THE SCHOOL FOR EXCELLENCE

UNIT 3 PHYSICS 2010

COMPLIMENTARY WRITTEN EXAMINATION 1 SOLUTIONS

SECTION A – CORE STUDIES

AREA OF STUDY 1 - MOTION IN ONE AND TWO DIMENSIONS

QUESTION 1 $N = m\,g\,\cos\theta = 1000 \times 10 \times \cos 20 = 9400\ N$

QUESTION 2

Work = Δ Ug - Δ E$_k$ $= m\,g\,h - \frac{1}{2} m\,v^2 = 1000 \times 10 \times 5 - 0.5 \times 1000 \times 6^2 = 3.2 \times 10^4\ J$

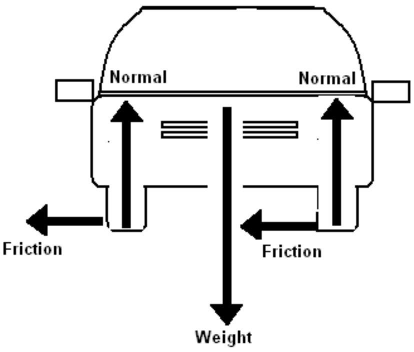
QUESTION 3

Length of path = $\frac{5}{\sin 20} = 14.6\ m$

$$Force = \frac{work}{displacement} = \frac{3.2 \times 10^4}{14.6} = 2.2 \times 10^3\ N$$

QUESTION 4 $F_C = \frac{m\,v^2}{r} = \frac{1.2 \times 10^3\ 20^2}{40} = 1.2 \times 10^4\ N$

QUESTION 5



QUESTION 6 $\tan\theta = \frac{F_C}{F_G} = \frac{v^2}{r\,g} = \frac{15^2}{40 \times 10} = 29^o$

QUESTION 7 (read from graph) 5 N kg^{-1}

QUESTION 8 $E_K = \frac{1}{2} m\,v^2 = 0.5 \times 24 \times 10^3 \times \left(3.6 \times 10^3\right)^2 = 1.56 \times 10^{11}\ J$

QUESTION 9 Gravitational potential energy is converted to kinetic energy

QUESTION 10

The gain in kinetic energy = loss of gravitational energy.

The gravitational energy change can be determined from the area under the graph.

ΔE = number of squares x value of square x mass of asteroid

= 36 x (5 x 0.5 x 10^7) x (2.4 x 10^4) (no. of squares = 36 ± 1)

= 2.16 x 10^{13}J

QUESTION 11

Total energy of asteroid at point of impact = 1.56 x 10^{11} + 2.16 x 10^{13} = 2.18 x 10^{13}J (Consequential Ans Q8 + Ans Q10).

E_K = 2.18 x 10^{13} = $\frac{1}{2} m v^2$

Velocity = 4.26 x 10^3 ms^{-1}

QUESTION 12

From $\frac{G M m}{R^2} = \frac{m 4 \pi^2 R}{T^2}$

$$T = \sqrt{\frac{4 \pi^2 R^3}{G M}} = \sqrt{\frac{4 \times \pi^2 \left(1.9 \times 10^8\right)^3}{6.67 \times 10^{-11} \times 2.7 \times 10^{27}}} = 3.9 \times 10^4 s$$

QUESTION 13 Answer is B

Rearranging $\frac{G M m}{R^2} = \frac{m v^2}{R}$ *gives* $v \propto \sqrt{\frac{1}{R}}$

The inverse relationship shows that the smaller the orbital radius the greater the velocity.

QUESTION 14

First find the time of flight using: $d = u t + \frac{1}{2} a t^2$; t = 0.77s

$$speed = \frac{\text{distance}}{time} = \frac{10}{0.77} = 13\, ms^{-1}$$

QUESTION 15 Answer is E

QUESTION 16

First find the vertical component of the impact velocity:

$$v = u + a t = 0 + 10 \times 0.77 = 7.7\, ms^{-1}$$

Impact velocity = $\sqrt{7.7^2 + 13^2}$ = 15.1 ms^{-1}

(Consequential)

QUESTION 17 $F = \frac{m \Delta v}{t} = \frac{80 \times 14}{0.4} = 2800\,N$

QUESTION 18

Inelastic. The slower rebound speed demonstrates that there has been a reduction in kinetic energy. An elastic collision is one in which kinetic energy has been conserved.

AREA OF STUDY 2 - ELECTRONICS AND PHOTONICS

QUESTION 1 Placing the resistors in series results in a resistance of **40Ω**

QUESTION 2 Placing the resistors in parallel results in a resistance of **2.5Ω**

QUESTION 3 Answer is **A.** 6.7Ω can't be created using these 4 resistors.

QUESTION 4 maximum current will be when resistance in the circuit is at a minimum which is when the 4 resistors are in parallel. R_{total} = 20/7 = 2.86 Ω
The current is subsequently 12 ÷ 2.86 = **4.2 A**

QUESTION 5 From the graph: $R_{thermistor}$ = **2k Ω** when T = 10 ºC

QUESTION 6 From the LED characteristics graph, the threshold (switch on) voltage is approximately **1.8 V**.

QUESTION 7 With the LED taking 1.8 V, 24 V remains across the thermistor which at 10 ºC has a resistance of 2000 Ω. This restricts the current to:

$I = \frac{24}{2000} =$ **12 mA**

QUESTION 8 **Yes** it will work. Any increase in temperature above 10 ºC will decrease the resistance of the thermistor resulting in more current flowing in the LED which results in the LED emitting light.

QUESTION 9 Answer is **B.** A resistor is regarded as "ohmic" where-as the other three devices are generally considered as "non-ohmic".

QUESTION 10 The current in truly ohmic devices will vary with voltage with the resistance remaining constant. For example a thermistor should have a constant resistance when the temperature is constant. Globes, LED's and diodes all vary in resistance as the potential difference across them varies. An **LDR** should maintain its resistance when the light intensity is constant and also when the temperature is constant (which is a parameter when electrical devices are being tested in this way) and can be considered "ohmic".

QUESTION 11 To make the alarm adequately audible 6V is required across the alarm, therefore the required current is 6/3000 = 2 mA which corresponds (from the LED graph) to a light intensity of **0.4 W/m^2**

QUESTION 12 As long as the supply voltage is at least 6 V a light intensity of **0.4 W/m^2** will provide the necessary 2 mA and the alarm will adequately respond.

QUESTION 13 From the input signal graph, 1.5T = 80 ms.
Therefore T = 53.3 ms = 5.33×10^{-2} s.
f = 1/T = **18.8 Hz**

QUESTION 14 **Inverting**, Voltage gain = **1000**, clipped at **± 9 V**

QUESTION 15 Answer is **A**

QUESTION 16 **Phototransistor, light-dependent resistor**

SECTION B – DETAILED STUDIES

DETAILED STUDY 1 - EINSTEIN'S SPECIAL RELATIVITY

QUESTION 1 Answer is **B**

QUESTION 2 Answer is **A**

QUESTION 3 Answer is **C**

QUESTION 4 Answer is **C**

QUESTION 5 Answer is **D**

QUESTION 6 Answer is **A**

QUESTION 7 Answer is **C**

$$t = \frac{10}{\sqrt{1 - \frac{(0.9c)^2}{c^2}}}$$
$$= \frac{10}{\sqrt{1 - 0.9^2}}$$
$$= 22.9 \text{ seconds}$$

QUESTION 8 Answer is **B**

QUESTION 9 Answer is **D**

$$L_0 = \frac{200}{\sqrt{1 - 0.9^2}} = 458\ m$$

QUESTION 10 Answer is **B**

$$\frac{105.7 \times 10^6 \times 1.6 \times 10^{-16}}{\left(3 \times 10^8\right)^2} = 1.9 \times 10^{-28}\ kg$$

QUESTION 11 Answer is **C**

$$KE = M - M_o$$
$$KE = 1\times10^{9} - 105.7\times10^{6}\ eV = 890\times10^{6} eV = 890 MeV$$

QUESTION 12 Answer is **C**

$$\gamma = \frac{M}{M_o} = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$
$$v = \frac{1}{\sqrt{1-\frac{M_o^2}{M^2}}} c = 0.99c$$

QUESTION 13 Answer is **D**

DETAILED STUDY 2 - FURTHER ELECTRONICS

QUESTION 1 The answer is **B**
The diode only allows current in one direction but has a voltage of 0.7 V across it causing a decrease from a peak of 7.0 V to a peak of 6.3 V across the resistor.

QUESTION 2 The answer is **A**

QUESTION 3 The answer is **D**

QUESTION 4 The answer is **A**

$$P = \frac{V^2}{R} = \frac{12^2}{180} = \frac{144}{180} = 0.8\,W$$

QUESTION 5 The answer is **C**

$$\frac{N_1}{N_2} = \frac{V_1}{V_2} \qquad \frac{N_1}{200} = \frac{240}{16}$$

$N_1 = 3000$

QUESTION 6 The answer is **B**

16 V_{RMS} relates to a peak voltage of 22.6 V. With a scale of 4.5 V/cm, the signal will have an amplitude of 5 squares.
A frequency of 50 Hz relates to a period of 20 ms. With a scale of 2.5 ms/cm, the period of the wave will be 8 squares wide.

QUESTION 7 The answer is **A**

The voltage is regulated. It remains as 12 V as long as sufficient voltage is provided.

QUESTION 8 The answer is **D**

QUESTION 9 The answer is **A**

QUESTION 10 The answer is **C**

The voltage is regulated and will remain the same. The increased resistance will result in a decreased current.

QUESTION 11 The answer is **D**

Other than to increase the time constant, resistance is generally unwanted in a circuit. The average amplitude of the voltage signal should be as high as easily arranged to suit the purpose required. There is no real need to minimise capacitance. A ripple voltage of minimum amplitude ensures a near constant voltage, which is closer to the required DC.

QUESTION 12 The answer is **B**

Given that $\tau = R \times C$, the largest product will result in the greatest time constant.

QUESTION 13 The answer is **D**

$$R = \frac{\tau}{C} = \frac{1.5}{250\times10^{-6}} = 6\times10^{3}\ \Omega$$

$$R = \frac{\tau}{C} = \frac{1.5}{250\times10^{-6}} = 6\times10^{3}\ \Omega$$

DETAILED STUDY 3 - STRUCTURES AND MATERIALS

QUESTION 1 Answer is **B**

QUESTION 2 Answer is **B**

Support force at A is 2N, support force at B is N
moments about A: 3N - 600x = 0
moments about B: 3(2N) - 600(3-x) = 0
solving these two equations for x, x = 1 m

QUESTION 3 Answer is **B**

Sum all forces:
2N + N – 600 = 0
3N = 600
N=200 N

QUESTION 4 Answer is **C**

Maximum force on A will occur when the student stands at A.
Moments at B: $3N_A = 3(600)$
$N_A = 600$ N

QUESTION 5 Answer is **C**

Largest area under graph

QUESTION 6 Answer is **D**

Undergoes plastic deformation before fracture

QUESTION 7 Answer is **B**

Steepest gradient

QUESTION 8 Answer is **B**

$$\sigma = \frac{F}{A} = \frac{3\times10^{3}}{3.5\times10^{-5}}$$

$$\varepsilon = \frac{\sigma}{E} = \frac{3\times10^{3}}{3.5\times10^{-5}\times206\times10^{9}}$$

$$\Delta l = \varepsilon \times l = \frac{3\times10^{3}}{3.5\times10^{-5}\times206\times10^{9}} \times 3 = 1.25\ mm$$

QUESTION 9 Answer is **C**

Strain energy = area under graph up to stress 120 MPa

$$\text{strain energy} = \frac{1}{2} \times 0.0016 \times 120 \times 10^{6} = 96000J \approx 100000J$$

QUESTION 10 Answer is **D**

Young’s Modulus = gradient of graph.

$$E = \frac{stress}{strain} = \frac{80\times10^{6}}{0.0012} = 66 \times 10^{9} Pa \approx 70\ GPa$$

QUESTION 11 Answer is **D**

QUESTION 12 Answer is **C**

QUESTION 13 Answer is **A**