PHYSICS

Unit 3 – Written examination 1

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SOLUTIONS

SECTION A – Core

Area of Study 1 - Motion

Question 1

Answer: 340 N

Explanation:

$$F_{NET} = ma$$
$$F_{NET} = 85 \times 4$$
$$F_{NET} = 340\,N$$

Question 2

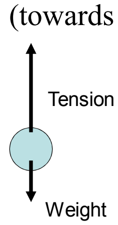
Answer: 1190 N

Explanation: The net force on the stuntman is 340 N up. So the overall result of Tension and Weight must give 340 N

$$F_{NET} = T - W$$
$$340 = T - 850$$
$$T = 1190\,N$$

Question 3

Answer: As per diagram. Note tension force should be greater than weight as the net force must be up (towards the centre of the circular path)



Question 4

Answer: **Up**

Explanation: For uniform circular motion, the centripetal force (net force) must be towards the centre of the circle. In this case, this means up.

Question 5

Answer: **6.24 N**

Explanation:

$$a = \frac{4\pi^2 r}{T^2}$$

$$a = \frac{4\pi^2 \times 0.85}{0.8^2}$$

$$a = 52.4\, m\, s^{-2}$$

$$F_{NET} = ma$$

$$T - W = 0.1 \times 52.4$$

$$T = 5.24 + 0.1 \times 10$$

$$T = 6.24\, N$$

Question 6

Answer: **7.35 m s^{-1}**

Explanation:

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

$$0 = u^2 + 2 \times -10 \times 2.7$$

$$u = 7.35\, m\, s^{-1}$$

Question 7

Answer: **5.44 m s^{-1}**

Explanation: First, determine time taken to reach the top (vertically)

$$t = \frac{v-u}{a}$$

$$t = \frac{0-7.35}{-10}$$

$$t = 0.735\, s$$

Then horizontally:

$$v = \frac{d}{t}$$

$$v = \frac{4}{0.735}$$

$$v = 5.44\, m\, s^{-1}$$

Question 8

Answer: **53°, 9.1 m s^{-1}**

Explanation: Determine angle via trigonometry. Speed can be found using Pythagoras or trig.

$$\theta = \tan^{-1}\left(\frac{7.35}{5.44}\right)$$

$$\theta = 53^o$$

$$v = \sqrt{7.35^2 + 5.44^2}$$

$$v = 9.1\,m\,s^{-1}$$

Question 9

Answer: **22,500 kg m s^{-1} East**

Explanation: Taking east as positive

$$\Delta p = m\Delta v$$

$$\Delta p = 1500 \times (3 - -12)$$

$$\Delta p = 22500\,kg\,m\,s^{-1}$$

Question 10

Answer: **93,750 N East**

Explanation: Taking east as positive

$$\Delta p = F\Delta t$$

$$F = \frac{\Delta p}{t}$$

$$F = \frac{22500}{0.24}$$

$$F = 93750\,N$$

Question 11

Answer: The collision is not isolated, because external forces (that is, the wall) transfer momentum to the Earth.

Question 12

Answer: **2.45 m**

Explanation:

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

$$s = \frac{v^2 - u^2}{2a}$$

$$s = \frac{-7^2}{2 \times -10}$$

$$s = 2.45\, m$$

Question 13

Answer: **6.2 m s^{-1}**

Explanation: Use conservation of energy principles

$$E_{TOP} = mgh$$

$$E_{TOP} = 5 \times 10 \times 2.45$$

$$E_{TOP} = 122.5\, J$$

$$E_{0.5} = 122.5 J$$

$$122.5 = mgh + 0.5mv^2$$

$$v = \sqrt{\frac{122.5 - 5 \times 10 \times 0.5}{0.5 \times 5}}$$

$$v = 6.24\, m\, s^{-1}$$

Question 14

Answer: **2500 N m^{-1}**

Explanation: Use conservation of energy principles – with elastic potential energy included (a compression of x = 0.3 m

$$E_{0.2} = 122.5J$$

$$122.5 = mgh + 0.5kx^2$$

$$k = \frac{122.5 \text{ - } 5 \times 10 \times 0.2}{0.5 \times (0.3)^2}$$

$$k = 2500\, N\, m^{-1}$$

Question 15

Answer: **7.7 x 10^{2} m s^{-1}**

Explanation: Using area under Graph 1 to determine increase in kinetic energy (that is, loss of potential energy).

$$KE_{surface} = KE_{400km} + area \times mass$$
$$KE_{surface} = 0.5 \times m \times v^2 + 4 \times 10^5 \times 0.5 \times [0.370 + 0.593] \times 650$$
$$KE_{surface} = 6.58 \times 10^7 + 12.52 \times 10^7$$
$$KE_{surface} = 1.91 \times 10^8 J$$
$$v = 767\, m\, s^{-1}$$

Question 16

Answer: **2.46 x 10^{6} m**

Explanation:

$$\frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$
$$R = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$$
$$R = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 2 \times 10^{22} \times \left(2.1 \times 10^4\right)^2}{4\pi^2}}$$
$$R = 2.46 \times 10^6\, m$$

Question 17

Answer: **56 N**

Explanation: AW = Apparent Weight. g = 10, a = 3. Both are in the same direction.

$$AW = m(g - a)$$
$$AW = 8 \times (7)$$
$$AW = 56\, N$$

SECTION A – Core

Area of Study 2 – Electronics and Photonics

Question 1

Answer: **3 – 15 ^{o}C**

Explanation:
Use voltage divider ideas:

e.g. For V_{out} = 2.25 V

$$V_{out} = V_{in}\left(\frac{R_{therm}}{R_1 + R_{therm}}\right)$$
$$2.25 = 9\left(\frac{R_{therm}}{3 + R_{therm}}\right)$$
$$R_{therm} = 1\,k\Omega$$
$$T = 15\,^{o}C\ from\ graph$$

For V_{out} = 4.5 V, T = 3 ^{o}C

Question 2

Answer: **B**

Explanation:
If the fixed resistor is decreased, the thermistor will take a larger share of the input voltage, so V_{out} will increase as required.

Question 3

Answer: If the cat blocks the light from the LED in circuit A, the photodiode will cease to conduct and therefore the current through the 30 kΩ resistor will decrease. Thus, the output voltage will decrease.

Question 4

Answer: **2 W m^{-2}**

Explanation:
$$I = \frac{V}{R}$$
$$I = \frac{3}{3\times10^4}$$
$$I = 100\,\mu A$$
$$V_{photodiode} = 9 - 3 = 6\,V$$
Use Figure 4 to locate the correct Φ curve.

Question 5

Answer: **C**

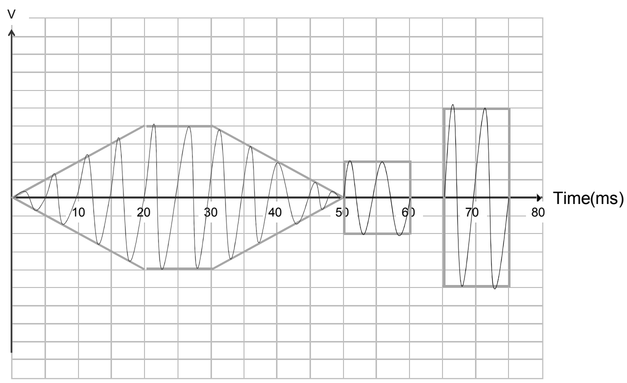
Explanation:
The voltage across the LED would be constant (2.25 V according to Figure 5). The current would increase due to the reduced resistance. Power would also increase with increased current, so the brightness of the LED would increase. Eventually, if the current were excessive, the LED would burn out.

Question 6

Answer: Opto-electrical transducer.

Question 7

Answer: As per graph



Explanation: A modulated signal must retain the frequency of the carrier wave and the amplitude of the information signal.

Question 8

Answer: **Gain = -300, Inverting**

Explanation:

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

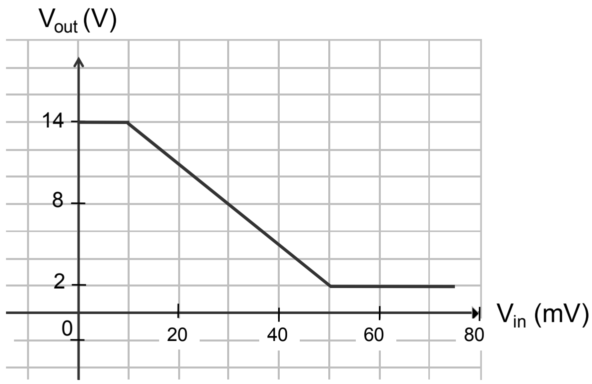
$$Gain = \frac{-6}{0.02}$$

$$Gain = -300$$

Note that the gain must be calculated for a region before any clipping occurs.

Question 9

Answer: As per graph. Note the clipping occurs for input voltages that cover a "flat" part of the transfer curve.



Question 10

Answer: **4 V**

Explanation:

$$R_T = 4 + \frac{4 \times 4}{4 + 4}$$

$$R_T = 6\,\Omega$$

$$V_Z = 6 \times \frac{4}{6}$$

$$V_Z = 4V$$

Question 11

Answer: **A**

Explanation:
Brightness is proportional to Power, which is proportional to Voltage and Current. Globe Z has a voltage drop of 4 V and all of the current, so it will be brighter than the X and Y, which have a 2 V drop and only half the total current.

Question 12

Answer: Globe Z will become brighter.

Explanation: As per Question 11, brightness is proportional to power in each globe. The addition of Globe W will further reduce the effective resistance of the parallel section of the circuit, so Globe Z will take an even larger share of the 6 V input. Furthermore, the reduction in overall resistance will increase the current, which is also the current through Globe Z.

SECTION B – Detailed Studies

Detailed Study 1 – Einstein's Special Relativity

Question 1

Answer: **B**

Explanation: Inertial reference frames must not have any acceleration, centripetal or linear. Even the Earth's rotation and centripetal acceleration around the Sun makes it a non-inertial reference frame, albeit very close to one!

Question 2

Answer: **D**

Explanation: All other answers are ideas that were contradicted by Special Relativity.

Question 3

Answer: **C**

Explanation: Michelson-Morley could not find any evidence of the aether, which meant that light did not require a medium to travel through.

Question 4

Answer: **A**

Explanation: Length contraction for relatively moving observers.

$$L = \frac{L_o}{\gamma}$$
$$L = \frac{250}{1.9}$$
$$L = 132\,m$$

Question 5

Answer: **D**

Explanation: Time dilation for relatively moving observers.

$$T = T_o\gamma$$
$$T = 4 \times 1.9$$
$$T = 7.6\,hrs$$

Question 6

Answer: **A**

Explanation:

$$v = 0.85c$$
$$v = 0.85 \times 3 \times 10^8$$
$$v = 2.55 \times 10^8 ms^{-1}$$
$$v = 9.18 \times 10^8 \ km\,hr^{-1}$$
$$d = v \times t$$
$$d = 9.18 \times 10^8 \times 7.6$$
$$d = 6.98 \times 10^9 \ km$$

Question 7

Answer: **C**

Explanation: Speed of light is constant.

Question 8

Answer: **A**

Explanation:

$$E_k = (\gamma - 1)m_o c^2$$
$$E_k = (1.9 - 1) \times 15000 \times (3 \times 10^8)^2$$
$$E_k = 1.215 \times 10^{21} \ J$$

Question 9

Answer: **D**

Explanation:

$$m = m_o \gamma$$
$$m = 1.5 \times 10^4 \times 1.9$$
$$m = 2.85 \times 10^4 \ kg$$

Question 10

Answer: **B**

Explanation: Length contraction applies for the moving muons, so they will have less time to decay and therefore more arrive at the end of the detection zone.

Question 11

Answer: **D**

Explanation:

$$\Delta m = \frac{\Delta E}{c^2}$$

$$\Delta m = \frac{8 \times 10^9 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2}$$

$$\Delta m = 1.42 \times 10^{-26}\ kg$$

Question 12

Answer: **C**

Explanation: By definition, proper time requires the observer to be at rest relative to the event.

Question 13

Answer: **B**

Explanation: Note that light will always be measured with a speed of c, which violates Maxwell's ideas.

SECTION B – Detailed Studies

Detailed Study 2 – Materials and their use in structures

Question 1

Answer: **C**

Explanation:

$$E = \frac{\sigma}{\varepsilon}$$

$$E = \frac{150 \times 10^6}{0.006}$$

$$E = 2.5 \times 10^{10}$$

$$E = 25\,GPa$$

Question 2

Answer: A

Explanation: Material A shows no plastic deformation, with a linear elastic region and then failure.

Question 3

Answer: **D**

Explanation:

$$\sigma = \frac{F}{A}$$

$$\sigma = \frac{66 \times 10^3}{0.03 \times 0.02}$$

$$\sigma = 110 \times 10^6$$

$$\sigma = 110\,MPa$$

Question 4

Answer: **C**

Explanation:
Referring to Figure 1, the graph of stress vs. strain shows that 110 MPa would fall in the linear elastic region for Material B.

Question 5

Answer: **A**

Explanation:
Using Figure 1, a strain of 0.08% applies with a stress of 110 MPa.

$$\varepsilon = \frac{\Delta l}{L}$$
$$\Delta l = L \times \varepsilon$$
$$\Delta l = 12 \times 0.0008$$
$$\Delta l = 0.0096$$
$$\Delta l = 9.6\,mm$$

Question 6

Answer: **D**

Explanation:
Toughness refers to the strain energy acquired prior to fracture. Stiffness refers to Young's Modulus. In both cases, the value for Material B is greater.

Question 7

Answer: **A**

Explanation:
$$\sigma = \frac{F}{A}$$
$$F = \sigma \times A$$
$$F = 42 \times 10^6 \times \frac{\pi \times (0.06)^2}{4}$$
$$F = 119\,kN$$

Question 8

Answer: **C**

Explanation: A, B & D would all be subjected to tensile loads which would make the non-reinforced concrete unsuitable. C would be essentially subjected to compressive loads only, so a mass concrete footing would be suitable.

Question 9

Answer: **D**

Explanation: Basic design calls for concrete where compression is most prevalent and steel reinforcement where tensile loads could cause the concrete to crack.

Question 10

Answer: **C**

Explanation:

$$\tau = F \times d$$
$$\tau = 15 \times 10^3 \times 16$$
$$\tau = 240 \times 10^3$$
$$\tau = 240\,kNm$$

The 15 kN would tend to rotate the beam in an clockwise direction about Point A, so C is the correct answer.

Question 11

Answer: **B**

Explanation: Assuming rotational equilibrium about Point A, and taking anticlockwise torques as positive.

$$\Sigma\tau_A = 0$$
$$-5 \times 4 \quad -4 \times 8 + R_C \times 9 \quad -15 \times 16 = 0$$
$$R_C = 32.4\,kN$$

Question 12

Answer: **D**

Explanation: This working applies to Questions 12 & 13.

$$\Sigma F_x = 0$$
$$F_A \sin 35 = F_B \sin 65$$
$$F_A = F_B \frac{\sin 65}{\sin 35}$$
$$F_A = 1.58 F_B$$

$$\Sigma F_y = 0$$
$$F_A \cos 35 + F_B \cos 65 = 40$$
$$1.58 F_B \cos 35 + F_B \cos 65 = 40$$
$$F_B (1.294 + 0.423) = 40$$
$$F_B = 23\,N$$

$$F_A = 1.58 F_B$$
$$F_A = 36.8 N$$

Question 13

Answer: **B**

Explanation: As above.

SECTION B – Detailed Studies

Detailed Study 3 – Further electronics

Question 1

Answer: **C**

Explanation:

$$V_{p-p} = 25 \times 2\sqrt{2} = 71V$$

Question 2

Answer: **C**

Explanation:
$I_{prim} = 4$ A
$I_{sec} = 20$ A.
So, we require a step-down (voltage) transformer, with a turns ratio equivalent to 5:1. Hence, 100:20 is the best answer.

Question 3

Answer: **D**

Explanation:
Period = 0.02 (per half wave, based on 25 Hz signal fully rectified).
V_{peak} is 6 V RMS, less two diode drops.
$$V_p = 6\sqrt{2} - 1.4 = 7.1V$$

Question 4

Answer: **A**

Explanation: A correctly describes the operation of the capacitor.

Question 5

Answer: **D**

Explanation: Extensive smoothing would be achieved.
$$\frac{\tau}{T} = \frac{4700 \times 10^{-6} \times 200}{0.02} = 47$$
If this ratio is greater than ~ 20, extensive smoothing would be apparent.

Question 6

Answer: **A**

Explanation: The size of the ripple voltage depends on a number of factors. One way of remembering the relationship is via the proportionality expression:

$$V_{ripple} \, \alpha \, \frac{V_{\max} T}{RC}$$

Question 7

Answer: **C**

Explanation: The stem of the questions indicates a time constant of 5 sec, as 3.3/9 ~ 37%.

$$\begin{aligned}
&\tau = RC \\
&5 = 500 \times C \\
&C = \frac{1}{100} \\
&C = 0.01 \\
&C = 10\, mF
\end{aligned}$$

Question 8

Answer: **A**

Explanation: The voltage across the capacitor must start at 9 V and decrease so that after 5 sec, it has lost 63% of its charge. The discharge is exponential in shape.

Question 9

Answer: **C**

Explanation: Current = series. Voltage = parallel. Resistance = parallel (with circuit disconnected).

Question 10

Answer: **C**

Explanation: Voltage across the zener is 4 V (according to the curve and assuming sufficient current, which is verified in the calculation). Voltage across the resistor is thus 1 V

Question 11

Answer: **B**

Explanation: Voltage across the zener is 4 V. Voltage across the resistor is thus 1 V.

$$I = \frac{V}{R}$$
$$I_R = \frac{1}{46}$$
$$I_R = 22\,mA$$

Question 12

Answer: **A**

Explanation: If the voltage is less than 4V, the zener diode has not reached its avalanche point, so it will not conduct.

Question 13

Answer: **C**

Explanation: A satisfactory setup must direct current from either input terminal to the positive output, then from the negative output to the other "input".