INSIGHT

YEAR 12 ***Trial Exam Paper***

2012
PHYSICS
UNIT 3
Written examination 1

Worked Solutions

This book presents:

- worked solutions, giving you a series of points to show you how to work through the questions
- mark allocation details
- tips

SECTION A – Core

Area of study 1 – Motion in one and two dimensions

The following information relates to Questions 1–4.

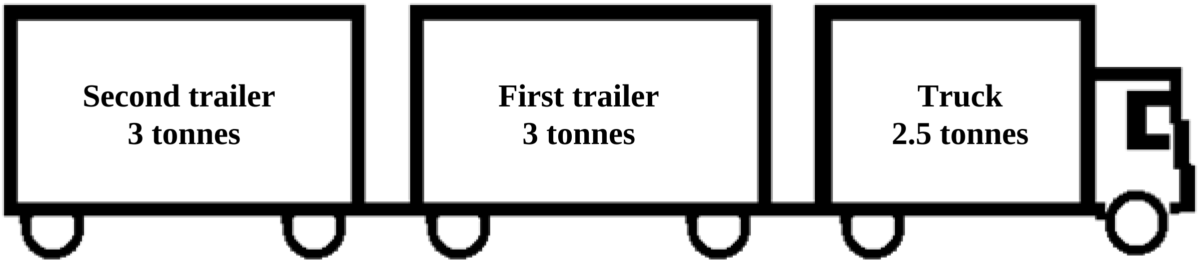


Figure 1

A truck of mass 2.5 tonnes is attached to two trailers, each of mass 3 tonnes as shown in Figure 1. There are frictional forces acting of 0.25 N kg^{-1}, which remain constant.
The truck accelerates at a constant rate of 0.75 m s^{-2} from rest until it reaches the speed limit of 60 km h^{-1}.

Question 1

What is the magnitude of the net force on the system of the truck and trailers while the truck accelerates?

Worked solution

$$\Sigma F = ma$$
$$= (8500)(0.75)$$
$$= 6375 \text{ N}$$

6375 N

2 marks

Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.

Question 2

What is the driving force provided by the truck engine to propel the load forwards while accelerating?

Worked solution

ΣF = driving force + frictional force

$6375 = F_d - (0.25 \times 8500)$

$6375 = F_d - 2125$

$F_d = 6375 + 2125$

$F_d = 8500$ N

8500 N

2 marks

Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.

Tip

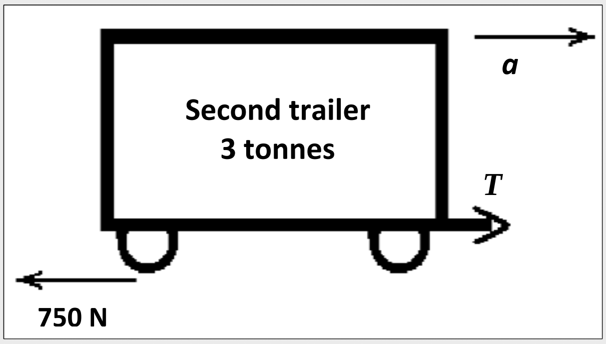
- *Resolve forces into components.*

Question 3

Calculate the tension between the second and first trailers while the truck is accelerating.

Worked solution

$$F_{\text{2nd trailer}} = T + F_{\text{friction}}$$
$$ma = T - 750$$
$$3000 \times 0.75 = T - 750$$
$$2250 = T - 750$$
$$T = 3000 \text{ N}$$



3000 N

2 marks

Mark allocation

- 1 mark for finding resultant force on trailer.
- 1 mark for correct answer.

Tip

- *Treat second trailer as an isolated system.*

Question 4

How long would it take for the truck to reach the legal speed limit of 60 km h^{-1}, at which time it will stop accelerating?

Worked solution

$u = 0$ m s^{-1}

$v = 60$ km h^{-1} $= 16.67$ m s^{-1}

$a = 0.75$ m s^{-2}

$t = ?$

$v = u + at$

$16.67 = 0 + (0.75)t$

$t = 22.22$ s

22.22 s

2 marks

Mark allocation

- 1 mark for converting km h^{-1} into m s^{-1}.
- 1 mark for correct answer.

Tip

- *Consider acceleration to be constant throughout the process.*

The following information relates to Questions 5–8.

During a NASCAR race, a driver and his racing car have a combined mass of 2500 kg. At a particular circular section of the track, which is inclined at an angle θ to the horizontal, the car is travelling at a constant speed of 50 m s^{-1} around a radius of 150 m. Ignore retarding friction.

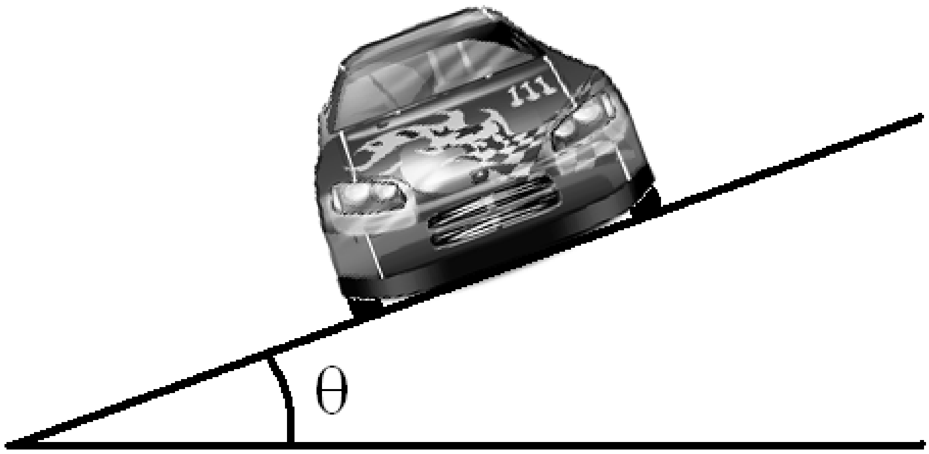


Figure 2

Question 5

What is the magnitude of the net force on the driver and car?

Worked solution

$$\Sigma F = \frac{mv^2}{R}$$

$$= \frac{(2500)(50)^2}{150}$$

$$= 41666.7$$

$$= 4.2 \times 10^4 \text{ N}$$

4.2×10^4 N

2 marks

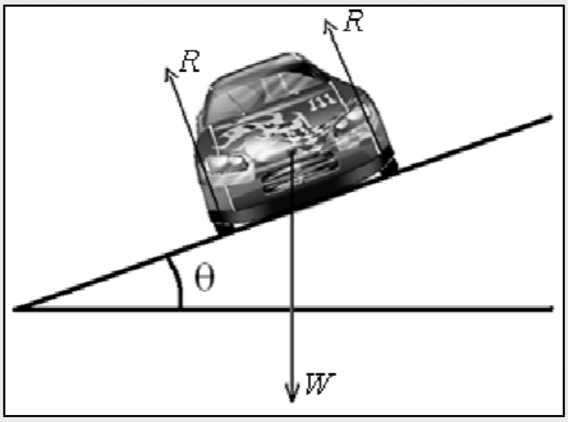
Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.

Question 6

On Figure 2, draw the normal reaction force (*R*) and the weight force (*W*) acting on the car.

Worked solution



2 marks

Mark allocation

- 1 mark for arrows pointing in appropriate direction.
- 1 mark for weight vector being longer than each reaction force.

Question 7

Calculate the angle θ of the banked curve that the NASCAR travels around.

Worked solution

$$\tan\theta = \frac{v^2}{Rg}$$

$$\tan\theta = \frac{50^2}{(150)(10)}$$

$$\tan\theta = 1.67$$

$$\therefore \quad \theta = 59.04°$$

59.04°

2 marks

Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.

Question 8

Explain the purpose of having banked curves.

Worked solution

Banked curves allow the car to travel faster. The maximum centripetal force is the sum of the frictional force due to the road and normal component acting towards the centre of motion.

2 marks

Mark allocation

- 1 mark for each correct response.

The following information relates to Questions 9–13.

A basketball of mass 1.5 kg strikes a wall at 10 m s^{-1} horizontally and rebounds at 8 m s^{-1} horizontally. The collision between the ball and the wall lasts for 0.1 seconds. This situation is shown in Figure 3.

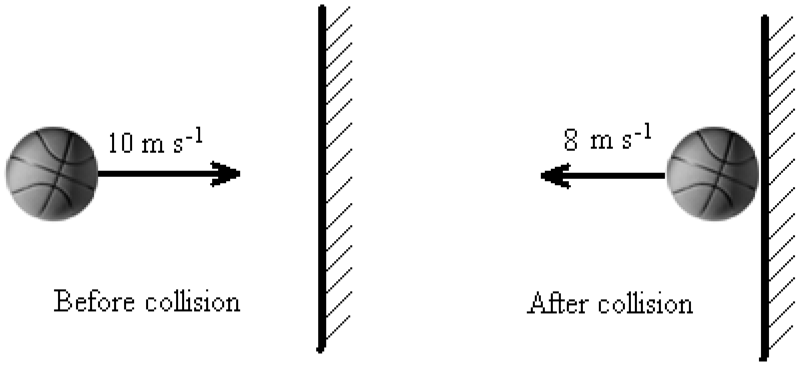


Figure 3

Question 9

What is the change in speed of the ball after the collision?

Worked solution

$$\Delta v = v_f - v_i$$
$$= 8 - 10$$
$$= -2 \text{ m s}^{-1}$$
or
$$= 2 \text{ m s}^{-1}$$

2 m s^{-1}

2 marks

Mark allocation

- 2 marks for correct answer.

Tip

- *Speed is a scalar quantity.*

Question 10

Calculate the magnitude of the change in momentum of the ball.

Worked solution

$\Delta P =$ final momentum - initial momentum

$= mv - mu$

$= m(v - u)$

$= 1.5(-8 - 10)$

$= -27$ kg m s^{-1}

or

$= 27$ kg m s^{-1}

27 kg m s^{-1}

2 marks

Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.

Tip

- *Momentum is a vector quantity and direction is in the same direction as acceleration.*

Question 11

What is the average force the wall exerts on the ball? Also indicate the direction of the force.

Worked solution

$I = Ft = \Delta p$

Change in momentum of ball is -27 kg m s^{-1} or 27 kg m s^{-1}

$F \times 0.1 = -27$

$F = -270$ N

i.e. Force $= 270$ N Direction = left

270 N	Direction = left

2 marks

Mark allocation

- 1 mark for each correct response.

Tip

- *Change in momentum is equal to impulse.*

Question 12

What is the force the ball exerts on the wall? Also indicate direction.

Worked solution

Newton's third law applies, i.e. force equal and opposite.

Force = 270 N Direction = right

270 N	Direction = right

2 marks

Mark allocation

- 1 mark for each correct response.

Tip

- *Newton's third law applies to all objects.*

Question 13

Using calculations, show if the collision is inelastic.

Worked solution

$\Sigma\mathrm{KE}(\text{initially}) = \frac{1}{2}mv^2$ before collision

$= \frac{1}{2} \times 1.5 \times 10^2$

$= 75\ \mathrm{J}$

$\Sigma\mathrm{KE}(\text{finally}) = \frac{1}{2}mv^2$ after collision

$= \frac{1}{2} \times 1.5 \times 8^2$

$= 48\ \mathrm{J}$

$\Sigma\mathrm{KE}$ before collision $\neq$ $\Sigma\mathrm{KE}$ after collision so collision is inelastic.

2 marks

Mark allocation

- 1 mark for calculating both final and initial kinetic energy.
- 1 mark for stating collision is inelastic.

Tips

- *Most collisions are inelastic. Momentum is conserved in all collisions.*
- *The sum of the final kinetic energy cannot be greater than the initial in such collisions.*

Sean takes a ride in a cart at a theme park. The combined mass of Sean and the cart is 200 kg. He begins from rest (point A) at a height of 80 m above the ground (Figure 4).

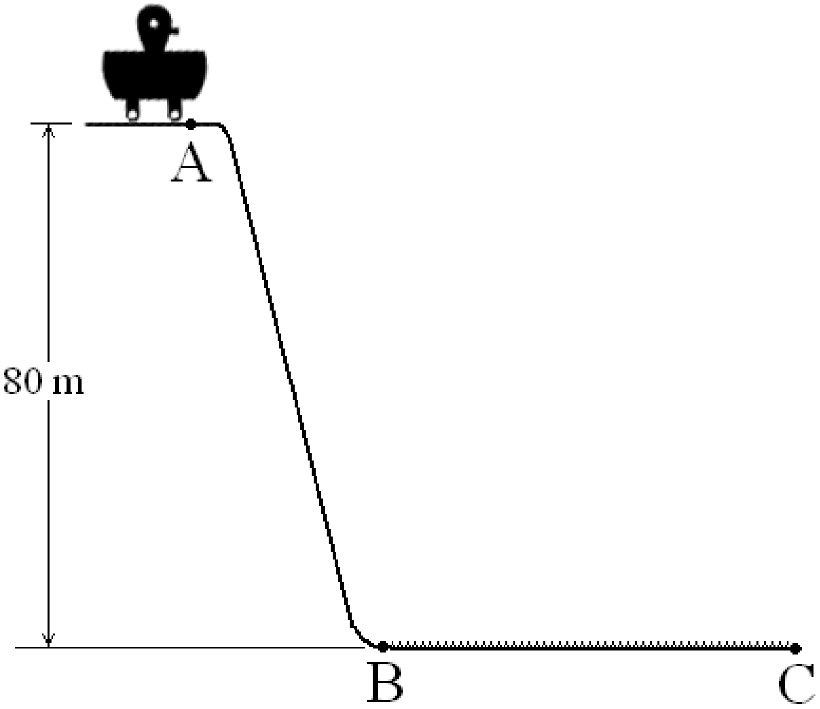


Figure 4

Question 14

Calculate Sean's speed at point B, if frictional forces are ignored.

Worked solution

KE at point B = total energy at point A

$\frac{1}{2}mv^2 = \Delta \text{PE}$ from A to B

$\frac{1}{2}\cancel{m}v^2 = \cancel{m}gh$

$v^2 = 2 \times 10 \times 80$

$v = \sqrt{1600}$

$= 40 \text{ m s}^{-1}$

40 m s^{-1}

2 marks

Mark allocation

- 1 mark for calculation.
- 1 mark for correct answer.

Tip

➢ *Energy is never lost, just transformed to other forms.*

Question 15

After point B, friction is introduced in order to bring the cart and Sean to rest at point C. If the distance between point B and C is 40 m, calculate the deceleration of the cart.

Worked solution

$u = 40\ \text{m s}^{-1}$ $\quad v = 0\ \text{m s}^{-1}$ $\quad s = 40\ \text{m}$ $\quad a = ?$

$v^2 = u^2 + 2as$

$0^2 = 40^2 + 2a(40)$

$a = -20\ \text{m s}^{-2}$

or

$W = Fs$

$1.6 \times 10^5 = F \times 40$

$F = 4000\ \text{N}$

$F = ma$

$\therefore \quad 4000 = 20 \times a$

$a = 20\ \text{m s}^{-2}$

$20\ \text{m s}^{-2}$

2 marks

Mark allocation

- 1 mark for calculation.
- 1 mark for correct answer.

Tip

- *Work done can equal change in kinetic or potential energy.*

Question 16

A spring-loaded gun fires 10 g bullets at a speed of 100 km h^{-1}. If the spring is compressed by 20 cm, calculate its spring constant.

Worked solution

$\Sigma KE =$ energy stored in spring

$$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$$

$$\frac{1}{2}(0.01)(27.78)^2 = \frac{1}{2}k(0.2)^2$$

$$0.02k = 3.8586$$

$$k = 192.9 \text{ N m}^{-1}$$

192.9 N m^{-1}

2 marks

Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.

Tip

- *Elastic potential energy has been converted to kinetic energy.*
- *100 km h^{-1} =27.78 m s^{-1}.*

Question 17

Malcolm takes a set shot 50 m from goal (Figure 5). He realises that to clear the last defender, the ball needs to have a minimum height of 3 m at the goal line. If he kicks the ball at 24 m s^{-1} from ground level at an angle of 45° to the horizontal, assuming he is accurate, does he kick a goal? Use calculations to explain your answer.

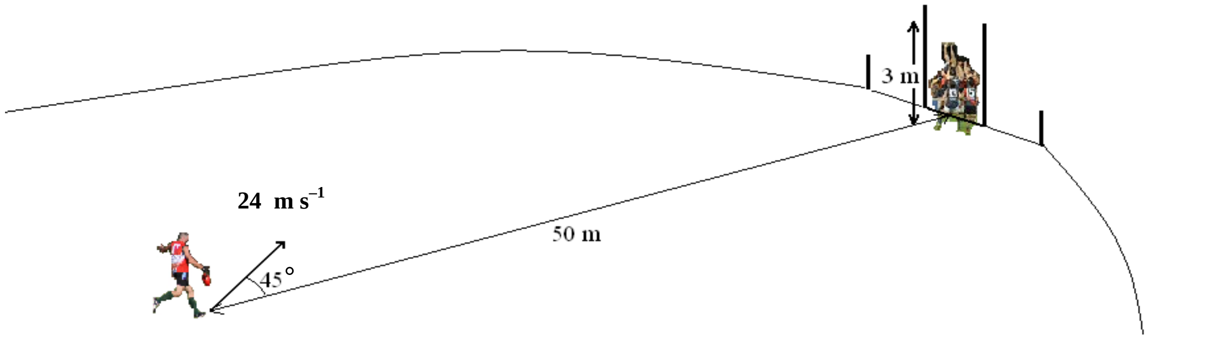


Figure 5

Worked solution

Time to reach goal determined by horizontal component:

$$t = \frac{\text{range}}{u_h} = \frac{50}{16.97}$$

$t = 2.95$ s

Require vertical height of ball after 2.95 seconds.

$$s = ut + \frac{1}{2}at^2$$

$$= (16.97)(2.95) + \frac{1}{2}(-10)(2.95)^2$$

$= 50 - 43.51$

$= 6.49$ m

The ball is well above the minimum 3 metres height. YES

6.49 m	(Yes) / No

3 marks

Mark allocation

- 1 mark for calculating time of flight.
- 1 mark for calculation to derive correct answer.
- 1 mark for correct answer.

Tips

- *Time of flight is determined by vertical components.*
- *Horizontal velocity is constant in the absence of air resistance.*
- *Gravity only influences vertical components.*

Question 18

Luke and his car have a combined mass of 2500 kg. He decides to compete a stunt by driving his car around a vertical track of radius 80 m, as shown in Figure 6.

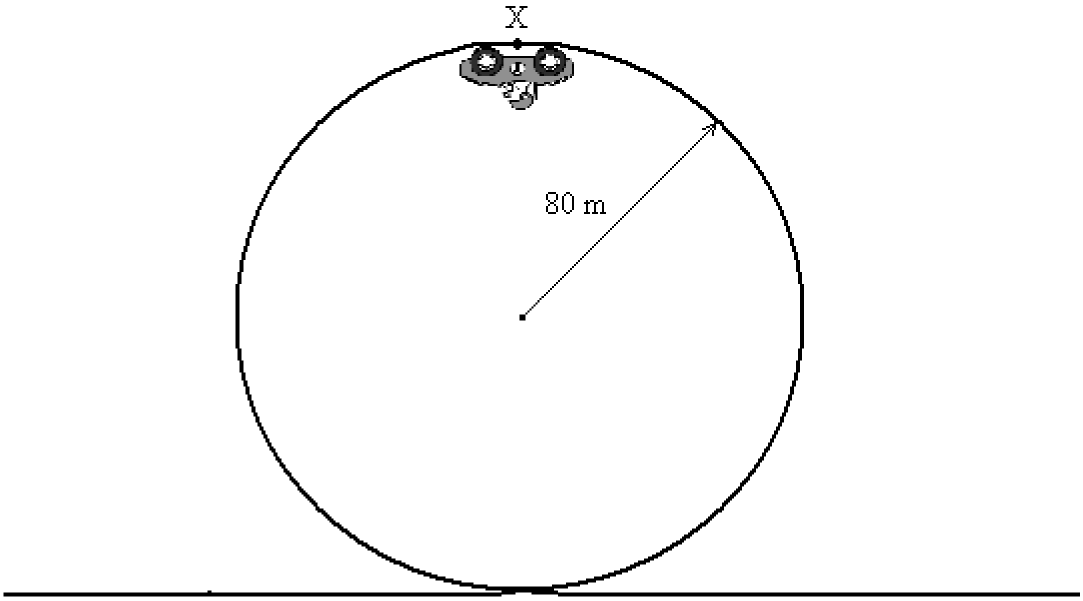


Figure 6

In order to successfully complete the stunt, the car wheels must not leave the track at point X. What is the minimum speed the car must have at X so that it does not leave the track?

Worked solution

$$\Sigma F = \frac{mv^2}{R} = N + w \qquad N = 0$$

$$\frac{-(\not{2500})(v^2)}{80} = 0 - (\not{2500})(10)$$

$$\frac{v^2}{80} = 10$$

$$v = \sqrt{800}$$

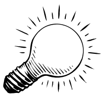
$$= 28.3 \text{ m s}^{-1}$$

28.3 m s^{-1}

2 marks

Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.



Tips

- *At top of loop, the net force is downwards. Direction is particularly important.*
- *At bottom of loop, the net force would have been upwards.*

The following information relates to Questions 1–22.

The secret satellite ‘SPY’ has a circular orbit of radius 1.50×10^7 m and a mass of 1000 kg.

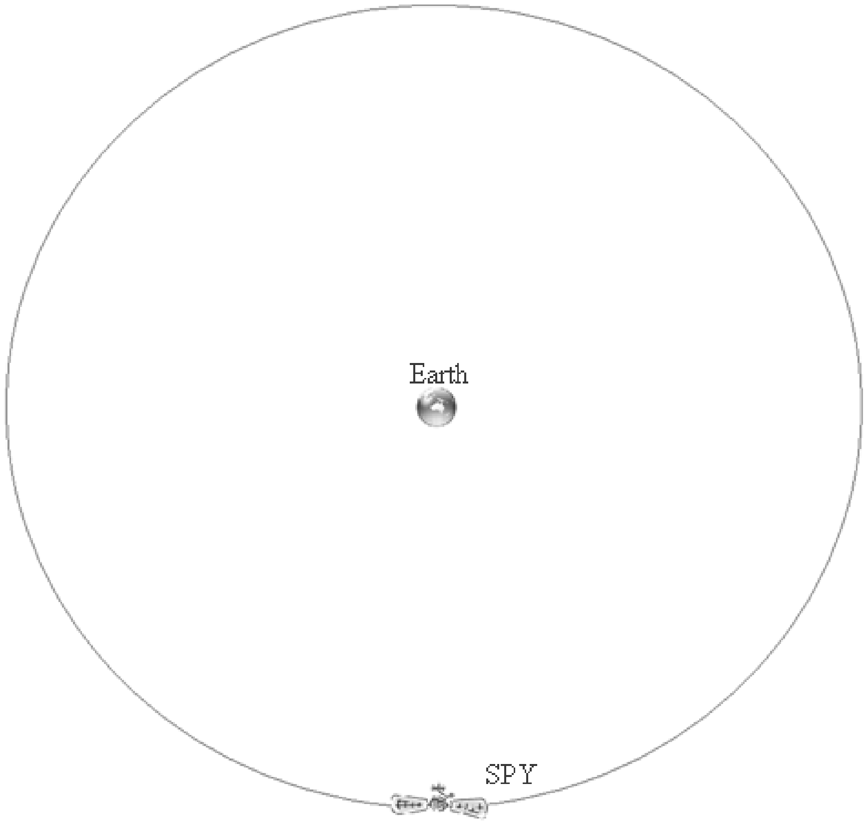
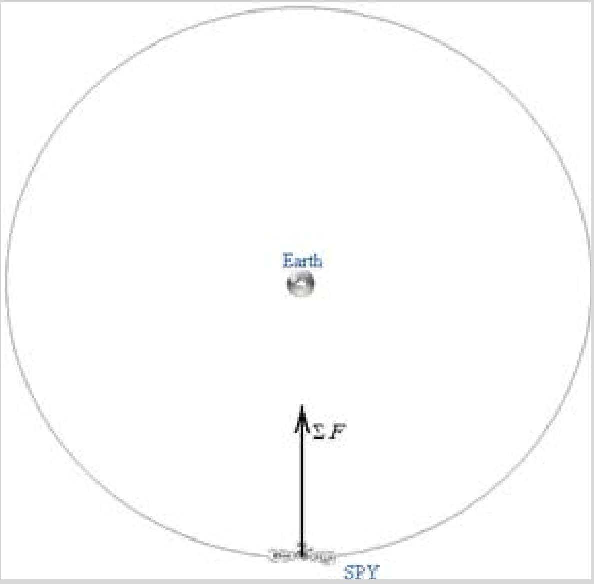


Figure 7

Question 19

On Figure 7 above, draw one or more arrows to indicate the direction of any force acting on the satellite SPY.

Worked solution



1 mark

Mark allocation

- 1 mark for arrow

Question 20

What is the weight of the satellite SPY in its orbit?

Worked solution

$$F = \frac{GMm}{R^2}$$

$$= \frac{\left(6.67\times10^{-11}\right)\left(5.98\times10^{24}\right)\left(1000\right)}{\left(1.5\times10^{7}\right)^2}$$

$$= 1772.7 \text{ N}$$

1772.7 N

2 marks

Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.

Question 21

What is the period of orbit of the satellite around Earth?

Worked solution

$$T = \sqrt{\frac{4\pi^2R^3}{GM}}$$

$$= \sqrt{\frac{4\pi^2\left(1.5\times10^{7}\right)^3}{\left(6.67\times10^{-11}\right)\left(5.98\times10^{24}\right)}}$$

$$= \sqrt{3.34\times10^{8}}$$

$$= 1.83\times10^{4} \text{ s}$$

1.83×10^4 s

2 marks

Mark allocation

- 1 mark for correct substitution.
- 1 mark for correct answer.

Question 22

An astronaut repairing the satellite while in orbit believes he is weightless. Is his assumption correct? Explain your answer.

Worked solution

No

- He is not weightless as gravity acts on him.
- He is experiencing apparent weightlessness.
- Apparent weightlessness occurs when $N = 0$.

2 marks

Mark allocation

- 1 mark for stating 'No'.
- 1 mark for any correct explanation.

END OF AREA OF STUDY 1

Area of study 2 – Electronics and photonics

The following information relates to Questions 1–4.

Luke sets up the circuit shown in Figure 1.

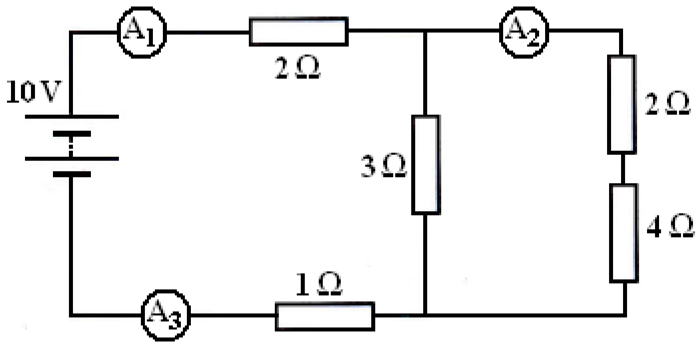


Figure 1

Question 1

Calculate the total resistance of the circuit. Show your working.

Worked solution

Resistances in parallel:

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{3} + \frac{1}{6} \quad = \frac{2}{6} + \frac{1}{6}$$

$$\therefore R_{\text{parallel}} = \frac{6}{3} \quad = 2\ \Omega$$

$$R_t = R_{\text{parallel}} + R_{\text{series}}$$

$$= 2 + 2 + 1 \quad = 5\ \Omega$$

5 Ω

2 marks

Mark allocation

- 1 mark for calculation.
- 1 mark for correct answer.

Tips

- *Calculate resistance in each branch, then apply resistors in parallel.*
- *Combination circuit.*

Question 2

What is the reading on the ammeters?

Worked solution

$V_t = I_t \times R_t$

$10 = I_t \times 5$

$I_t = 2$ A

$\therefore$ $A_1 = A_3 =$ 2 A

For A_2, using ratios:

$\frac{1}{3} \times I_t = \frac{1}{3} \times 2$

$\therefore A_2 = 0.7$ A

A_1 = 2 A	A_2 = 0.7 A	A_3 = 2 A

3 marks

Mark allocation

- 1 mark for each correct response.

Tip

➢ *More current flows through branch that has least resistance.*

Question 3

What is the potential difference across the 1 Ω resistor?

Worked solution

$V = IR$

$= 2 \times 1$

$= 2$ V

2 V

2 marks

Mark allocation

- 1 mark for calculation.
- 1 mark for correct response.

Question 4

What is the power across the 3 Ω resistor?

Worked solution

$$P = VI$$
$$= 4 \times \frac{4}{3}$$
$$= 5.3 \text{ W}$$

5.3 W

2 marks

Mark allocation

- 1 mark for calculation.
- 1 mark for correct response.

The following information relates to Questions 5 & 6.

Quang sets up the circuit shown in Figure 2 using two identical LEDs and an 18 Ω resistor. The *I*–*V* characteristics of the diodes are shown in Figure 3.

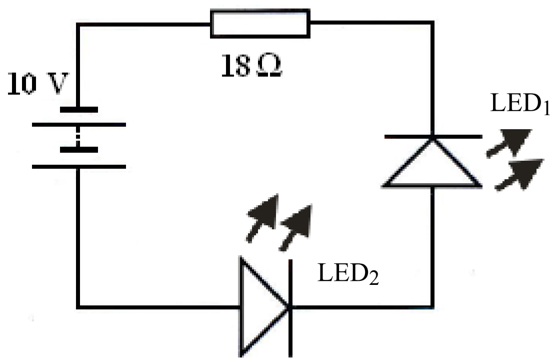


Figure 2

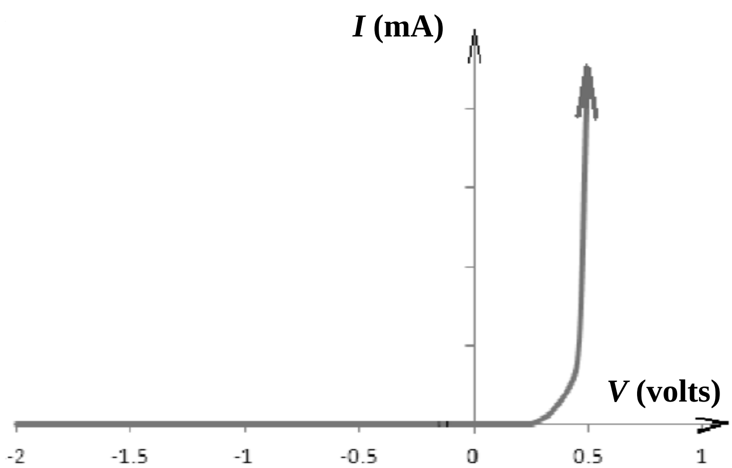


Figure 3

Question 5

What is the power rating across LED_1? Show your working.

Worked solution

$$VRes = 10 - 0.5 - 0.5 = 9\ V$$

$$V = IR \quad = 9 = I \times 18$$

$$\therefore I = \frac{18}{9} \quad = 0.5\ A$$

$$\therefore P_{LED} = VI \quad = 0.5 \times 0.5 \quad = 025\ W$$

0.25 W

3 marks

Mark allocation

- 1 mark for p.d. across resistor.
- 1 mark for current of 0.5 A.
- 1 mark for answer of 0.25 W.

Question 6

Quang decides to reverse LED_1 and measure the potential difference across it. What is the reading on the voltmeter? Explain your answer.

Worked solution

p.d. = 10 V

When LED_1 is reversed, it has infinite resistance and maximum p.d.

2 marks

Mark allocation

- 2 marks for correct answer.

Tip

- ➢ *When LED is reversed, it has infinite resistance and maximum p.d.*

The following information relates to Questions 7–10.

The temperature-resistance characteristics of a thermistor are shown in Figure 4.

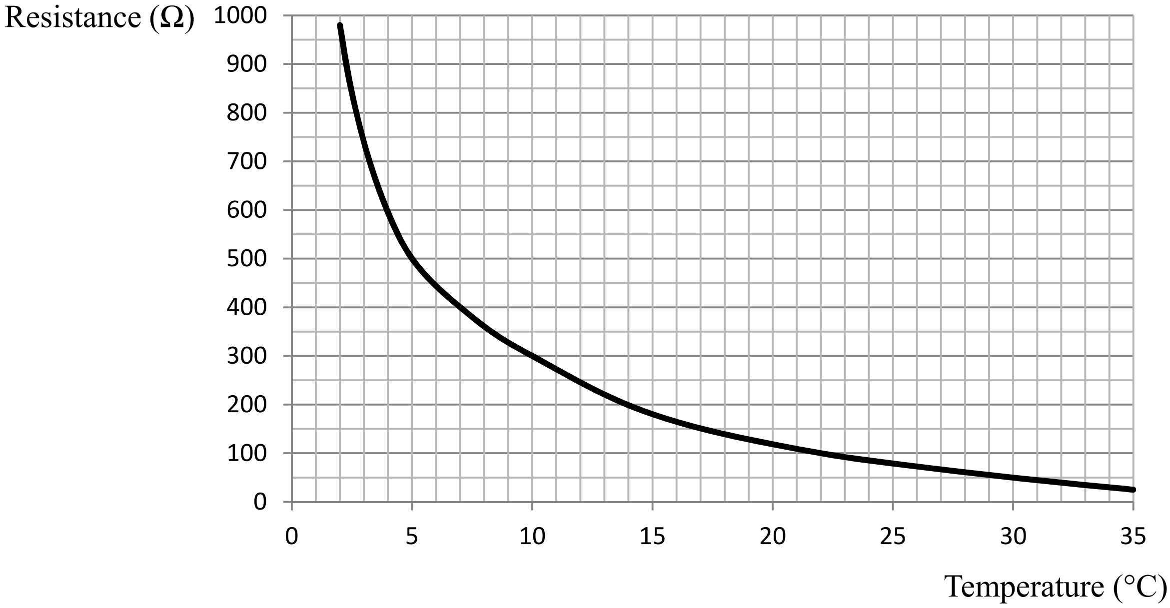


Figure 4

Question 7

What is the resistance of the thermistor at 5°C?

Solution

500 Ω

1 mark

Mark allocation

- 1 mark for correct answer.

Peter uses the thermistor in series with a variable resistor as shown in Figure 5.

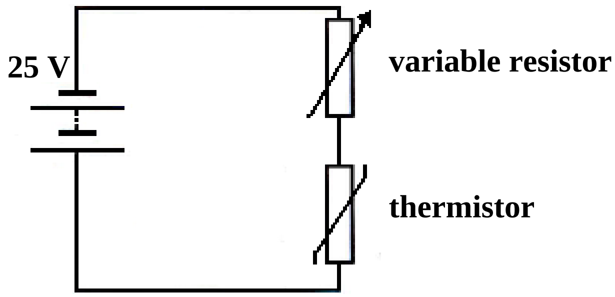


Figure 5

Question 8

Calculate the potential difference across the thermistor at 10°C, when the variable resistor is 1200 Ω.

Worked solution

$$V_{\text{out}} = \frac{R_{\text{thermistor}}}{R_{\text{total}}} \times V_{\text{in}} \qquad = \frac{300}{1500} \times 25$$

$= 5\text{ V}$

5 V

2 marks

Mark allocation

- 1 mark for calculation.
- 1 mark for correct answer.

Tip

- *Application of voltage dividers.*

Peter wants to use the circuit as an input switch to a heater. The heater will switch on when the input of the switch is 5 V or more.

Question 9

Where should the input of the heater be placed: across the thermistor or across the 1200 Ω resistor? Explain your answer.

Solution

The switch should be placed across the thermistor. As temperature decreases, the resistance of the thermistor increases, thus there is greater p.d. across the thermistor. You don't want the heater coming on when the temperature increases, which would occur if it was placed across the variable resistor.

3 marks

Mark allocation

- 1 mark for each of the above points.

Question 10

Peter wants the heater to switch on when the temperature drops below 15°C. Should the variable resistor be increased or decreased to achieve this? Explain your answer.

Solution

Input of switch remains at 5 V to switch on. At 10°C, the resistance of the thermistor is 300 Ω, in comparison to at 15°C, when the resistance of the thermistor is less than 200 Ω. The ratio across the thermistor and variable resistor needs to be maintained. The value of the variable resistor needs to be decreased.

3 marks

Mark allocation

- 1 mark for the above points, maximum of three marks.

Tips

- *Consider what occurs when there is a change in resistance.*
- *Ratio of potential difference across each resistor needs to be maintained.*
- *Apply voltage divider mentally.*

Question 11

A voltage amplifier has the characteristics shown in Figure 5. The input signal is displayed in Figure 6.

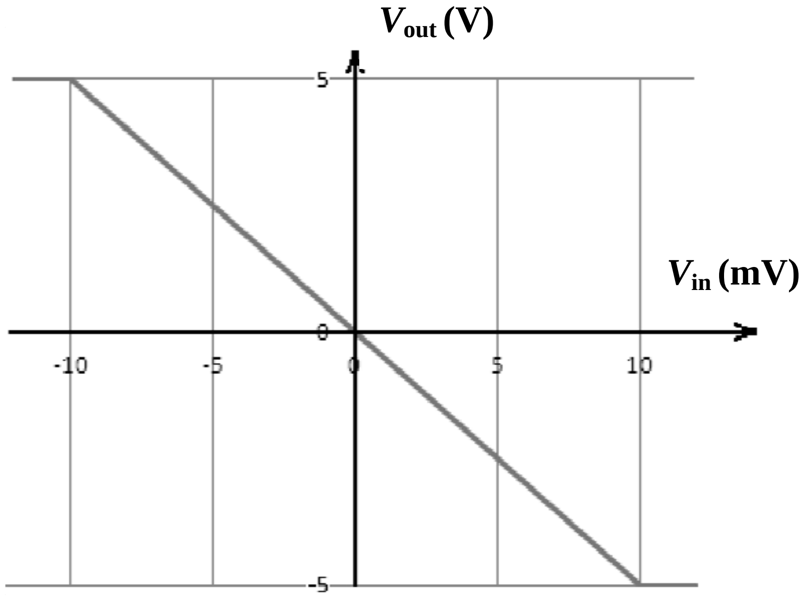


Figure 5

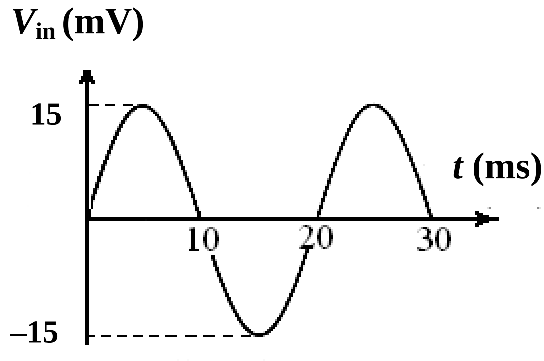
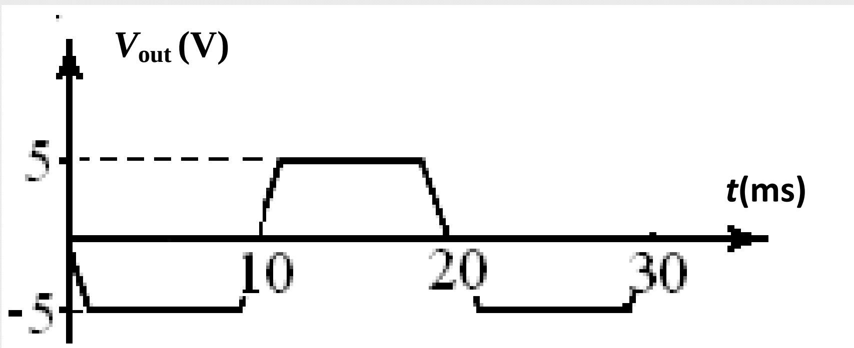


Figure 6

Draw the output signal and include values on your axes.

Worked solution



– show clipping at +5 V and –5 V
– frequency the same
– invert signal

3 marks

Mark allocation

- 1 mark for clipping.
- 1 mark for frequency.
- 1 mark for inverting signal.

END OF SECTION A
TURN OVER

SECTION B – Detailed studies

Detailed study 1 – Einstein's special relativity

Question 1

When Einstein's equation $E = mc^2$ is applied to an electron with mass '*m*', which of the following is true?

A. Electrons travelling at high speeds convert their energy into light, according to $E = mc^2$.

B. Electrons have no energy since their mass is extremely small.

C. **Electrons have an energy of *E*, purely because of their existence.**

D. Einstein's relativity does not apply to quantum particles.

Answer is C.

Question 2

The mass of an electron at rest is 9.1×10^{-31} kg according to Einstein's special theory of relativity. This is equivalent to an energy of:

A. 0 J

B. 9.1×10^{-31} J

C. 4.1×10^{14} J

D. $\mathbf{8.2 \times 10^{-14}}$ **J**

Answer is D.

Worked solution

$[E = mc^2]$ $E = (9.1 \times 10^{-31})(3 \times 10^8)^2 \quad = 8.2 \times 10^{-14}$ J

Tip

- *Application of $E = mc^2$.*

Question 3

An electron accelerator can accelerate an electron to a speed that will increase its mass by a factor of 22. As the electron leaves the accelerator, what is the value of the Lorentz factor?

A. 11

B. **22**

C. 44

D. 220

Answer is B.

The following information relates to questions 4 & 5.

A radioactive particle in an accelerator is found to have a half-life of 20 seconds when travelling at 0.8*c* and is observed by a stationary scientist.

Question 4

What is the particle's half-life in its own frame of reference?

A. 20 s

B. **12 s**

C. 40 s

D. 10 s

Answer is B.

Worked solution

$$\gamma = \left(1 - 0.8^2\right)^{-\frac{1}{2}} \quad = 1.67$$

$$t = t_0 \times \gamma \qquad t_0 = \frac{20}{1.67} = 12 \text{ s}$$

Question 5

The radioactive particle is inside a detector of length 8 m. From the particle's frame of reference, how long is the detector?

A. **4.8 m**

B. 4.0 m

C. 8.0 m

D. 13.3 m

Answer is A.

Worked solution

$$L = \frac{L_0}{\gamma} \quad = \frac{8}{1.67} \quad = 4.8 \text{ m}$$

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Question 6

Which of the following quantities is *not* affected by travel at speed close to the speed of light when measured by both stationary and moving observers?

A. **speed of light**

B. mass in kg

C. velocity

D. length

Answer is A.

Tip

- *Speed of light is independent of stationary and moving observers.*

Question 7

An electron of mass 9.1×10^{-31} kg is accelerated across a potential of 20 MeV. The speed of this electron in Newtonian physics would be

A. 1.35×10^{7} m s^{-1}

B. 2.65×10^{7} m s^{-1}

C. 3.00×10^{8} m s^{-1}

D. $\mathbf{2.65 \times 10^{9}}$ **m s^{-1}**

Answer is D.

Worked solution

$$v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{(2)(20\times10^{6})(1.6\times10^{-19})}{9.1\times10^{-31}}} \quad = 2.65\times10^{9}\ \text{m s}^{-1}$$

Tip

- *Excessive speed for electron.*

Question 8

At the Synchrotron an electron is accelerated to a speed of 2.5×10^{8} m s^{-1}. The mass of such an electron measured by an observer would be

A. 9.1×10^{-31} kg

B. 3.2×10^{-30} kg

C. **1.65×10^{-30} kg**

D. 9.1×10^{-30} kg

Answer is C.

Worked solution

$$v = \frac{\left(2.5\times10^{8}\right)}{\left(3\times10^{8}\right)} \quad = 0.833\ \text{c}$$

$$\gamma = \left(1-0.833^{2}\right)^{-\frac{1}{2}} = 1.80$$

$$\text{Heavier } m = m_{0}\times\gamma = \left(9.1\times10^{-31}\right)\times1.80 \quad = 1.65\times10^{-30}\ \text{kg}$$

Tip

- *As velocity increases, the mass of the electron also increases.*

The following information relates to questions 9 & 10.

A neutron of rest mass 1.675×10^{-27} kg travels at 0.2*c*.

Question 9

The momentum of the neutron would be

A. 8.350×10^{-27} kg m s^{-1}

B. 3.350×10^{-28} kg m s^{-1}

C. 1.675×10^{-19} kg m s^{-1}

D. **1.026×10^{-19} kg m s^{-1}**

Answer is D.

Worked solution

$\gamma = \left(1 - 0.2^2\right)^{\frac{1}{2}} \quad =1.021$

$P = mv = m_0\gamma v \quad = \left(1.675 \times 10^{-27}\right)\left(1.021\right)\left(0.2\right)\left(3 \times 10^8\right)^2$

$= 1.026 \times 10^{-19}$ kg m s^{-1}

Question 10

The kinetic energy of the neutron would be

A. 8.35×10^{-12} J

B. **3.10×10^{-12} J**

C. 3.35×10^{-12} J

D. 1.69×10^{-12} J

Answer is B.

Worked solution

$\text{KE} = \left(\gamma - 1\right)M_0c^2 \quad = \left(1.021 - 1\right)\left(1.675 \times 10^{-27}\right)\left(3 \times 10^8\right)^2$

$= 3.10 \times 10^{-12}$ J

Detailed study 2 – Further electronics

Question 1

An audio amplifier operates on a DC power supply, but the supply has an AC ripple component. The magnitude of the ripple voltage is best measured using

A. **an oscilloscope**

B. an ammeter

C. a voltmeter

D. a variable resistor

Answer is A.

The following information relates to questions 2–4.

A regulated DC power supply is shown in Figure 1 below. The input voltage is from 6 V RMS AC supply. The AC power supply has an input supply of 240 V RMS.

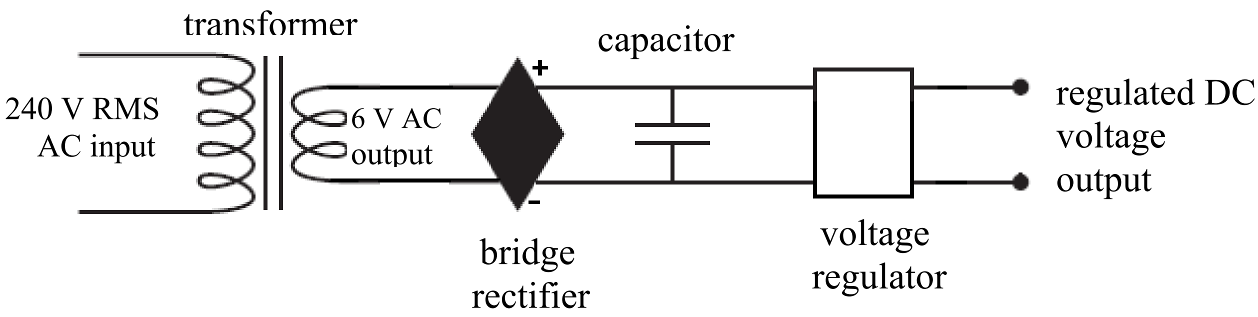


Figure 1

Question 2

If the primary side of the transformer has 120 turns, how many turns are there on the secondary side of the transformer?

A. 40

B. **3**

C. 6

D. 24

Answer is B.

Worked solution

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \qquad \frac{N_s}{120} = \frac{6}{240} \qquad N_s = 3$$

Tips

- *Step-down transformer.*
- *Power of primary and secondary is equal.*

Question 3

If the current flowing in the primary coil is 0.1 A, what is the power supplied to the bridge rectifier, assuming the transformer is ideal?

A. 12 W

B. 6 W

C. 18 W

D. **24 W**

Answer is D.

Worked solution

$P_p = P_s = VI \quad = 240 \times 0.01 \quad = 24 \text{ W}$

Tip

- *Ideal transformers assume no power loss, which is not realistic.*

Question 4

What is the peak current supplied to the bridge rectifier?

A. 0.143 A

B. 1.43 A

C. **5.66 A**

D. 2.83 A

Answer is C.

Worked solution

$\frac{I_s}{I_p} = \frac{V_p}{V_s} \qquad \frac{I_s}{0.1} = \frac{240}{6} \qquad I_s = 4 \text{ A}$

$\therefore\ I_s\ (\text{peak}) = I_s \times \sqrt{2} \qquad = 5.66 \text{ A}$

Tip

- *Beware of the difference between ‘peak to peak’ and simply ‘peak’ current.*

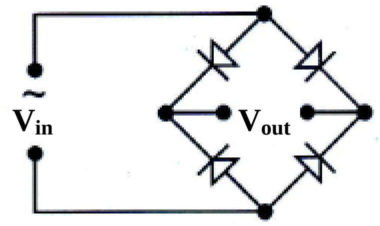
The following information relates to Questions 5 & 6

A full-wave bridge rectifier is to be used in a circuit that produces DC from an AC input.

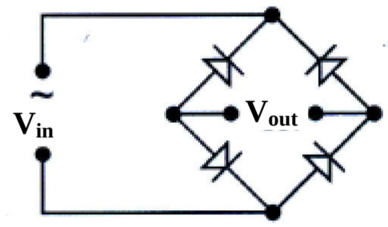
Question 5

Which of the following circuits would be most suitable?

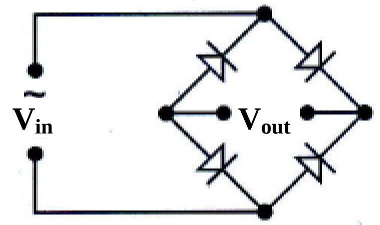
A.



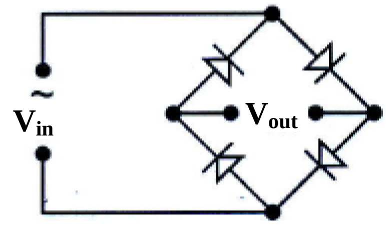
B.



C.



D.



Answer is C.

Explanatory note

- Only correct option.

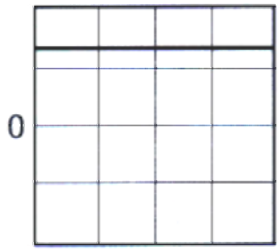
Tip

- *Diodes only allow current to flow through them when forward biased.*

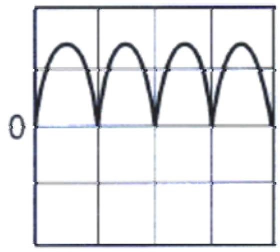
Question 6

With the rectifier correctly connected and functioning, which of the following signals would be observed if an oscilloscope was connected across the output (V_{out}) of the bridge rectifier?

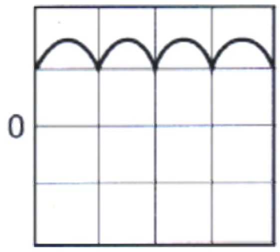
A.



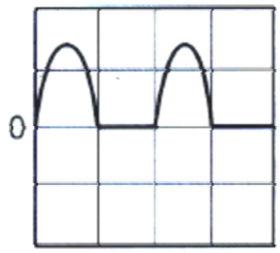
B.



C.



D.



Answer is B.

Explanatory note

- Full-wave rectifier.

The following information relates to Questions 7 & 8.

Malcolm uses an oscilloscope to test a circuit. He connects the oscilloscope to an AC signal generator. The vertical scale is set on 4 V cm^{-1}, and the horizontal scale on 40 ms cm^{-1}. He observes the display on the oscilloscope, as shown below in Figure 2.

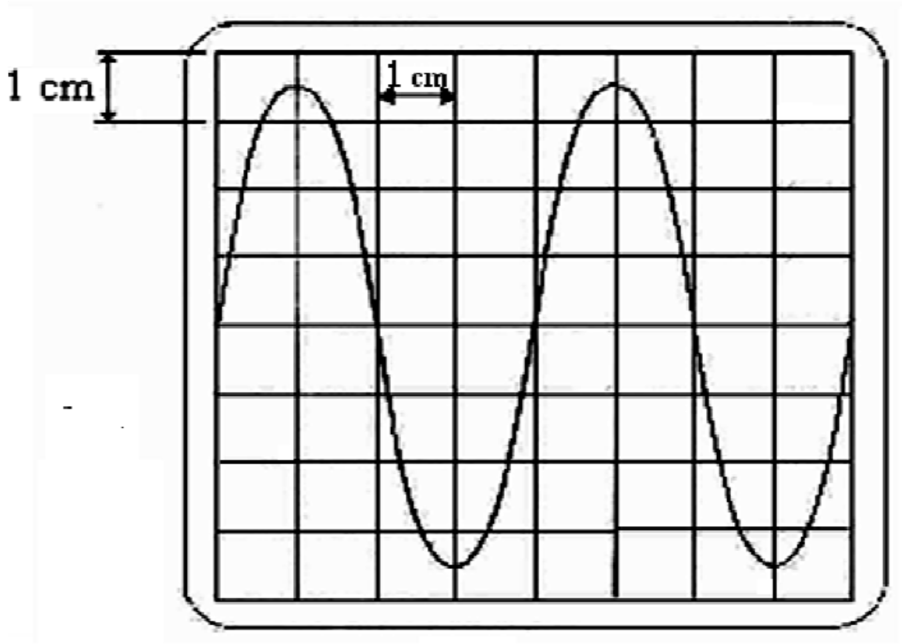


Figure 2

Question 7

Which of the following best gives the correct value of the peak-to-peak voltage of the AC signal generator?

A. 14 V

B. 20 V

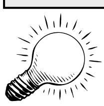
C. 7 V

D. **28 V**

***Answer is D*.**

Worked solution

$4 \text{ V cm}^{-1} \times 7 \text{ cm} = 28 \text{ V}$



Tips

- *Need to count squares accurately.*
- *Vertical axis represents voltage.*

Question 8

Which one of the following best gives the frequency from the signal generator?

A. **6.25 Hz**

B. 4 Hz

C. 16 Hz

D. 13.5 Hz

Answer is A.

Worked solution

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

$$= \frac{1}{\left(160 \times 10^{-3}\right)}$$

$$= 6.25 \text{ Hz}$$

Tips

- *Application of waves.*
- *Frequency is the number of cycles per second.*

The following information relates to Questions 9 & 10.

Nabilla studies the voltage–current characteristics of a zener diode as shown in Figure 3.

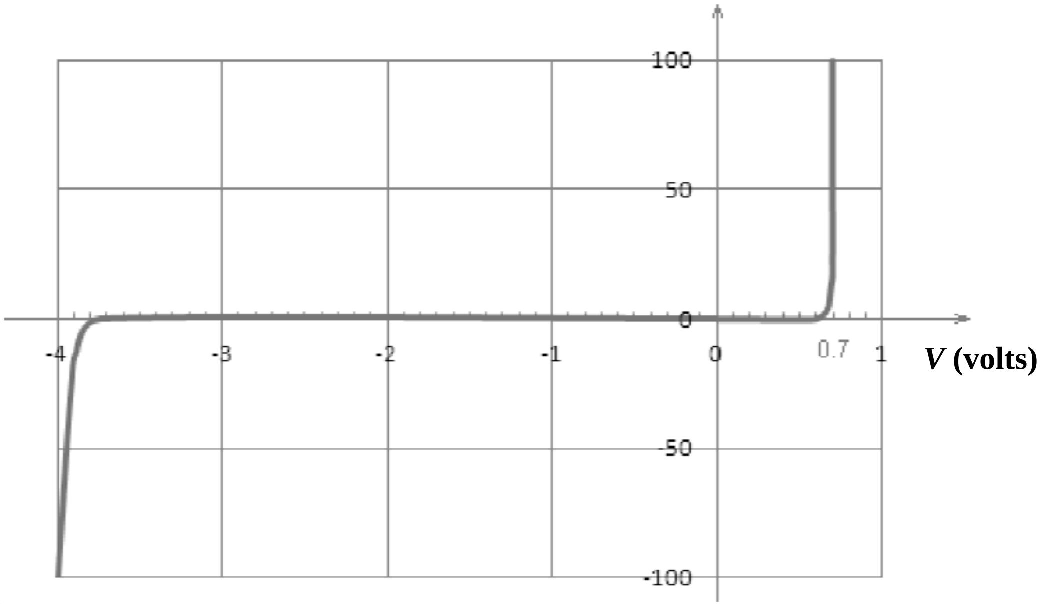


Figure 3

Nabilla places the zener diode in the circuit as shown in Figure 4.

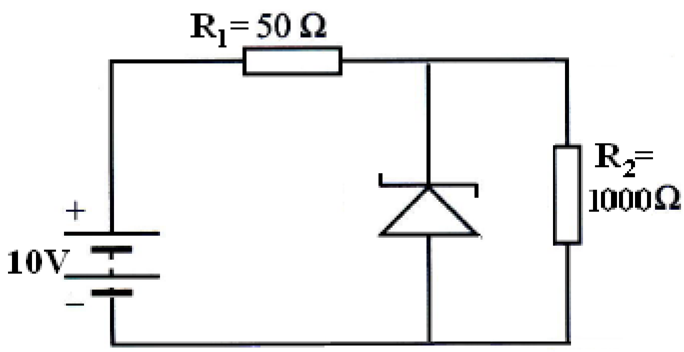


Figure 4

Question 9

The voltage Nabilla measured across R_1 is?

A. 4 V

B. **6 V**

C. 0.6 V

D. 12 V

Answer is B.

Worked solution

Diode is reverse biased and p.d. will be 4 V across it. 10 – 4 = 6 V across R_1.

Question 10

What will be the current across the zener diode?

A. 0.105 A

B. 0.011 A

C. **0.116 A**

D. 0.120 A

Answer is C.

Worked solution

Current through R_1: $I_1 = \frac{6}{50} = 0.12$ A

Current through R_2: $I_2 = \frac{4}{1000} = 0.004$ A

$\therefore$ Current through diode = 0.12 - 0.004 = 0.116 A

Tips

- *Total current in series remains constant.*
- *Current splits accordingly at parallel part of circuit.*

Detailed study 3 – Materials and their use in structures

The following information relates to Questions 1–5.

A group of students are testing the tensile strength of three different materials. Each material has a length of 5.00 m exactly when no tension is applied. The materials are labelled as 1, 2 and 3 on the graph below (Figure 1). The letter B represents the point where the material breaks.

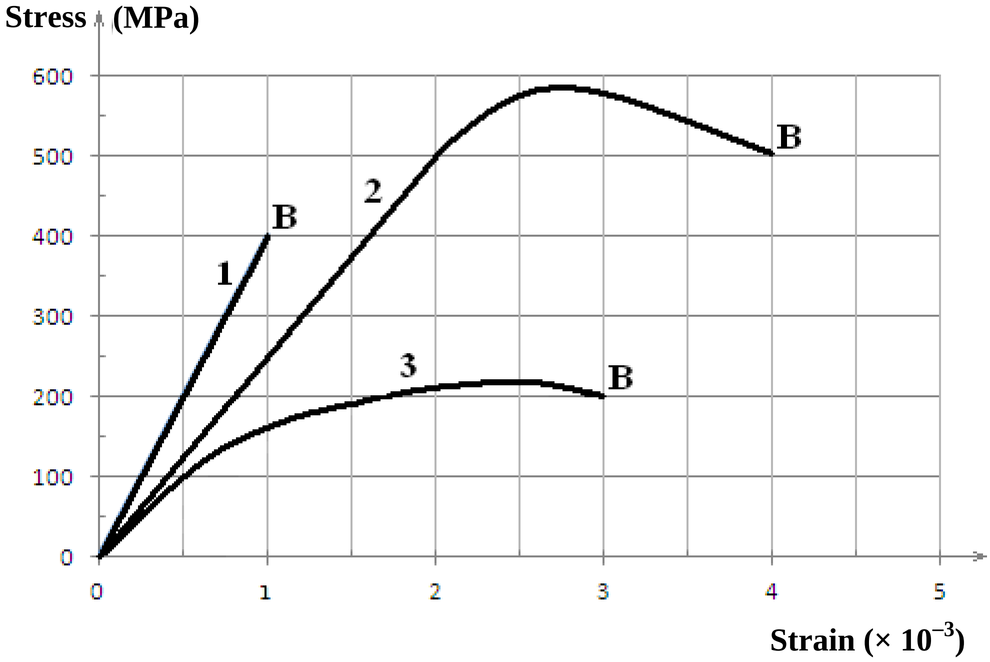


Figure 1

Question 1

Which of the following is the best estimate of Young's modulus for material 2?

A. **2.5×10^{11} N m^{-2}**

B. 5×10^{6} N m^{-2}

C. 2×10^{-3} N m^{-2}

D. 4×10^{-9} N m^{-2}

Answer is A.

Worked solution

$$E = \frac{\sigma}{\varepsilon} = \frac{500 \times 10^{6}}{2 \times 10^{-3}} = 250 \times 10^{9}$$

$$= 2.5 \times 10^{11} \text{ N m}^{-2}$$

Tip

- *Note units on vertical and horizontal axes.*

Question 2

Material 1 breaks when the force applied to it is 1.5×10^5 N. This indicates that it would have a cross-sectional area of

A. 4.50×10^{-3} m^2

B. 6.00×10^{-3} m^2

C. **3.75×10^{-4} m^2**

D. 2.50×10^{-4} m^2

Answer is C.

Worked solution

$$\sigma = \frac{F}{A} \qquad \therefore\ 400 \times 10^6 = \frac{1.5 \times 10^5}{A}$$

$$A = \frac{1.5 \times 10^5}{400 \times 10^6} \qquad = 3.75 \times 10^{-4}\ \text{m}^2$$

Tip

- *Read graph carefully.*

Question 3

What is the length of material 1 when it breaks?

A. 5.500 m

B. **5.005 m**

C. 5.050 m

D. 4.995 m

Answer is B.

Worked solution

$$\varepsilon = \frac{\Delta 1}{1} \qquad \therefore 1 \times 10^{-3} = \frac{\Delta 1}{5.00} \qquad \Delta 1 = 5 \times 10^{-3} = 0.005\ \text{m}$$

$$\therefore\ \text{length} = 5.005\ \text{m}$$

Question 4

Comparing the three materials, which statement is true regarding strength and toughness?

A. 1 is the strongest and 3 is the toughest.

B. 1 is the toughest and 2 is the strongest.

C. **2 is the toughest and the strongest.**

D. 2 is the toughest and 3 is the strongest.

***Answer is C*.**

Worked solution

Largest stress point = strongest; most area = toughest.

Tip

- *Toughest is the one with the largest area under the graph until it breaks.*

Question 5

The students further investigate material 3, which has a cross-sectional area of 2.5×10^{-5} m^2 and length of 5 m. Which of the following best gives the energy stored in the sample just before it breaks?

A. **62.5 J**

B. 25.5 J

C. 35.5 J

D. 12.5 J

***Answer is A*.**

Worked solution

Energy = area under curve × volume

$= [10 \text{ squares (counted)} \times 100 \times 10^{6} \times 0.5 \times 10^{-3}] \times [5 \times 2.5 \times 10^{-5}]$

$= 62.5$ J

Tip

- *Area under graph gives energy per unit volume.*

The following information relates to Questions 6 & 7.

Jack, with a mass of 80 kg, and his friend Fiona, with a mass of 50 kg, are playing on a see-saw.

Question 6

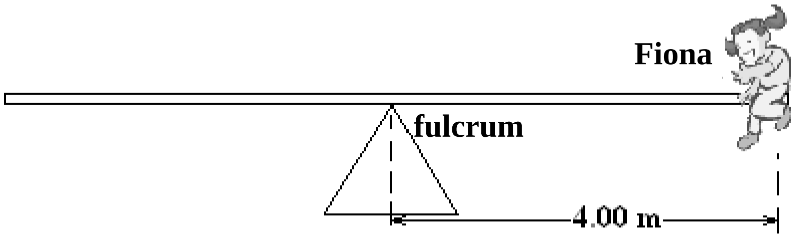
If Fiona sits at 4.00 m from the pivot point, where should Jack sit to balance the see-saw?

A. 0.63 m left of fulcrum

B. 1.6 m left of fulcrum

C. 2.0 m left of fulcrum

D. **2.5 m left of fulcrum**



Answer is D.

Worked solution

Take fulcrum as pivot, ε_τ left = ε_τ right $\therefore x \times 800 = 4 \times 500$

$x = 2.5$ m

Tip

- *Torque is a vector quantity and proper sign convention must be used.*

Question 7

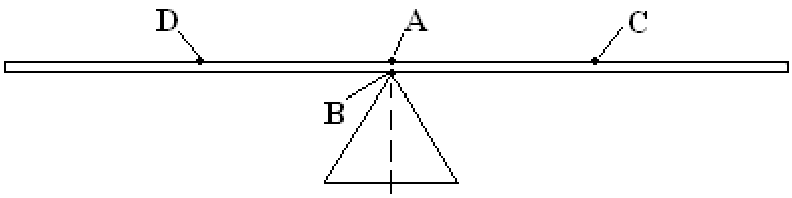
The see-saw is made of concrete. Where is the see-saw most likely to fracture?

A. **point A**

B. point B

C. point C

D. point D



Answer is A.

Worked solution

Concrete is weaker under tension.

Tip

- *Concrete is reinforced with steel to compensate for its low tensile strength.*

The following information relates to Questions 8 & 9.

A sign of weight 50 N hangs from a beam, which has a weight of 10 N and is supported by a strut (ignore weight) as shown in Figure 2.

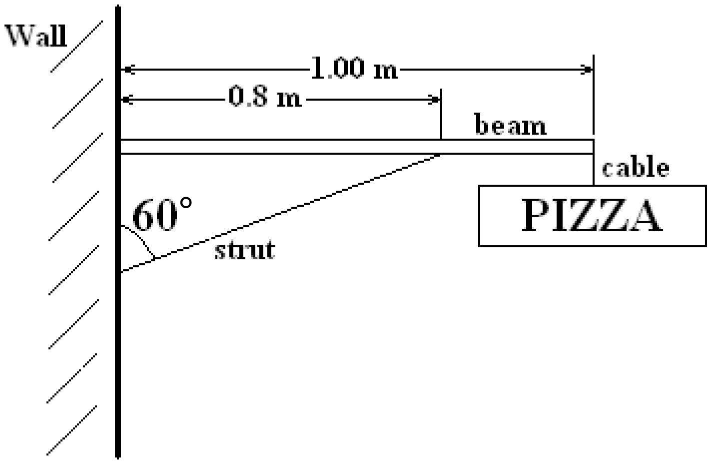


Figure 2

Question 8

The tension in the cable holding the pizza sign up is best estimated as

A. **50 N**

B. 60 N

C. 25 N

D. 43 N

Answer is A.

Worked solution

Tension = mg = weight of sign = 50 N

Question 9

The compressive force acting on the strut is

A. **1.4×10^2 N**

B. 60 N

C. 2.6×10^2 N

D. 6.8×10^2 N

Answer is A.

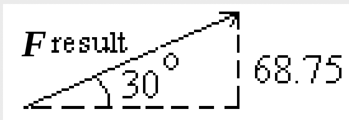
Worked solution

$\varepsilon_\tau = (-0.5 \times 10) + (0.8 \times F_{strut}) + (-1 \times 50) = 0$

$F_{strut} = 68.75$ N vertical component

$\sin 30° = 68.75 / F_{result}$

$F_{result} = 137.5 = 1.4 \times 10^2$ N



Tip

- *Resolve forces vertically to the wall and use torque (vectors) to solve.*

Question 10

A shear force is best defined as

A. a stretching force where molecules are pulled apart.

B. a compressive force where molecules are squashed.

C. **a twisting force where molecule layers slide over each other.**

D. a compressive force at the top and tensile stress at the bottom of a material.

Answer is C.

Tip

- *Explain difference between shear, compressive and tensile force.*

END OF SOLUTIONS BOOK