$F = GM_{Xeros}M_{Kumos}/r^2$
$= (6.67 \times 10^{-11} \times 6.4 \times 10^{21} \times 9.3 \times 10^{20}) \div (4.3 \times 10^{13})^2$
$= 2.147 \times 10^5$ N or 2.1×10^5 N

Answer:

2.1×10^5 N

QUESTION 16 **2 marks**

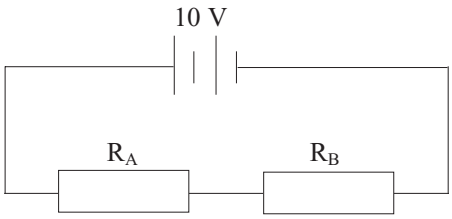
If Kumos has a radius of 2.1×10^5 m, what is the size of the gravitational field strength on the surface of Kumos?

$g = GM_{Kumos}/r^2$
$= (6.67 \times 10^{-11} \times 9.3 \times 10^{20}) \div (2.1 \times 10^5)^2$
$= 1.4$ Nkg^{-1}

Answer:

1.4 Nkg^{-1}

In the following circuit, the resistance of R_A is four times that of R_B.



QUESTION 17 **2 marks**

If a current of 100 mA flows in the circuit, determine the value of R_A.

Voltage across $R_A = 4 \times$ voltage across R_B
Therefore, 8 V across R_A.
$R_A = V \div I$
$= 8 \div (100 \times 10^{-3})$
$= 80\ \Omega$

Answer:

80 Ω

QUESTION 18 **2 marks**

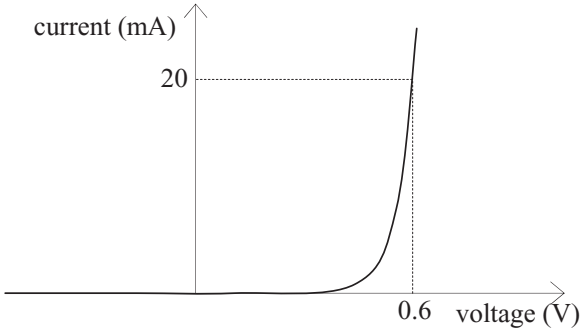
What amount of power is dissipated across R_B?

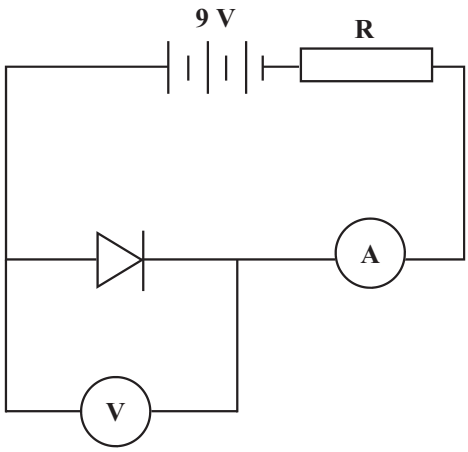
$P = I^2R$
$= (100 \times 10^{-3})^2 \times 20$
$= 0.2$ W

Answer:

0.2 W

A p−n junction diode has the following characteristic curve and circuit diagram.





QUESTION 19 **2 marks**

Is the diode forward biased or reverse biased in the circuit above? Explain your answer.

Answer:

The diode is forward biased.

The positive battery terminal is connected to the positive terminal of the diode.

QUESTION 20 **2 marks**

If the voltmeter reads 0.6 V, what would be the power output of the diode? Give your answer in mW.

When $V = 0.6$ V, $I = 20$ mA from the graph.

$P = VI$

$= 0.6 \times 20 \times 10^{-3}$

$= 0.012$ W or 12 mW

Answer:

12 mW

QUESTION 21 **3 marks**

What is the value of the resistor R?

$V_R = 9 - 0.6$

$= 8.4$ V

$R = V/I$

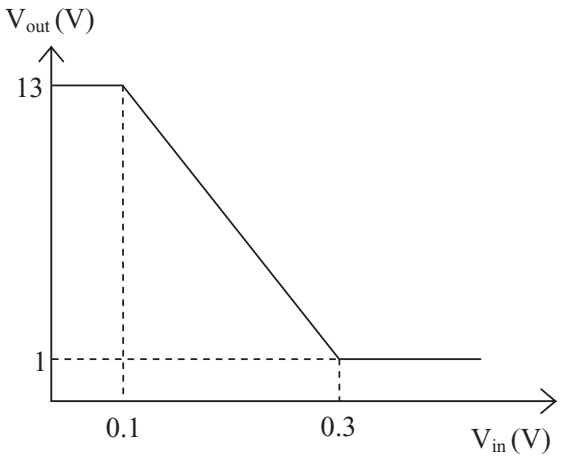
$= 8.4 \div 0.02$

$= 420\ \Omega$

Answer:

420 Ω

A typical voltage amplifier has the transfer characteristic shown below.



QUESTION 22 **2 marks**

What is the voltage gain of this amplifier?

Gain $= \Delta V_{out} \div \Delta V_{in}$

$= 12 \div 0.2 = 60$

Answer:

60

QUESTION 23 **2 marks**

Is it an inverting or non-inverting amplifier? Justify your answer.

Answer:

Inverting

The gradient of the transfer characteristic is negative.

OR

An increase in V_{in} results in a decrease in V_{out}.

QUESTION 24 **2 marks**

If an input signal of 0.4 V peak to peak is applied to the amplifier, a distorted output signal is produced. Explain why this happens.

Answer:

The maximum input signal is 0.2 V peak to peak.

Because the 0.2 V maximum is exceeded, the output signal will be clipped. Clipping produces distortion.

A student is experimenting with photonic transducers and a length of optic fibre. He sends a signal down the fibre and uses a detector at the other end.

For the next two questions, choose from the following answer key.

A thermistor

B photodiode

C LED

D LDR

QUESTION 25 **2 marks**

Choose the best device to provide an input signal to the fibre.

Answer:

C

An LED will send light along the fibre.

QUESTION 26 **2 marks**

Choose the best device to detect the signal at the other end of the fibre.

Answer:

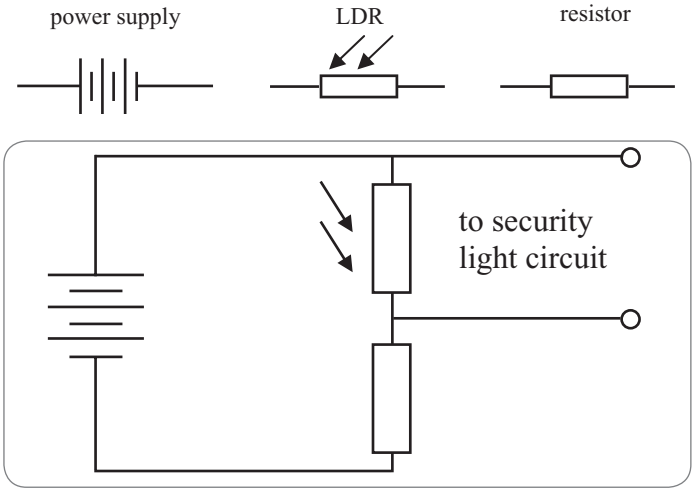
B

A photodiode will detect the signal and convert it into an electric current.

A security light circuit is designed to be switched on at night and switched off in the morning as the sun comes up. Typically, the resistance of an LDR decreases as the light intensity falling on it increases.

QUESTION 27 **2 marks**

Design a security light circuit that uses the following components to achieve the function described above. Indicate which part of the circuit leads to the security light circuit.



QUESTION 28 **2 marks**

Explain how your circuit operates to achieve the desired function.

Answer:

As the sun rises, the light intensity falling on the LDR increases and its resistance drops. Consequently, the voltage across it also drops, supplying less voltage to the security light circuit and switching them off.

Section B: Detailed studies short answer questions

Specific instructions to students

- Answer the following questions for ONE detailed study only.

Detailed study 1: Einstein's special relativity

Relevant data:

Speed of light $c = 3.0 \times 10^8$ ms^{-1}
Rest-mass of an electron $= 9.1 \times 10^{-31}$ kg

A moving electron has a kinetic energy of 2.2×10^{-13} J. The rest-mass energy of an electron is 8.2×10^{-14} J.

QUESTION 1 **3 marks**

According to Newtonian mechanics where $KE = \frac{1}{2} mv^2$, what is the speed of the moving electron?

$KE = \frac{1}{2} mv^2$ or $v = \sqrt{(2KE/m)}$
$2.2 \times 10^{-13} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$
$v = 6.95$ or 7.0×10^8 ms^{-1} (which is faster than the speed of light and therefore not possible)

Answer:

7.0×10^8 ms^{-1}

QUESTION 2 **2 marks**

What would be the relativistic mass of the moving electron?

$E = mc^2 = KE + m_o c^2$
$m \times (3 \times 10^8)^2 = 2.2 \times 10^{-13} + 8.2 \times 10^{-14}$
$m = 3.4 \times 10^{-30}$ kg

Answer:

3.4×10^{-30} kg

QUESTION 3 **2 marks**

What is the value of the Lorentz factor for the moving electron?

$m = \gamma m_o \rightarrow \gamma = m \div m_o$

$\gamma = (3.4 \times 10^{-30}) \div (9.1 \times 10^{-31})$

$= 3.7$

Answer:

3.7

QUESTION 4 **3 marks**

What is the correct speed of the moving electron?

$v = c\,(1 - 1/\gamma^2)^{1/2}$

$= c\,(1 - 1 \div 3.65^2)^{1/2}$

$= 0.962 \times 3 \times 10^8$

$= 2.9 \times 10^8\ ms^{-1}$

Answer:

$2.9 \times 10^8\ ms^{-1}$

QUESTION 5 **2 marks**

For a very high speed aircraft, it is true to say that:

A shrinkage due to length contraction is not measurable and there are no design features to deal with shrinkage.

B shrinkage due to length contraction is measurable but there are no design features to deal with this shrinkage.

C shrinkage due to length contraction is not measurable but there are design features to deal with shrinkage.

D shrinkage due to length contraction is measurable and there are design features to deal with shrinkage.

Answer:

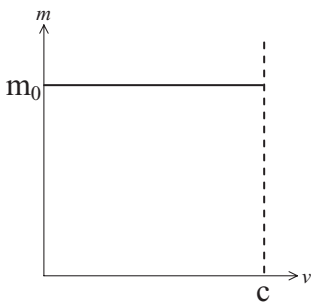
Answer A is correct.

Any shrinkage is relative and therefore not measurable. Even if the aircraft was a relativistic spacecraft, in its own frame of reference there is no shrinkage and it has proper length. Therefore, no design features are needed to deal with shrinkage.

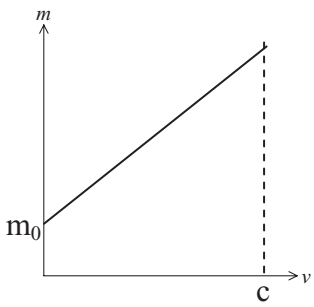
QUESTION 6 **2 marks**

In a particle accelerator, electrons can be accelerated to speeds approaching the speed of light. Which one of the following graphs best represents the relationship between the mass and speed of such electrons?

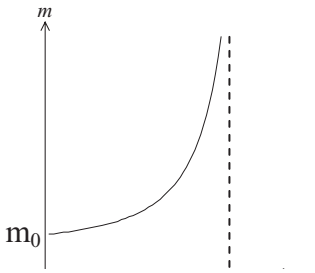
A



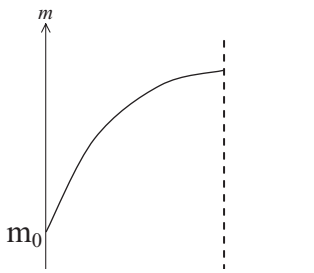
B



C



D



Answer:

Graph C is correct.

As electrons are accelerated and approach the speed of light, their mass increases towards infinity and speed never reaches c.

Evidence to support the theory of Special Relativity comes from muons. Muons come to the Earth in cosmic ray showers at speeds approaching the speed of light (0.999c). They are created at the top of the atmosphere and travel approximately 10 km to the Earth's surface where they can be detected. The muons disintegrate after a very short time of 2.2×10^{-6} *s*. This time and speed data would indicate that the muons don't in fact reach the Earth's surface at all, yet a large proportion actually do.

QUESTION 7 **2 marks**

Calculate the Lorentz factor for muons travelling at a speed of 0.999c.

$\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$

$= (1 - 0.999^2)^{-1/2}$

$= 22.4$

Answer:

22.4

QUESTION 8 **2 marks**

What distance do the muons travel from the top of the Earth's atmosphere to the surface of the Earth in their frame of reference?

$L = L_o/\gamma$
$= 10000 \div 22.4$
$= 446$ m

Answer:

446 m

QUESTION 9 **3 marks**

Will the muons be able to travel the distance from the top of the Earth's atmosphere to the surface of the Earth before disintegrating? Justify your answer.

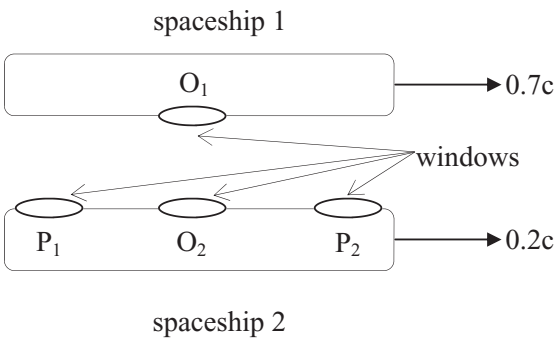
Before disintegrating, the muons will travel a distance
= speed × time
$= 0.999 \times 3 \times 10^8 \times 2.2 \times 10^{-6}$
$= 659$ m
Justification:
Because muons only see their distance to travel as 446 m, yes they will make it. Alternatively, calculate the time they need to travel 446 m, i.e. 1.49×10^{-6} s.

Answer:

Yes, they make it before disintegrating.

QUESTION 10 **2 marks**

Two spaceships are travelling parallel to each other through space and have a relative velocity of 0.5c.



On each spaceship, observers O_1 and O_2 are positioned in the middle of their respective spaceships and can look out through a window at each other. Spaceship 2 has two passengers with torches (P_1 and P_2) standing next to a window at each end of the spaceship. The passengers switch on their torches as the two spaceships come alongside each other. This event is seen simultaneously when viewed by observer O_2. What will observer O_1 see?

A Both torches being switched on simultaneously.

B The torch of P_1 being switched on before that of P_2.

C The torch of P_2 being switched on before that of P_1.

D It is impossible to tell which torch O_1 will see switched on first.

Answer:

Answer C is correct.

In the time it takes for the light to travel from the torches to O_1, spaceship 1 has moved on slightly and so O_1 is closer to P_2 than P_1 and will see the light from the torch of P_2 first.

QUESTION 11 **2 marks**

When a uranium-235 nucleus is bombarded with a slow neutron, it can undergo nuclear fission. The fission fragments fly off with large amounts of kinetic energy. This kinetic energy is a result of which of the following? Explain your answer.

A The destruction of the neuron.

B The electrostatic repulsion of the two fission fragment nuclei.

C The kinetic energy of the neutron.

D The loss of mass between the reactants and the products of the nuclear fission reaction.

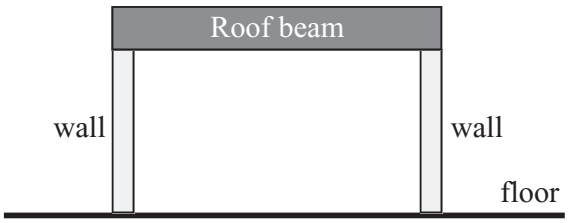
Answer:

Answer D is correct.

This reaction converts lost mass into energy according to the equation $E = \Delta mc^2$. The Δm is the mass loss in the fission reaction.

Detailed study 2: Materials and their use in structures

A roof beam inside a building is supported at each end by the walls of the building as shown in the diagram below.



QUESTION 1 **2 marks**

What type of forces are the walls subjected to and what characteristics must the wall material have to be considered for this job?

Answer:

The walls are subjected to compressive forces. This means that the material from which the walls are made must be strong in compression.

QUESTION 2 **2 marks**

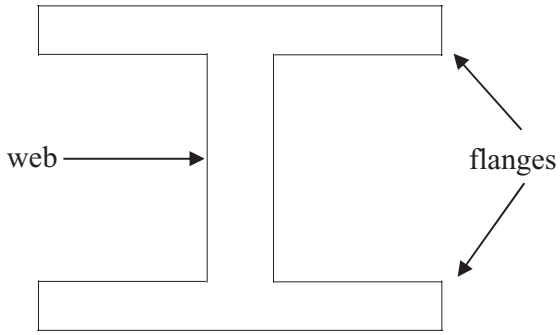
What type of forces is the roof beam subjected to and what characteristics must the roof beam material have to be considered for this job?

Answer:

The roof beams are subjected to bending forces. This involves both tension and compression, so the material from which the roof beams are made must be strong in both tension and compression.

QUESTION 3 **4 marks**

Roof beams are often made from steel I-beams. With reference to the following diagram, explain why I-beams are useful as roof beams.



Answer:

In a roof beam, the top and bottom surfaces are in tension and compression. Steel is strong in both tension and compression. As shown in the diagram, most of the material in the I-beam is along the flanges and located where the tension and compression forces are greatest.

QUESTION 4 **2 marks**

An alternative material to steel I-beams are precast reinforced concrete beams. What is meant by the term 'reinforced concrete'?

Answer:

Reinforced concrete has steel rods embedded in it to increase its tensile strength.

A 6.7 m length of 1.2 mm radius aluminium cable is used to support a tensile force of 18 N.

QUESTION 5 **2 marks**

Calculate the amount of stress in the aluminium cable.

$\sigma = F/A$
$A = \pi r^2 = \pi \times (1.2 \times 10^{-3})^2$
$= 4.52 \times 10^{-6}\ m^2$
$\sigma = 18 \div (4.52 \times 10^{-6})$
$= 4.0 \times 10^6$ Pa

Answer:

4.0×10^6 Pa

QUESTION 6 **2 marks**

Under the influence of this force, the aluminium cable stretches by 0.38 mm. What is the strain in the cable?

$\varepsilon = \Delta L \div L$
$= (0.38 \times 10^{-3}) \div 6.7$
$= 5.7 \times 10^{-5}$

Answer:

5.7×10^{-5}

QUESTION 7 **2 marks**

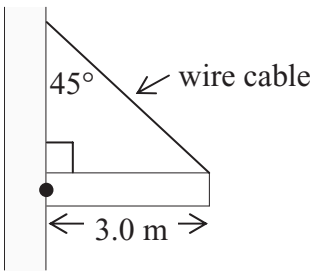
What is the value of Young's modulus for the aluminium cable?

$Y = \sigma/\varepsilon$
$= (4.0 \times 10^6) \div (5.7 \times 10^{-5})$
$= 7.0 \times 10^{10}$ Pa

Answer:

7.0×10^{10} Pa

A 3.0 m long cantilevered overhang is supported by a wire cable as shown below.



The weight of the overhang is 640 N.

QUESTION 8 **3 marks**

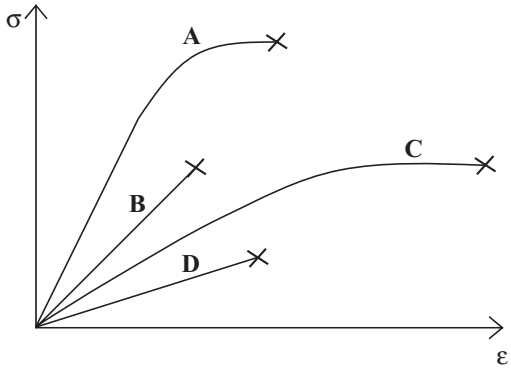
Calculate the tension force in the wire cable.

Taking torques about the left-hand end of the cantilever:
$640 \times 1.5 = T \cos 45° \times 3$
$T = 960 \div 2.12$
$T = 452.5$ N or 450 N

Answer:

450 N

Four different construction materials have the following stress–strain characteristics.



QUESTION 9 **2 marks**

Which of the four materials is the most brittle? Justify your answer.

Answer:

Answer B is correct.

Brittle materials don't stretch very much before they break. Material B has the lowest strain before fracture.

QUESTION 10 **2 marks**

Which of the four materials is the most ductile? Justify your answer.

Answer:

Answer C is correct.

Ductile materials can be stretched out into wires very easily and exhibit large strain before fracture. Material C has the largest amount of stretch.

QUESTION 11 **2 marks**

Which of the four materials is the strongest? Justify your answer.

Answer:

Answer A is correct.

Strong materials have high stress values. Material A has the highest stress value.

Detailed study 3: Further electronics

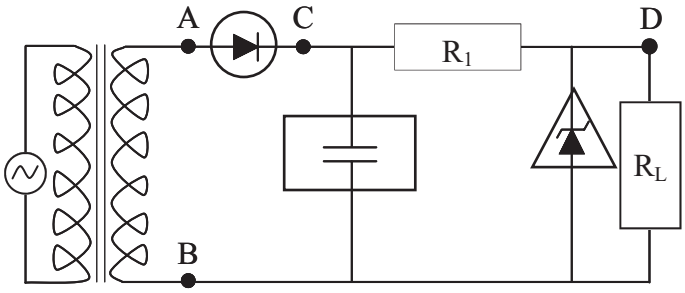
QUESTION 1 **3 marks**

Carefully describe how to use a multimeter as an ammeter.

Answer:

Connect the multimeter into the circuit so that current will flow through it (i.e. in series). Move the rotating switch to select the highest current range, switch on the power, adjust the meter to give an adequate reading, take the reading and switch off the circuit.

A fully functioning AC to DC regulated power supply circuit diagram appears below.



QUESTION 2 **1 mark**

Draw a circle around the component of the circuit responsible for rectifying the voltage.

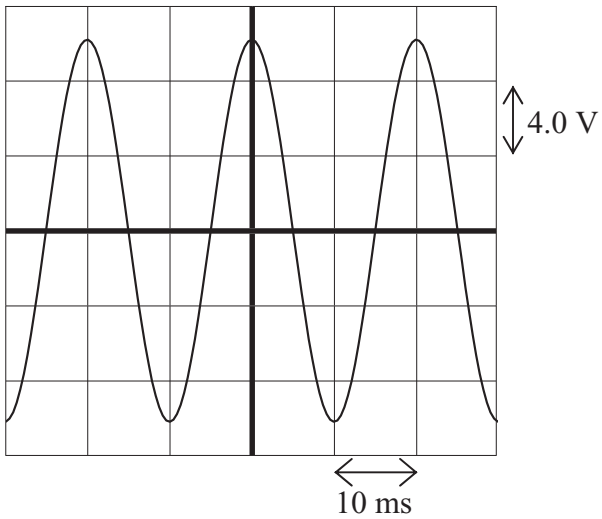
QUESTION 3 **1 mark**

Draw a rectangle around the component of the circuit responsible for smoothing the voltage.

QUESTION 4 **1 mark**

Draw a triangle around the component of the circuit responsible for regulating the voltage.

A cathode-ray oscilloscope is connected between points A and B on the circuit diagram. The following signal appears on the CRO screen. The settings on the CRO are as shown below.



QUESTION 5 **2 marks**

What is the frequency of the AC signal?

T = 2 squares = 20 ms

$f = 1/T$

$= 1 \div (20 \times 10^{-3})$

$= 50$ Hz

Answer:

50 Hz

QUESTION 6 **1 mark**

What is the peak voltage of the signal?

V_{peak} = 2.5 squares
= 2.5 × 4
= 10 V

Answer:

10 V

QUESTION 7 **2 marks**

What is the RMS voltage of the signal?

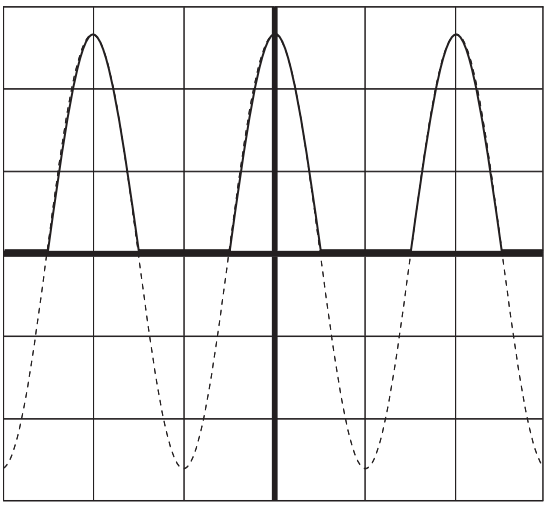
$V_{RMS} = V_{peak} \div \sqrt{2}$
$= 10 \div \sqrt{2}$
= 7.1 V

Answer:

7.1 V

QUESTION 8 **2 marks**

Sketch the signal on the grid below when the CRO is connected between points B and C.

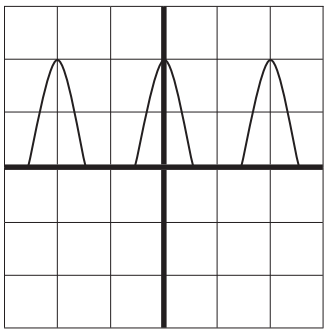


or similar

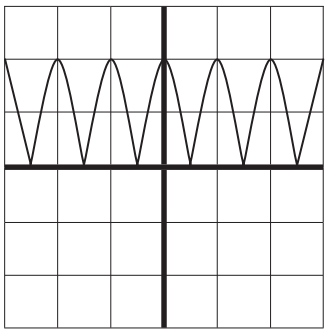
QUESTION 9 **2 marks**

If the CRO is now connected between points B and D, the output signal would most likely appear as:

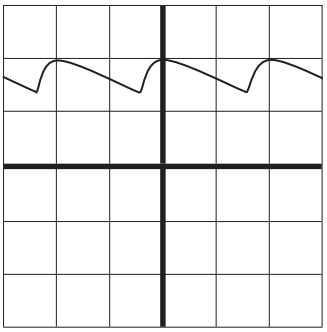
A



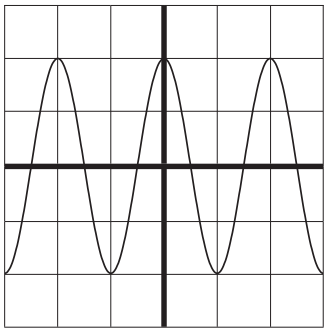
B



C



D



Answer:

Answer C is correct.

The circuit is smoothed by the capacitor. Graph C shows the only smoothed signal.

QUESTION 10 **2 marks**

If R_1 in the circuit has a value of 10 Ω and has a current of 200 mA flowing through it, what power does it dissipate?

$P = I^2R$
$= 0.2^2 \times 10$
= 0.4 W

Answer:

0.4 W

QUESTION 11 **2 marks**

The voltage regulator maintains a constant output voltage of 9.0 V DC. If a current of 130 mA flows through the zener diode, how much current flows through the load resistor?

$I = 200 - 130$
= 70 mA or 0.07 A

Answer:

0.07 A

QUESTION 12 **2 marks**

Determine the amount of power dissipated by the zener diode?

$P = VI$

$= 9.0 \times 130 \times 10^{-3}$

$= 1.17$ or 1.2 W

Answer:

1.2 W

QUESTION 13 **2 marks**

Which component of the circuit is most likely to generate a considerable amount of heat and how can this heat be effectively dissipated?

Answer:

The voltage regulator is most likely to generate heat which is dissipated with a heat sink.

QUESTION 14 **2 marks**

If the supply voltage fluctuates, the current through the circuit will fluctuate also. When this happens, explain what happens to the current through, and the voltage across, the load resistor.

Answer:

The current through, and the voltage across, the load resistor is kept constant. The zener diode has a constant voltage drop across it and therefore across the load resistor. Any fluctuations in the current flow through the zener diode.