PHYSICS

Unit 3 – Written examination 1

2008 Trial Examination

SOLUTIONS

SECTION A: Core

Area of Study 1 – Motion in one and two dimensions

Question 1

Distance = Area Under Graph (do not include sign)

$= 0.5 \times (15 + 5) \times 10 + 0.5 \times 10 \times 10 = 150\,\text{m}$

1 mark

Question 2

Displacement = Area Under Graph (include sign)

$= 0.5 \times (15 + 5) \times 10 - 0.5 \times 10 \times 10 = 50\,m$ East

2 marks

Question 3

Average Velocity $= \dfrac{displacement}{time}$

$= \dfrac{50\,m\,E}{30\,s}$

= 1.67 m/ s East

2 marks

Question 4

Acceleration = Gradient

$= \dfrac{10}{10}$

= 1 m/ s^2 West

Net force $= ma$

$= 90 \times 1$

= 90 N West

2 marks

Question 5

Vertical component of velocity = 50 sin 60°
= 43.3 m/s

In vertical direction,

$v = u + at$

$0 = 43.3 + -10t$

$t = 4.33\,s$

Hence total time of flight $= 2t = 2 \times 4.33 = 8.66\,s$

3 marks

Question 6

Horizontal component of velocity = 50 cos 60°
= 25 m/ s

In horizontal direction,

$d = vt$

$d = 25 \times 8.66$

$d = 216.5\,m$

2 marks

Question 7

Acceleration = g = 10 m/s^2 down

1 mark

Question 8

Air resistance would reduce the range of the golf ball.

1 mark

Question 9

Given that the collision is isolated, we can assume momentum is conserved
Total momentum before the collision = Total momentum after the collision
Assign East as positive momentum

$+0.03 \times 3 + 0 = -0.03v + +0.08 \times 1.5$

v = 1 m/ s East

3 marks

Question 10

Change in momentum of blue ball = Final Momentum – Initial Momentum
$= +0.08 \times 1.5 - 0$
= +0.12 kg m/ s

Ft = Change in momentum

$F \times 0.15 = +0.12$

$F = 0.8N$ East

Average force exerted by blue ball on red ball is 0.8 N East.

3 marks

Question 11

The collision is inelastic.

Total Kinetic Energy before collision = $0.5 \times 0.03 \times 3^2$

$= 0.135J$

Total Kinetic Energy after collision = $0.5 \times 0.03 \times 1^2 + 0.5 \times 0.08 \times 1.5^2$

$= 0.105J$

Since Total Kinetic Energy before collision > Total Kinetic Energy after collision the collision is inelastic.

3 marks

Question 12

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}{(3.4 \times 10^6)^2} = 3.70\ Nkg^{-1}$$

2 marks

Question 13

687.5 days $= 687.5 \times 24 \times 60 \times 60$

$= 5.94 \times 10^7 s$

1 mark

Question 14

Acceleration of Mars around Sun

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

$$= \frac{4\pi^2 \times 2.28 \times 10^{11}}{(5.94x10^7)^2}$$

$$= 2.55 \times 10^{-3} m/s^2$$

$$g = \frac{GM}{r^2}$$

$$2.55 \times 10^{-3} = \frac{6.67 \times 10^{-11} \times M}{(2.28 \times 10^{11})^2}$$

$$M = 1.99 \times 10^{30} kg$$

Hence mass of Sun is $1.99 \times 10^{30} kg$

3 marks

Question 15

$$T = 24 \times 60 \times 60 + 39 \times 60 = 88740s$$

$$r^3 = \frac{GMT^2}{4\pi^2}$$

$$= \frac{6.67 \times 10^{-11} \times 6.42 \times 10^{23} \times 88740^2}{4\pi^2}$$

$$= 8.54 \times 10^{21}$$

So $r = 2.04 \times 10^7 m$

$= 2.04 \times 10^4 km$

Hence distance above planet surface:

$$= 2.04 \times 10^4 km - 3.4 \times 10^3 km$$

$$= 1.7 \times 10^4 km$$

4 marks

Question 16

$\frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$ or use $v = \frac{2 \times \pi \times r}{T}$

So $v^2 = \frac{4\pi^2 x(2.04x10^7)^2}{88740^2}$

$= 2.09 \times 10^6$

So v = 1.44 km/s

2 marks

Question 17

Velocity R relative to J = Velocity R – Velocity J

$= 300m/s\ S - 400m./s\ W$

$= 300m/s\ S - -400m/s\ W$

$= 300m/s\ S + 400m/s\ E$

By Pythagoras Velocity R relative to $J = \left(300^2 + 400^2\right)^{0.5} = 500\,m/s$

Let a be the angle between the 300 m/s S and 400 m/s E velocity vectors then:

$\tan a = \frac{400}{300}$

$a = 53^{\circ}$

So bearing from North = 180º + 53º = 233º

2 marks

Question 18

20 km/ hr $= \frac{20}{3.6}$ m/s

= 5.6 m/s

1 mark

Question 19

Net Force $= \frac{mv^2}{r}$

$= \frac{1200 \times 5.6^2}{3.5}$

$= 1.08 \times 10^4\ N$ towards the centre

2 marks

Area of Study 2 – Electronics and Photonics

Question 1

At $50^\circ C$ $R = 2k\Omega$

So $V_{xy} = 12 \times 2(4+2) = 4V$

2 marks

Question 2

At $20^\circ C$ $R = 6k\Omega$

So $V_{xy} = 12 \times 6(4+6) = 7.2V$

2 marks

Question 3

Kate should connect the heating element across XY.

As the temperature of the water falls the resistance of the thermistor increases. An increase in voltage across the thermistor will lead to an increase in the voltage drop across XY and hence across the heating element.

2 marks

Question 4

Kate should lower the value of the resistance of the heating element.

A smaller resistance for the heating element will mean a larger amount of power is dissipated in the heating element as Power = $\dfrac{V^2}{R}$.

2 marks

Question 5

From the graph, assume $V_{led} = 2V \quad so \quad V_R = 4V$

Hence $I_{led} = \dfrac{P}{V} = \dfrac{0.3}{2} = 0.15A$ (which validates initial assumption)

Resistance = $R = \dfrac{V}{I} = \dfrac{4}{0.15} = 26.7\Omega$

3 marks

Question 6

$$R_{led} = \frac{V^2}{P} = \frac{2^2}{0.3} = 13.3\Omega$$

1 mark

Question 7

Janet should choose a phototransistor. Phototransistors give a large variation in output voltage in response to small variations in light intensity. A phototransistor allows a current to flow from collector to emitter in proportion to the light intensity incident on the base of the phototransistor.

2 marks

Question 8

Gain = gradient of characteristic curve in the linear region.

$= -\frac{20}{2}$ either correct graph or should be = $-\frac{19.5}{2}$ = -9.5

$= -10$

Magnitude = 10 (accept range of 9.5 - 10 according to graph)

1 mark

Question 9

The supply voltage can be determined from the maximum value of V_{out}.
From the graph this is 20 V.

1 mark

Question 10

The optimum quiescent point is the mid point on the linear region of the characteristic curve.
From the graph this is at: (1.5, 10)

1 mark

Question 11

The input voltage must be shifted to be centred around 1.5 V (the quiescent point) which will be the voltage across the lower resistor.
Hence from the voltage divider formula,

$$1.5 = 20 \times \frac{R_L}{R_L + 500}$$

$$R_L = 40.5k\Omega$$

3 marks

Question 12

A capacitor is able to decouple a signal as it blocks DC voltage and allows AC voltage to pass. This will remove the DC component present in a combined AC and DC signal and just leave the AC.

2 marks

Question 13

A

Increasing the light intensity on the photodiode will allow a larger current through the photodiode and hence through the 100 kΩ resistor. An increase in current through the 100 kΩ resistor will result in a larger volt drop as $V = IR$

2 marks

Question 14

B C

A LED converts electrical energy to light energy so a LED is an electric-opto transducer.
A photodiode converts light energy into electrical energy so a photodiode is an opto-electric transducer.

1 mark

SECTION B – Detailed Studies

Detailed Study 1 – Einstein's special relativity

Question 1

Answer: C

Explanation:

According to Newton:
Velocity of Jerry relative to Tom = $2.3\times10^{8} - -2.3\times10^{8} = 4.6\times10^{8}\, m/s$
This is in excess of the speed of light so is incorrect.

Question 2

Answer: A

Explanation:

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

Hence $\gamma = \dfrac{1}{\sqrt{1-\dfrac{(2.3\times10^{8})^2}{(3\times10^{8})^2}}} = 1.5575 = 1.56$

Question 3

Answer: A

Explanation:

Newton's law's of motion are valid and give a good approximation for objects moving at speeds much slower than the speed of light. Everyday objects such as cars move at these speeds making these laws useful. As objects move faster the accuracy of these laws decreases and the laws developed by Einstein in his theory of special relativity need to be used.

Question 4

Answer: A

Explanation:

Time = $\frac{d}{s} = \frac{5.9 \times 10^{12}}{0.3 \times 3 \times 10^{8}}$ = 65 555.6 *s* = 18 hrs 12 mins 35.6 *s*.

Hence Daisy's watch would read 6:12:36 am.

Question 5

Answer: C

Explanation:

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

Substitute v with $0.3c$ and solve for $\gamma = 1.0483$

Hence Donald would measure a time of $\frac{65555.6}{1.0483}$ = 62 537.0 *s* or 17 hours 22 mins 17.0 *s*.

Hence Donald's watch would read 5:22:17 am. (a range of values within a minute or two of this would be acceptable depending upon the degree of rounding off in Q4 and Q5)

Question 6

Answer: B

Explanation:

Length = $\frac{L_o}{\gamma} = \frac{7}{1.0483}$ = 6.68 m

Question 7

Answer: C

Explanation:

$$\gamma = \frac{L_o}{L} = \frac{10}{9} = 1.11$$

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

Substitute $\gamma = 1.11,\ c = 3 \times 10^8$

And solve for v to get $v = 1.31 \times 10^8\, m/s$

This is 43.6 % of light speed

Question 8

Answer: C

Explanation:

2 days 13 hours 4 minutes and 47 seconds = 219 887 *s*

Time taken as measured by Minnie = $219840 \times 1.11 = 244075 s$

Or 2 days 19 hours 47 minutes and 54 seconds

Question 9

Answer: D

Explanation:

$$\Delta E = 11 GeV = 11 \times 10^9 \times 1.6 \times 10^{-19} J = 1.76 \times 10^{-9} J$$

$$\Delta E = \Delta m c^2$$

$$\Delta m = \frac{\Delta E}{c^2} = \frac{1.76 \times 10^{-9}}{(3 \times 10^8)^2} = 1.96 \times 10^{-26} kg$$

Question 10

Answer: D

Explanation:

Increase = $\dfrac{1.96 \times 10^{-26}}{1.67 \times 10^{-27}}$ = 11.7 times

Question 11

Answer: B

Explanation:

The Michelson Morley experiment was designed to measure the speed the Earth moves through the aether.

Question 12

Answer: B

Explanation:

An inertial frame is one in which Newton's laws of motion hold. This means the frame is not moving or moving at constant velocity.

Question 13

Answer: B

Explanation:

The Lorentz factor will increase the mass and contract (i.e. decrease the length).

Detailed Study 2- Investigating materials and their use in structures

Question 1

Answer: B

Explanation:

$$\sigma_{allow} = \frac{\sigma_{\max}}{SafetyFactor} = \frac{400MPa}{4} = 100 \text{ MPa}$$

Question 2

Answer: C

Explanation:

Force = $10 \times 10^3 \times 10 = 10 \times 10^4 \, N$

Area = $\frac{F}{\sigma_{allow}} = \frac{1 \times 10^5 \, N}{100MPa}$ MPa = 1000 mm^2

Question 3

Answer: B

Explanation:

$\pi r^2 = Area =$ 1000 mm^2
r = 17.84 mm
So $D = 2r = 35.7$ mm

Question 4

Answer: D

Explanation:

$$\varepsilon = \frac{\sigma}{E} = \frac{100MPa}{210 \times 10^3 \, MPa} = 4.76 \times 10^{-4}$$

Question 5

Answer: C

Explanation:

$$\Delta L = \varepsilon L = 4.76 \times 10^{-4} \times 20 = 9.5 \times 10^{-3} \, m = 9.5mm$$

Question 6

Answer: A

Explanation:

Strain Energy = $0.5E\varepsilon^2$
Strain Energy = $0.5 \times 210 \times 10^9 Pa \times \left(4.76 \times 10^{-4}\right)^2 = 2.38 \times 10^4 J/m^3$

Question 7

Answer: B

Explanation:

Volume = $Ah = 1000 \times 10^{-6} m^2 \times 20 = 2.00 \times 10^{-2} m^3$

Question 8

Answer: D

Explanation:

Energy stored in rod = $2.38 \times 10^4 J/m^3 \times 2.00 \times 10m^{-2} = 476J$

Question 9

Answer: A

Explanation:

A brittle material such as cast iron fails soon after reaching its yield strength. That is cast iron does not exhibit any significant plastic behaviour. A ductile material such as mild steel undergoes extensive deformation before failure and as a result is able to absorb significant more strain energy. This makes mild steel a better building material.

Question 10

Answer: B

Explanation:

Paper (this material is strong when stretched but weak when squashed. Compression should not be confused with buckling, eg steel wire will buckle under a load but not fail under compression)

Question 11

Answer: A

Explanation:

Concrete (this material is weak when stretched but strong when squashed)

Question 12

Answer: B

Explanation:

$\sigma_{allow} = \frac{20MPa}{4} = 5$ MPa

Force = $15 \times 10^3 \times 10 = 1.50 \times 10^5 N$

Area = $\frac{Force}{\sigma_{allow}} = \frac{1.50 \times 10^5 N}{5MPa} = 3.00 \times 10^4 mm^2$

So side length = $\sqrt{Area} = \sqrt{3.00 \times 10^4 mm^2} = 173$ mm

Question 13

Answer: C

Explanation:

When a beam is subject to a load it bends. As a result the top of the beam is in compression and the bottom of the beam is in tension. Concrete is weak in tension and will crack without reinforcement. Steel reinforcement which is strong in tension is used to take the tensile forces running along the bottom of the beam.

Detailed Study 3 –Further Electronics

Question 1

Answer: C

Explanation:

V_{pp} = 680 V (voltage from top to bottom)

Question 2

Answer: A

Explanation:

$$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{340}{\sqrt{2}} = 240 \text{ V}$$

Question 3

Answer: B

Explanation:

$$f = \frac{1}{T} = \frac{1}{20\times10^{-3}} = 50 \text{ Hz}$$

Question 4

Answer: D

Explanation:

Power = 0.5 $V_p I_p = 0.5\times340\times35\times10^{-3} = 5.95W$

Question 5

Answer: B

Explanation:

$$\frac{N_p}{N_S} = \frac{V_P}{V_S} = \frac{20}{1}$$

So $V_s = \frac{N_S}{N_P}\times V_P = \frac{1}{20}\times240$ = 12 V AC RMS

Question 6

Answer: C

Explanation:

The correct circuit layout is the order below:

1. Step Down transformer (reduce 240 V AC to 12 V AC)
2. 4 diodes arranged as a Full Wave bridge rectifier (get the current flowing in the one direction)
3. Smoothing Capacitor (smooth the large variation in the voltage from the full wave bridge rectifier)

Question 7

Answer: C

Explanation:

The purpose of the capacitor is to smooth the large variation in the voltage from the full wave bridge rectifier.

Question 8

Answer: C

Explanation:

The output from the secondary side of the step down transformer is 12 V.
The signal must then pass through 2 diodes on its way through the full wave bridge rectifier before getting to the radio.
Each diode consumes 0.7 V so the output to the radio is $12 - 2 \times 0.7 = 10.6V$.

Question 9

Answer: B

Explanation:

Amy should connect the 4.5 Zener diode in series with the 10 kΩ resistor.
The output to the IC chip should be connected in parallel across the 4.5 Zener diode as this will provide a constant 4.5 volts DC.

Question 10

Answer: A

Explanation:

The 10 kΩ resistor gets hot as it dissipates the voltage above 4.5 V that the Zener diode is not supplying to the IC chip.

Question 11

Answer: B

Explanation:

Signal varies as $5V\ DC + 2V_{pp}\ AC$
4.5 V Zener diode removes 4.5 V
So signal varies $0.5V\ DC + 2V_{pp}\ AC$
This is the same as $0.5V\ DC + \sqrt{2}V_{rms}\ AC$
Hence Power dissipated = $\frac{V^2}{R} = \frac{0.5^2}{10\times10^3} + \frac{\left(\sqrt{2}\right)^2}{10\times10^3} = 2.25\times10^{-4}W$

Question 12

Answer: A

Explanation:

A 7805 IC voltage regulator does not require an external 10 kΩ resistor as the excess voltage is dissipated as heat within the 7805 IC voltage regulator.

Question 13

Answer: B

Explanation:

$$T = \frac{1}{f} = \frac{1}{50} = 0.02$$

$$V_{n(pp)} = \frac{V_{\max}T}{RC}$$

$$= \frac{12\times0.02}{20\times10^3\times100\times10^{-6}}$$

$$= 0.12\ \text{V}$$