2015 Physics (Revised)

Advanced Higher

Finalised Marking Instructions

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration on Earth	g	$9{\cdot}8\ \text{m s}^{-2}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Radius of Earth	R_E	$6{\cdot}4 \times 10^{6}$ m	Charge on electron	e	$-1{\cdot}60 \times 10^{-19}$ C
Mass of Earth	M_E	$6{\cdot}0 \times 10^{24}$ kg	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Mass of Moon	M_M	$7{\cdot}3 \times 10^{22}$ kg	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Radius of Moon	R_M	$1{\cdot}7 \times 10^{6}$ m	Mass of alpha particle	$m_\propto$	$6{\cdot}645 \times 10^{-27}$ kg
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}$ m	Charge on alpha particle		$3{\cdot}20 \times 10^{-19}$ C
Solar radius		$6{\cdot}955 \times 10^{8}$ m	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ Js
Mass of Sun		$2{\cdot}0 \times 10^{30}$ kg	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\ \text{Fm}^{-1}$
1 AU		$1{\cdot}5 \times 10^{11}$ m	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \text{Hm}^{-1}$
Stefan-Boltzmann constant	σ	$5{\cdot}67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}\ \text{m s}^{-1}$
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\text{s}^{-2}$	Speed of sound in air	v	$3{\cdot}4 \times 10^{2}\ \text{m s}^{-1}$

REFRACTIVE INDICIES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49	Magnesium Fluoride	1·38

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*	*Element*	*Wavelength*/nm	*Colour*
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	*Lasers*		
	397	Ultraviolet	*Element*	*Wavelength*/nm	*Colour*
	389	Ultraviolet	Carbon dioxide	9550 10590	Infrared
Sodium	589	Yellow	Helium-neon	633	Red

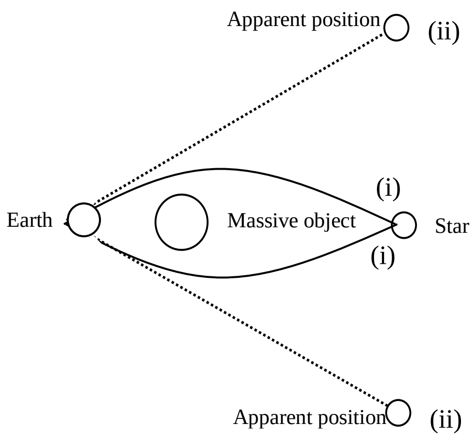
PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/ kg m^{-3}	*Melting Point*/K	*Boiling Point*/K	*Specific Heat Capacity*/ J kg^{-1} K^{-1}	*Specific Latent Heat of Fusion*/ J kg^{-1}	*Specific Latent Heat of Vaporisation* /J kg^{-1}
Aluminium	$2{\cdot}70 \times 10^3$	933	2623	$9{\cdot}02 \times 10^2$	$3{\cdot}95 \times 10^5$	….
Copper	$8{\cdot}96 \times 10^3$	1357	2853	$3{\cdot}86 \times 10^2$	$2{\cdot}05 \times 10^5$	….
Glass	$2{\cdot}60 \times 10^3$	1400	….	$6{\cdot}70 \times 10^2$	….	….
Ice	$9{\cdot}20 \times 10^2$	273	….	$2{\cdot}10 \times 10^3$	$3{\cdot}34 \times 10^5$	….
Gylcerol	$1{\cdot}26 \times 10^3$	291	563	$2{\cdot}43 \times 10^3$	$1{\cdot}81 \times 10^5$	$8{\cdot}30 \times 10^5$
Methanol	$7{\cdot}91 \times 10^2$	175	338	$2{\cdot}52 \times 10^3$	$9{\cdot}9 \times 10^4$	$1{\cdot}12 \times 10^6$
Sea Water	$1{\cdot}02 \times 10^3$	264	377	$3{\cdot}93 \times 10^3$	….	….
Water	$1{\cdot}00 \times 10^3$	273	373	$4{\cdot}19 \times 10^3$	$3{\cdot}34 \times 10^5$	$2{\cdot}26 \times 10^6$
Air	$1{\cdot}29$	….	….	….	….	….
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^4$	….	$4{\cdot}50 \times 10^5$
Nitrogen	$1{\cdot}25$	63	77	$1{\cdot}04 \times 10^3$	….	$2{\cdot}00 \times 10^5$
Oxygen	$1{\cdot}43$	55	90	$9{\cdot}18 \times 10^2$	….	$2{\cdot}40 \times 10^5$

The gas densities refer to a temperature of 273 K and pressure of $1{\cdot}01 \times 10^5$ Pa.

Part Two: Marking Instructions for each Question

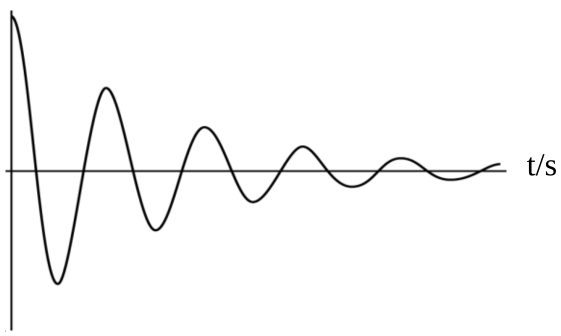
Question			Expected Answer/s	Max Mark	Additional Guidance
1	**a**		$I = \frac{1}{2}mr^2$ **(½)** $\frac{16 \times 0 \cdot 30^2}{2}$ **(½)** $= 0 \cdot 72$ kg m^2 **(1)**	**2**	
1	**b**	**i**	$\omega = \frac{v}{r} = \frac{3 \cdot 0}{0 \cdot 30} = 10\left(\text{rad s}^{-1}\right)$ **(½)+(½)** $\omega^2 = \omega_o{}^2 + 2\alpha\theta$ **(½)** $0 = 10^2 + 2 \times \alpha \times \left(2\pi \times 5\right)$ **(½)** $\alpha = -1 \cdot 6$ rad s^{-2} **(1)**	**3**	Alternative method possible: Calculate linear displacement (9·42 m), use to find acceleration, then convert to angular at end.
1	**b**	**ii**	Torque $= I\alpha$ **(½)** $= 0 \cdot 72 \times 1 \cdot 6$ **(½)** $= (-)1 \cdot 2$ N m **(1)**	**2**	
1	**c**		The speed of the mass will be less (than 3·0m s^{-1}) **(1)** Second mark for correct justification. eg: • Flywheel has greater moment of inertia • Flywheel will be more difficult to start moving • Smaller acceleration of flywheel • More energy required to achieve same angular velocity. **(1)**	**2**	**Must justify first statement or (0).**
1	**d**	**i**	$I = ½ \times 6 \cdot 0 \times (0 \cdot 15^2 + 0 \cdot 20^2)$ **(½)** $I = 0 \cdot 19$ kg m^2 **(½)**	**1**	

Question			Expected Answer/s	Max Mark	Additional Guidance
1	d	ii	$\omega = \frac{\theta}{t}$ **(½)** $\omega = \frac{6\cdot0\times10^4\times2\pi}{60}$ $\omega = 2000\pi\,(\text{rad s}^{-1})$ **(½)** $E_{krot} = ½I\omega^2$ **(½)** $= ½ \times 0\cdot19 \times (2000\pi)^2$ **(½)** $= 3\cdot8 \times 10^6$ J **(1)**	3 **(13)**	
2	a		Massive objects curve spacetime **(1)** Other objects follow a curved path through this (distorted) spacetime **(1)**	2	The Earth curves spacetime (because of its mass) **(1)** The moon follows a geodesic **(1)** Classical version **(0)**
2	b	i	Curved path around massive object (curve must be shown)	1	 (no arrows required)
2	b	ii	light beam from apparent position to observer	1	
2	c		B **(1)** Time passes more slowly at lower altitudes (in a gravitational field). **(1)** **or** Lower gravitational field strength at higher altitude. **(1)**	2 **(6)**	Must have justification for first mark.

Question			Expected Answer/s	Max Mark	Additional Guidance
3	**a**		$b = \frac{L}{4\pi r^2}$ **(½)** $b = 3{\cdot}9 \times 10^{26}/4\pi(1{\cdot}5 \times 10^{11})^2$ **(½)** $b = 1{\cdot}4 \times 10^{3}\ \mathrm{Wm^{-2}}$ **(1)**	**2**	
3	**b**		$10^{0\cdot2(m-M)} = \frac{d}{10}$ $10^{0\cdot2(5\cdot62-(-4\cdot38))} = \frac{d}{10}$ **(1)** d = 1000 (pc) **(1)** d = 1000 × 3·26 **(½)** = 3260 (ly) **(½)**	**3** **(5)**	

Question			Expected Answer/s	Max Mark	Additional Guidance
4			Demonstrates no understanding **(0)** Limited understanding **(1)** Reasonable understanding **(2)** Good understanding **(3)** This is an open-ended question. **1 mark:** The student has demonstrated a limited understanding of the physics involved. The student has made some statement(s) which is/are relevant to the situation, showing that at least a little of the physics within the problem is understood. **2 marks**: The student has demonstrated a reasonable understanding of the physics involved. The student makes some statement(s) which is/are relevant to the situation, showing that the problem is understood. **3 marks:** The maximum available mark would be awarded to a student who has demonstrated a good understanding of the physics involved. The student shows a good comprehension of the physics of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one.	**(3)**	Open ended question – a variety of Physics arguments can be used to answer this question. Marks are awarded on the basis of whether the answer, overall, demonstrates 'no', 'limited', 'reasonable' or 'good' understanding.

Question			Expected Answer/s	Max Mark	Additional Guidance
5	a	i	$L = 1 \times 10^{-2}$ solar luminosities (from diagram) **(½)** $L = 1 \times 10^{-2} \times 3{\cdot}9 \times 10^{26} = 3{\cdot}9 \times 10^{24}$ (W) **(½)**	1	
5	a	ii	T = 3000 K (from diagram) **(½)** $L = 4\pi r^2 \sigma T^4$ **(½)** $3{\cdot}9 \times 10^{24} = 4\pi r^2 \times 5{\cdot}67 \times 10^{-8} \times 3000^4$ **(1)** $r = 2{\cdot}6 \times 10^8$ m $= 3 \times 10^8$ m 1 s.f.		
5	a	iii	Difficult scale to read/information from diagram can only be read to 1 s.f.	1	
5	b	i	$f_{peak} = \dfrac{2{\cdot}8 k_b \mathrm{T}}{h}$ T=3000 K **(½)** $f_{peak} = \dfrac{2{\cdot}8 \times 1{\cdot}38 \times 10^{-23} \times 3000}{6{\cdot}63 \times 10^{-34}}$ **(½)** $f_{peak} = 2 \times 10^{14}$ Hz **(1)**	2	
5	b	ii	$v = f\lambda$ **(½)** $3{\cdot}0 \times 10^8 = f \times 1{\cdot}9 \times 10^{-3}$ **(½)** $f = 1{\cdot}6 \times 10^{11}$ (Hz) **(½)** $f_{peak} = \dfrac{2{\cdot}8 k_b \mathrm{T}}{h}$ $1{\cdot}6 \times 10^{11} = \dfrac{2{\cdot}8 \times 1{\cdot}38 \times 10^{-23} \mathrm{T}}{6{\cdot}63 \times 10^{-34}}$ **(½)** T=2·7 K **(1)**	3	
5	c		$\mathrm{M_{black\,hole}} = 2{\cdot}0 \times 10^{30} \times 1{\cdot}0 \times 10^{-10} = 2{\cdot}0 \times 10^{20}\,(\mathrm{kg})$ **(1)** $\mathrm{r_{Schwarzschild}} = \dfrac{2\mathrm{GM}}{\mathrm{c}^2}$ **(½)** $\mathrm{r_{Schwarzschild}} = \dfrac{2 \times 6{\cdot}67 \times 10^{-11} \times 2{\cdot}0 \times 10^{20}}{(3{\cdot}0 \times 10^8)^2}$ **(½)** $\mathrm{r_{Schwarzschild}} = 3{\cdot}0 \times 10^{-7}\,\mathrm{m}$ **(1)**	3 **(12)**	

Question			Expected Answer/s	Max Mark	Additional Guidance
6	**a**	**i**	Force acting on (acceleration of) object is directly proportional to and in the opposite direction to its displacement. (from equilibrium) *Mark is 1 or 0.*	**1**	
6	**a**	**ii**	$y = A\sin\omega t$ $\frac{dy}{dt} = A\omega\cos\omega t$ **(½)** $\frac{d^2y}{dt^2} = -A\omega^2\sin\omega t$ **(½)** $\frac{d^2y}{dt^2} = -\omega^2 y$ **(1)**	**2**	
6	**a**	**iii**	(Cos used when at $t = 0$) displacement is a maximum (A).	**1**	
6	**b**	**i**	$\omega = \frac{2\pi}{T}$ **or** $\omega = 2\pi f$ **(½)** $\omega = \left(\frac{2\pi}{0\cdot 50} = \right) 4\pi$ (= 12·6) (rad s^{-1}) **(½)** $v = (\pm)\omega\sqrt{A^2 - y^2}$ **(½)** $v = (\pm)4\pi\sqrt{0\cdot 05^2 - 0^2}$ **(½)** v = 0·63 m s^{-1} **(1)**	**3**	Alternative : differentiate $y = A\sin\omega t$ $v = A\omega\cos\omega t$ **(½)** = 0·05 × 4π × cos(0·5 × 4π) **(½)** = 0·63 m s^{-1} **(1)** $v_{max} = A\omega$ **(½)** = 0·05 × 4π **(½)** = 0·63 m s^{-1} **(1)**
6	**b**	**ii**	$a = (\pm)\omega^2 y$ **or** $(\pm)\omega^2 A$ **(½)** = $(4\pi)^2$ × 0·050 **(½)** = (±)7·9 m s^{-2} **(1)**	**2**	
6	**c**			**1** **(10)**	

Question			Expected Answer/s	Max Mark	Additional Guidance
7	a	i	$\lambda = \frac{h}{p}$ $\lambda = \frac{h}{mv}$ $\lambda = \frac{6 \cdot 63 \times 10^{-34}}{9 \cdot 11 \times 10^{-31} \times 3 \cdot 2 \times 10^{6}}$ **(½)** $\lambda = 2 \cdot 3 \times 10^{-10}\,(\text{m})$ **(½)** ------------------------------ $\Delta x \Delta p \geq \frac{\text{h}}{4\pi}$ **(½)** $2 \cdot 3 \times 10^{-10} \Delta p \geq \frac{6 \cdot 63 \times 10^{-34}}{4\pi}$ **(½)** $\Delta p \geq 2 \cdot 3 \times 10^{-25}\,\text{kg ms}^{-1}$ (Ns) **(1)**	3	
7	a	ii	λ reduced (or f increased) for X-rays, or >E transferred **(½)** Δx reduced for X-rays **(½)** Since $\Delta x \Delta p \geq \frac{\text{h}}{4\pi}$ **(½)** Δp increases **(½)**	2	
7	b		Since $\Delta E \Delta t \geq \frac{\text{h}}{4\pi}$ **(1)** Borrowing energy for a short period of time allows particles to escape **(1)**	2 **(7)**	

Question			Expected Answer/s	Max Mark	Additional Guidance
8	a	i	Two sets of coherent waves are necessary (for an interference pattern) **or** (Interference patterns can be produced by) Division of wavefront.	1	
8	a	ii	$(\Delta x = \frac{L}{6}) = 0\cdot011$ (m) **(1)** --- $\Delta x = \frac{\lambda D}{d}$ **(½)** $0\cdot011 = \frac{\lambda \times 4\cdot250}{0\cdot25 \times 10^{-3}}$ **(½)** $\lambda = 6\cdot5 \times 10^{-7}$ m **(1)**	3	
8	a	iii	% unc in $D = \frac{0\cdot005}{4\cdot250} \times 100 = 0\cdot12\%$ **(½)** % unc in $L = \frac{2}{67} \times 100 = 3\cdot0\%$ **(½)** % unc in $d = \frac{0\cdot01}{0\cdot25} \times 100 = 4\cdot0\%$ **(½)** Total % unc = $(3\cdot0^2 + 4\cdot0^2)^{½}$ $= 5\cdot0\%$ **(½)** Absolute unc = $0\cdot05 \times 6\cdot5 \times 10^{-7}$ $= 3 \times 10^{-8}$ m **(1)**	3	
8	b		% uncertainty in λ is greater **(1)** L (or Δx) will be less **or** **(1)** % uncertainty in L (or Δx) will be greater	2 **(9)**	

Question			Expected Answer/s	Max Mark	Additional Guidance
9	**a**	**i**	Force acts on particle at right angles to the direction of its velocity/motion **or** a central force on particle.	**1**	
9	**a**	**ii**	$\frac{mv^2}{r} = Bqv$ **(½)** for both equations and **(½)** for equality $r = \frac{mv}{Bq}$ $r = \frac{1\cdot673\times10^{-27}\times v}{B\times1\cdot6\times10^{-19}}$ **(½)** **(½)** $r = \frac{1\cdot05\times10^{-8}v}{B}$	**2**	
9	**b**		(Component of) velocity at right angles to field/ $v \sin\theta$, results in circular motion/central force. **(1)** (Component of) velocity parallel to field/ $v\cos\theta$ is constant/no unbalance force (in this direction). **(1)**	**2**	
9	**c**	**i**	$f = 4\cdot0$ Hz, $T = 1/f = 0\cdot25$ s **(½)** time between mirror points = 0·125 s **(½)** - - - - - - - - - - - - - - - - $d = vt$ **(½)** $= 1\cdot2\times10^7\times0\cdot125$ **(½)** $= 1\cdot5\times10^6$ m **(1)**	**3**	
9	**c**	**ii**	Magnetic field strength has decreased.	**1**	
9	**c**	**iii**	$r = \frac{1\cdot05\times10^{-8}v}{B}$ **(½)** $1\cdot0\times10^4 = \frac{1\cdot05\times10^{-8}\times1\cdot2\times10^7}{B}$ **(½)** $B = 1\cdot3\times10^{-5}$ T **(1)**	**2** **(11)**	

Question			Expected Answer/s	Max Mark	Additional Guidance
10	**a**	**i**	Force exerted per (unit) charge is constant at any point in the field.	**1**	
10	**a**	**ii**	E = gradient of line **or** $= \frac{y_2 - y_1}{x_2 - x_1}$ **(½)** $= \frac{3000 - 1000}{0{\cdot}124 - 0{\cdot}044}$ **(½)** $= 25000 \text{ V m}^{-1}$ **(1)** (Care with units, 0·025 kVmm^{-1} correct)	**2**	.
10	**a**	**iii**	$E = \frac{V}{d}$ **(½)** $25000 = \frac{5000}{d}$ **(½)** d = 0·20 m (200 mm) **(1)**	**2**	
10	**a**	**iv**	Any suitable answer eg • Systematic uncertainty in measuring *d or V* • Alignment of metre stick • The flame has a finite thickness so cannot get exactly to the zero point. • Factors causing field to be non-uniform. • A p.d. across the resistor for all readings. • Poor calibration of instruments measuring *V or d*.	**1**	
10	**b**		Deflection is less **(1)** E is less **(½)** Force/acceleration is less **(½)**	**2** **(8)**	

Question			Expected Answer/s	Max Mark	Additional Guidance
11			Demonstrates no understanding **(0)** Limited understanding **(1)** Reasonable understanding **(2)** Good understanding **(3)** This is an open-ended question. **1 mark:** The student has demonstrated a limited understanding of the physics involved. The student has made some statement(s) which is/are relevant to the situation, showing that at least a little of the physics within the problem is understood. **2 marks**: The student has demonstrated a reasonable understanding of the physics involved. The student makes some statement(s) which is/are relevant to the situation, showing that the problem is understood. **3 marks:** The maximum available mark would be awarded to a student who has demonstrated a good understanding of the physics involved. The student shows a good comprehension of the physics of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one.	**(3)**	Open ended question – a variety of Physics arguments can be used to answer this question. Marks are awarded on the basis of whether the answer, overall, demonstrates 'no', 'limited', 'reasonable' or 'good' understanding.

Question			Expected Answer/s	Max Mark	Additional Guidance
12	**a**	**i**	**Circuit must be able to make required measurements as shown or zero marks**. **Variable frequency supply, inductor, ammeter in series** **Voltmeter in parallel with supply to monitor constant voltage**	**2**	
12	**a**	**ii**	k values are 5·9 6·1 6·1 5·8 6·0 All k values correct **(1½)** I inversely proportional to f **(½)**	**2**	
12	**b**	**i**	V_s = 20 (V). **(½)** $V_R = 20 – 9$ **(½)** $= 11$ V **(1)**	**2**	
12	**b**	**ii**	$E = - L\, dI/dt$ **(½)** $-4{\cdot}2 = -3 \times dI/dt$ **(½)** $dI/dt = 1{\cdot}4$ A s^{-1} **(1)**	**2**	
12	**b**	**iii**	Rate of change of current/magnetic field is at its maximum	**1**	

Question			Expected Answer/s	Max Mark	Additional Guidance
12	**c**	**i**	for eqns + for equality **(1)** $2\pi f_0 L = \frac{1}{2\pi f_0 C}$ $f_0 = \frac{1}{2\pi\sqrt{LC}}$	**1**	
12	**c**	**ii**	$f_0 = \frac{1}{2\pi\sqrt{LC}}$ $f_0 = \frac{1}{2\pi\sqrt{2\cdot 2\times 10^{-3}\times 4\cdot 7\times 10^{-6}}}$ **(1)** = 1600 Hz **(1)**	**2**	
12	**c**	**iii**	$4\cdot 0\Omega$	**1** **(13)**	

[END OF MARKING INSTRUCTIONS]