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 $= \dfrac{F}{m} = \dfrac{7.0\times10^4}{100\times10^4} = 0.070$ 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,

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

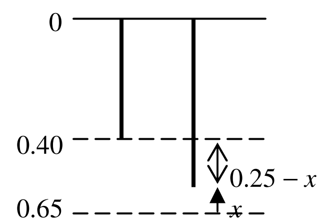
Q11 According to conservation of momentum,

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

$F_L\Delta t = F_T\Delta t$, $\therefore F_L = F_T$, 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 $F = \dfrac{GMm}{r^2}$

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

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

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

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

$= 7.20\times10^3$ 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

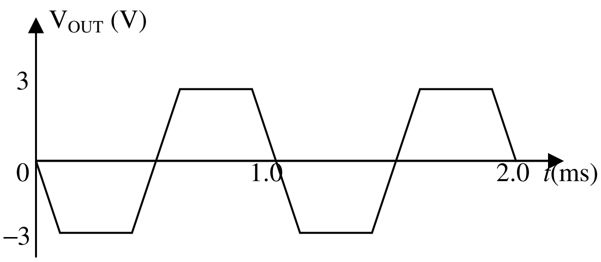
Q3 Voltage drop across $R_C = I_C R_C = 3$ mA × 1 kΩ = 3 V.
$\therefore V_Q = 6 - 3 = 3$ V.

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.

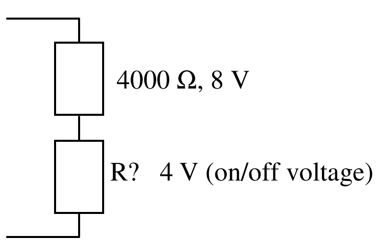
Q7



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	A	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 A short time later Nancy will be closer to Alan, and $\therefore$ the light from Alan will reach Nancy first. A

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

