2008 VCAA Physics Exam 1 Solutions

Area of study 1 – Motion in one and two dimensions

Q1 Force of tow rope on ship $= 9.0\times10^4$ N

Water resistance force on ship $= 2.0\times10^4$ N (from graph)

Resultant force on ship $= 9.0\times10^4 - 2.0\times10^4 = 7.0\times10^4$ N

Accel $= \frac{F}{m} = \frac{7.0\times10^4}{100\times10^4} = 0.070$ ms^{-1}.

Q2 At this constant speed, water resistance force = tow rope force $= 9.0\times10^4$ N. This corresponds to 4.0 ms^{-1} (from graph).

Q3 Ignoring friction between the car and the surface,

$T = \frac{mv^2}{r} = \frac{2.4\times2.0^2}{1.6} = 6.0$ N

Q4 Since the car is in uniform circular motion, the resultant force on the car is towards the centre of the circular path. Hence direction P.

Q5 Consider the vertical component:

$u={}^{+}30.0\sin36.9° = {}^{+}18.0126$, $a={}^{-}10$, $v=0$, find s.

Use $v^2 = u^2 + 2as$, $s={}^{+}16.2$. Max. height = 16.2 m.

Q6 The ball falls under gravity only while it is in flight. Hence the resultant force is R.

Q7 This question requires you to consider both components.
Horizontal component:

$u={}^{+}30.0\cos36.9° = {}^{+}23.9905$, $s={}^{+}72.0$, find t.

Use $s = ut$, $t = 3.0012$ s.

Vertical component:

$u={}^{+}30.0\sin36.9° = {}^{+}18.0126$, $a={}^{-}10$, $t = 3.0012$, find s.

Use $s = ut + \frac{1}{2}at^2 = {}^{+}9.02$ m

Height = 9.02 m.

Q8 Apply conservation of momentum:

$(80\times10^3)v = (20\times10^3)({}^{+}8.0) + (60\times10^3)(0)$

$v={}^{+}2.0$. Hence the speed = 2.0 ms^{-1}.

Q9 Impulse = change in momentum $= m(v-u)$

$I = (20\times10^3)({}^{+}2 - {}^{+}8) = {}^{-}1.2\times10^5$ kgms^{-1},

i.e. 1.2×10^5 kgms^{-1} west.

Q10 Total kinetic energy before collision

$= \frac{1}{2}(20\times10^3)8.0^2 = 6.4\times10^5$ J

Total kinetic energy after collision

$= \frac{1}{2}(80\times10^3)2.0^2 = 1.6\times10^5$ J

Not the same amount, inelastic collision.

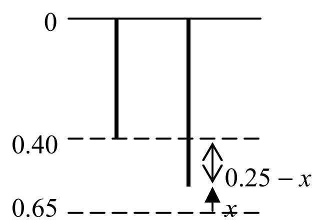
Q11 According to conservation of momentum,

$\Delta p_L + \Delta p_T = 0$, $\Delta p_L = {}^{-}\Delta p_T$, $|\Delta p_L| = |\Delta p_T|$, $|I_L| = |I_T|$,

$F_L\Delta t = F_T\Delta t$, $\therefore F_L = F_T$, i.e. Newton's third law.

Q12 Stored energy $= \frac{1}{2}kx^2 = \frac{1}{2}(10)0.20^2 = 0.2$ J

Q13



Total energy

E_T = gravitational p.e. + elastic p.e. + kinetic e. is constant.

$E_T = mgx + \frac{1}{2}k(0.25-x)^2 + E_k$

$\therefore E_k = E_T - mgx - \frac{1}{2}k(0.25-x)^2$ where E_T is a constant.

This is a quadratic function of x with a negative coefficient for x^2, i.e. an inverted parabola. At the top and bottom of the oscillations, the system is momentarily at rest, i.e. zero kinetic energy. Hence graph D.

Q14 Since the gravitational potential energy = mgx, linear function of x. Hence graph A.

Q15 The speed of the comet decreases from a maximum value at X to a minimum value at Y. Its total energy remains constant around its orbit.

Q16 Gravitational force $F = \frac{GMm}{r^2}$

$= \frac{(6.67*10^{-11})(6.42\times10^{23})(930)}{(3.83\times10^6)^2} = 2.71\times10^3$ N

Q17 Mars Global Surveyor is in free fall, $\therefore a = g$,

i.e. $\frac{4\pi^2 r}{T^2} = \frac{GM}{r^2}$,

$\therefore T = 2\pi\sqrt{\frac{r^3}{GM}} = 2\pi\sqrt{\frac{(3.83\times10^6)^3}{(6.67\times10^{-11})(6.42\times10^{23})}}$

$= 7.20\times10^3$ s.

Area of study 2 – Electronics and photonics

Q1 $V_{LED} = 2.5$ V (from graph)
$\therefore V_R = 8.0 - 2.5 = 5.5$ V
$I_{LED} = I_R = \frac{V_R}{R} = \frac{5.5}{300} = 0.0183$ A = 18.3 mA

Q2 $V_P = \frac{1}{1+2} \times 6 = 2$ V

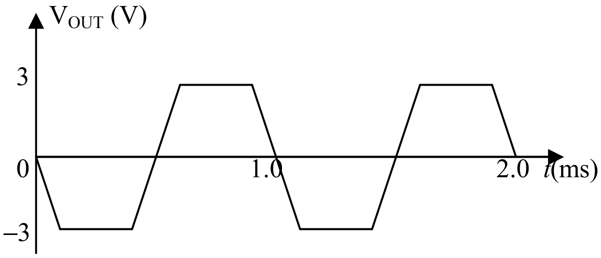
Q3 Voltage drop across $R_C = I_C R_C = 3$ mA × 1 kΩ = 3 V.
$\therefore V_Q = 6 - 3 = 3$ V.

Q4 Power = $(I_C)^2 R_C = (3\times10^{-3})^2(1\times10^3) = 9\times10^{-3}$ W

Q5 Voltage amplification $= \frac{\Delta V_{OUT}}{\Delta V_{IN}} = \frac{-3}{60\times10^{-3}} = -50$.

Q6 Negative slope: the amplifier gives inverted signals.
Horizontal section for $V_{IN} >^{+} 60$ mV: the amplifier is saturated, i.e. maximum current flows through the transistor.
Horizontal section for $V_{IN} <^{-} 60$ mV: the amplifier is at cut-off, i.e. minimum (zero) current flows through the transistor.

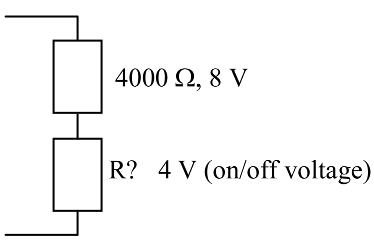
Q7



Q8 Without the coupling capacitor C, the voltage at Y will be forced to have similar voltage as that at X and may cause incorrect biasing of the second transistor amplifier. With C, the dc component of the output at X is removed and only the ac component is allowed to pass through to Y, which is at the correct biasing voltage.

Q9 Thermistor resistance at 20°C = 1000Ω (from graph).

Q10 Thermistor resistance at 5°C = 4000Ω (from graph).



Voltage divider ratio: $\frac{R}{4000} = \frac{4}{8}$, $R = 2000\ \Omega$.

Q11 Lower temperature, higher thermistor resistance and $\therefore$ higher variable resistor resistance is required to maintain the on/off voltage of 4 V. R should be increased.

Detailed study 1 – Einstein's special relativity

1	2	3	4	5	6	7	8	9	10	11	12	13
B	C	D	C	C	B	B	B	C	B	C	D	B

Q1 To the observer in the rocket, the window on the space station moves to the left (refer to given diagram) at relativistic speed. $\therefore$ the width of the window is shorter since it moves along the direction of motion. The height of the window remains the same. B

Q2 $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$. Relativistic effects are not observable when $\frac{v}{c}$ is very small, i.e. $\gamma \approx 1$. C

Q3 At the instant that Fred and Nancy were directly opposite each other, Fred received the light from both Alan and Bob simultaneously and both sides of Fred were illuminated simultaneously. Nancy and Fred witnessed this same event at that instant. Therefore, Nancy must have received the light from both Alan and Bob simultaneously as well. To Fred, Alan and Bob struck matches simultaneously. Nancy was further from Alan than Bob before she was directly opposite to Fred. To Nancy, Alan struck the match earlier than Bob did in order for her to receive light from Alan and Bob simultaneously.
While no given option is ideal, option D is the best option.

Q4 $L = \frac{L_O}{\gamma} = L_O\sqrt{1-\frac{v^2}{c^2}}$, $\therefore 10 = 20\sqrt{1-\frac{v^2}{c^2}}$,
$\frac{v^2}{c^2} = 0.75$, $v = 0.87c$. C

Q5 C

Q6 B

Q7 Speed of sound relative to Mary = 340 + 40 = 380.
Speed of sound relative to Trung = 340 – 40 = 300. B

Q8 Einstein's second postulate. B

Q9 Proper length is the length of an object measured by an observer at rest relative to the object. C

Q10 $E_k = m_o c^2(\gamma - 1)$. At $v = 0.99c$, $\gamma - 1 = 6.09$.
When the speed increases slightly (a very small percentage) to say $v = 0.995c$, $\gamma - 1 = 9.01$, so the increase in $E_k \approx 50\%$. B

Q11 $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = 4$, $\sqrt{1-\frac{v^2}{c^2}} = \frac{1}{4}$, $1-\frac{v^2}{c^2} = \frac{1}{16}$, $\frac{v^2}{c^2} = \frac{15}{16}$,
$\frac{v}{c} = 0.97$, $v = 0.97c$. C

Q12 Electron's frame of reference is a moving frame relative to the linear section, $\therefore$ the linear section appears shorter.

$L = L_o\sqrt{1-\frac{v^2}{c^2}} = 600\times\frac{1}{4} = 150$ m. D

Q13 Mass decreased $= (1.673+1.675-3.344)\times10^{-27}$
$= 4\times10^{-30}$ kg.
Energy released $= mc^2 = (4\times10^{-30})(3.0\times10^{8})^2 = 3.6\times10^{-13}$ J.
B

Detailed study 2 – Investigating materials and their use in structures

1	2	3	4	5	6	7	8	9	10	11	12	13
D	B	A	A	C	C	C	A	A	A	C	B	D

Q1 $E = \frac{\sigma}{\varepsilon} = \frac{8.0\times10^{7}}{15\times10^{-4}} = 5.3\times10^{10}$ Nm^{-2}. D

Q2 B

Q3 Compressive strength $= 8.0\times10^{7}$ Nm^{-2}.
Cross-sectional area $= 1.50$ m^2.
Max. force $= (8.0\times10^{7})(1.50) = 1.2\times10^{8}$ N. A

Q4 Area under (above) σ vs ε graph
$= \frac{1}{2}(8.0\times10^{7})(15.0\times10^{-4}) = 6.0\times10^{4}$ Jm^{-3}. A

Q5 Volume of column $= 20.0\times1.50 = 30.0$ m^3. C

Q6 $\Delta L = \varepsilon L = (5.00\times10^{-4})(20.00) = 0.010$ m
Compressed height $= 20.00 - 0.010 = 19.99$ m. C

Q7 Refer to the given σ vs ε graph. The slope in tension is greater than the slope in compression. C

Q8 A

Q9 A

Q10 Refer to the given σ vs ε graph. For steel P, greater slope means greater stiffness; less area under means lower toughness.
A

Q11 $\tau_Y = {}^{+}40000\times2 + {}^{-}F_X\times8 = 0$ for rotational equilibrium.
$\therefore F_X = 10000$ N C

Q12 $\tau_Y = {}^{+}40000\times2 + {}^{-}F_Z\times4 = 0$ for rotational equilibrium.
$\therefore F_Z = 20000$ N, $\therefore$ load $= \frac{20000}{g} = 2000$ kg. B

Q13 The underside of the section XY and the topside of the section YZ are in tension, $\therefore$ reinforcing steel rods are required.
D

Detailed study 3 − Further electronics

1	2	3	4	5	6	7	8	9	10	11	12	13
C	C	D	C	B	D	A	D	D	C	B	C	C

Q1 $\tau = RC = (5\times10^{3})(100\times10^{-6}) = 0.50$ s. C

Q2 After $\tau = 6$ s, voltage increases to 63% of 10 V, i.e. 6.3 V approx. C

Q3 After $\tau = 6$ s, voltage decreases by 63% of 10 V, down to 3.7 V approx. D

Q4 C

Q5 The plates are used as heat sinks. B

Q6 A Zener diode is connected in reversed bias when used as a voltage regulator. D

Q7 $\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{240}{10} = \frac{240\times20}{10\times20} = \frac{4800}{200}$. A

Q8 4 V/cm on the vertical scale, and 5.0 ms/cm on the horizontal scale.
$f = 50$, $T = \frac{1}{f} = \frac{1}{50}$ s $= 20$ ms $\equiv 4$ cm
Peak voltage $V_p = \sqrt{2}V_{rms} = \sqrt{2}\times10 \approx 14$ V $\cong 3.5$ cm. D

Q9 D

Q10 $\tau = RC = (400\times10^{-6})(10) = 4\times10^{-3}$ s $= 4$ ms.
The best answer is C. The ripples are much larger than that shown in the graph. The lowest voltage is approx. 37% of 14 V, i.e. 5 V.

Q11 The voltage should be around 6 V. More likely it is graph B than graph A. Refer to Q 10 and Q 13.

Q12 $P = \frac{V^2}{R} = \frac{6^2}{10} = 3.6$ W. C

Q13 Increasing the capacitance of the capacitor to a much higher value will ensure the supply voltage to the voltage regulator is well above 6 V for it to operate correctly with reduce ripple voltage at the output. C

Please inform physicsline@itute.com re conceptual, mathematical and/or typing errors

