Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number

Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 45 minutes

Paper reference **WPH15/01**

Physics

International Advanced Level
UNIT 5: Thermodynamics, Radiation, Oscillations and Cosmology

You must have:
Scientific calculator

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- **Show all your working out** in calculations and **include units** where appropriate.

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- The list of data, formulae and relationships is printed at the end of this booklet.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

P71881A

Q:1/1/1/

P 7 1 8 8 1 A 0 1 3 6

Pearson

SECTION A

Answer ALL the questions in this section.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The luminosity axis of a Hertzsprung-Russell diagram has a logarithmic scale.

Which of the following is the reason for this?

☐ **A** Stars all have very large luminosities.

☐ **B** The range of luminosities of stars is very large.

☐ **C** The range of distances to stars is very large.

☐ **D** The temperature axis has a logarithmic scale.

(Total for Question 1 = 1 mark)

2 A mass is hung from a spring and set into vertical oscillation. The mass is then changed so that the frequency of oscillation doubles. The amplitude of the oscillation is unchanged.

Which of the following quantities is also doubled?

☐ **A** the maximum acceleration of the mass

☐ **B** the maximum kinetic energy of the mass

☐ **C** the maximum velocity of the mass

☐ **D** the period of the oscillation

(Total for Question 2 = 1 mark)

3 Which of the following does **not** have the base unit s^{-1}?

☐ **A** angular velocity

☐ **B** frequency

☐ **C** redshift

☐ **D** rate of decay

(Total for Question 3 = 1 mark)

4 A communications satellite has a mass of 935 kg. The satellite has an orbital radius four times the radius of the Earth.

Which of the following gives the gravitational pull of the Earth on the satellite in its orbit?

☒ **A** 0 N

☒ **B** 570 N

☒ **C** 2300 N

☒ **D** 9200 N

(Total for Question 4 = 1 mark)

5 Which row of the table gives the conditions required in the core of a star for fusion to be sustained?

		Density	Temperature
☒	**A**	moderate	moderate
☒	**B**	moderate	very high
☒	**C**	very high	moderate
☒	**D**	very high	very high

(Total for Question 5 = 1 mark)

6 The gravitational field strength at the surface of the Earth is g.

Another planet has the same density as the Earth, but twice the radius of the Earth.

What is the gravitational field strength at the surface of this planet?

☒ **A** $4g$

☒ **B** $2g$

☒ **C** $\frac{g}{2}$

☒ **D** $\frac{g}{4}$

(Total for Question 6 = 1 mark)

7 A fixed mass of a gas occupies a constant volume. The temperature of the gas is increased.

Which of the following is **not** true?

☒ **A** The internal energy of the gas increases.

☒ **B** The mean kinetic energy of the molecules increases.

☒ **C** The mean momentum of the molecules increases.

☒ **D** The pressure exerted by the gas increases.

(Total for Question 7 = 1 mark)

8 Boyle's law states that, under certain conditions, the pressure exerted by a gas is inversely proportional to the volume occupied by the gas.

Which of the following conditions is **not** necessary?

☒ **A** The gas must be ideal.

☒ **B** The mean kinetic energy of the molecules must stay constant.

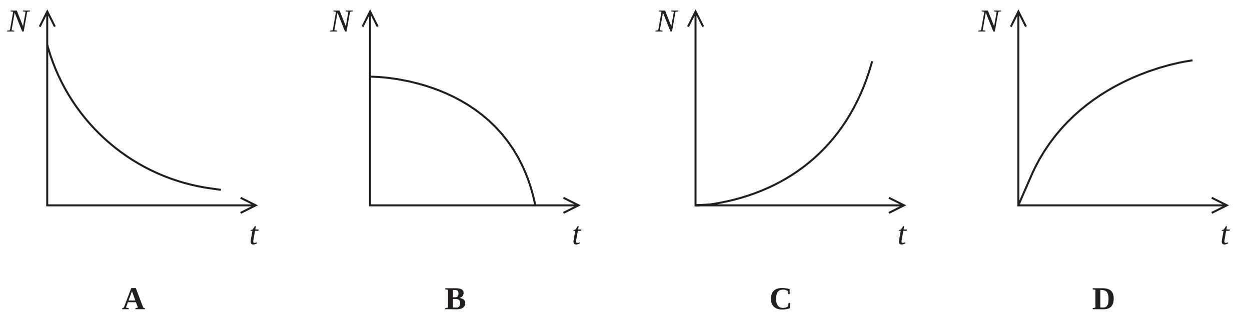
☒ **C** The molecules in the gas must be identical.

☒ **D** The number of molecules in the gas must stay constant.

(Total for Question 8 = 1 mark)

9 Bismuth decays to form a stable isotope of thallium.

Which graph shows how the number N of thallium atoms in a sample of bismuth varies with time t?



☒ **A**

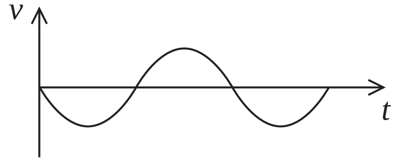
☒ **B**

☒ **C**

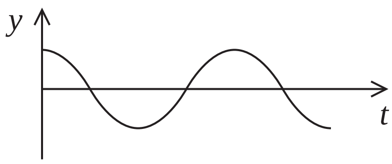
☒ **D**

(Total for Question 9 = 1 mark)

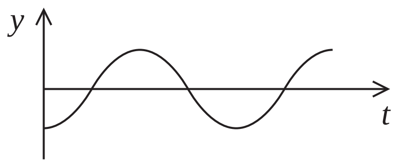
10 A mass oscillates with simple harmonic motion. The graph shows how the velocity v varies with time t for the mass.



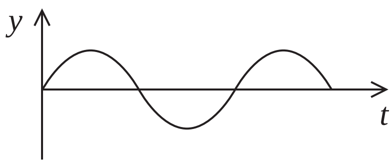
Which graph shows how the displacement y from the equilibrium position varies with t over the same time interval?



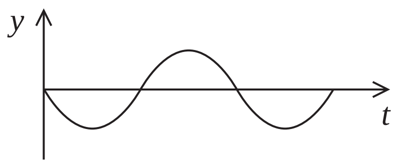
A



B



C



D

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 A standard candle in the galaxy M81 has a luminosity 14 800 times the luminosity of the Sun. The intensity of radiation received from the standard candle, measured at the top of the Earth's atmosphere, is $3.64 \times 10^{-17}\,\mathrm{W\,m^{-2}}$.

Calculate the distance of the M81 galaxy from Earth.

$L_{\mathrm{Sun}} = 3.83 \times 10^{26}\,\mathrm{W}$

Distance of M81 from Earth = ...

(Total for Question 11 = 3 marks)

12 Astronomers often use the unit megaparsec (Mpc) for astronomical distances. In a textbook a value for the Hubble constant is given as $72\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$.

(a) (i) Show that $72\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$ is equivalent to a Hubble constant of about $2.3 \times 10^{-18}\,\text{s}^{-1}$.

$1\,\text{Mpc} = 3.09 \times 10^{22}\,\text{m}$

(2)

....

....

....

....

....

(ii) Determine a value for the age of the universe in years.

$1\text{ year} = 3.16 \times 10^{7}\,\text{s}$

(2)

....

....

....

....

Age of universe = ... years

(b) In the 1950s, astronomers realised that they had made an error in their determination of distances to galaxies. Galaxies are twice as far away as astronomers had previously thought.

Explain how this changed the age of the universe as calculated by astronomers.

(2)

....

....

....

....

(Total for Question 12 = 6 marks)

13 Potassium-40 (^{40}K) is a radioactive isotope. ^{40}K can decay by β^- emission.

(a) Complete the nuclear equation for the decay of ^{40}K by β^- emission.

$$^{40}_{\ldots\ldots}K \rightarrow {}^{\ldots\ldots}_{20}Ca + {}^{\ldots\ldots}_{\ldots\ldots}\beta^- + {}^{0}_{0}\bar{v}$$

(2)

(b) Occasionally ^{40}K decays by emitting a β^+ particle.

Give two similarities between a β^- particle and a β^+ particle.

(2)

....

....

....

....

(c) A fertiliser contains potassium chloride. The activity of a sample of the fertiliser due to radioactive potassium was 48.6 Bq.

It is claimed that the time *t* taken for the activity of the sample to fall below the background count rate would be more than 9×10^9 years.

Deduce whether this claim is correct.

background count rate = 0.42 Bq
half-life of ^{40}K = 1.25×10^9 years

(3)

....

....

....

....

....

....

....

(Total for Question 13 = 7 marks)

***14** A teacher is teaching her class about the phenomenon of resonance. To do this, she uses a drinking glass to produce sound in two different ways.

When the glass is gently struck, the glass emits sound for a short time.

When a wet finger is slid around the top of the glass, it is possible to produce a loud continuous sound.

Explain these observations.

(Total for Question 14 = 6 marks)

15 A nucleus of polonium-210 decays to lead-206 by emitting an alpha particle. The masses of the particles are shown in the table.

	Mass / kg
Polonium-210	3.48572×10^{-25}
Lead-206	3.41918×10^{-25}
Alpha particle	6.64437×10^{-27}

(a) (i) Show that the energy released in the decay is about 9×10^{-13} J.

(3)

....

....

....

....

....

....

(ii) 98% of the energy from the decay is released as kinetic energy of the alpha particle.

Calculate the velocity of the alpha particle immediately after the decay.

(2)

....

....

....

....

Velocity of alpha particle = ...

DO NOT WRITE IN THIS AREA

(b) Explain why not all of the energy from the decay is released as kinetic energy of the alpha particle.

(2)

....

....

....

....

(Total for Question 15 = 7 marks)

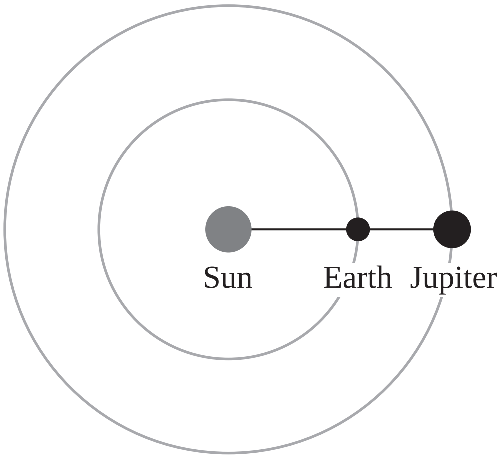
16 The planets orbit the Sun in approximately circular orbits. The orbital time T of a planet is related to the average distance r of the planet from the Sun.

(a) (i) Show that T is related to r by the expression:

$$T^2 \propto r^3$$

(3)

(ii) When planets align as they orbit the Sun they are said to be 'in opposition'.
The diagram shows the Earth and Jupiter in opposition.



NOT TO SCALE

A website states that the Earth and Jupiter are in opposition every 13 months.

Deduce whether this statement is correct.

mean distance from Earth to Sun = 1.5×10^{11} m
mean distance from Jupiter to Sun = 7.8×10^{11} m
T_{Earth} = 12 months

(5)

....

....

....

....

....

....

....

....

....

....

....

(b) The distance of Jupiter from the Sun varies from 7.4×10^{11} m to 8.2×10^{11} m.

Calculate the change in gravitational potential energy of Jupiter as it moves from its closest distance to its furthest distance from the Sun.

mass of Sun = 2.0×10^{30} kg
mass of Jupiter = 1.9×10^{27} kg

(3)

Change in gravitational potential energy = ...

(Total for Question 16 = 11 marks)

BLANK PAGE

17 A man is about to dive into the sea from a high diving board. The board is horizontal before he walks to the end of the board.

When the man stands on the end of the board, it bends as shown.

(Source: © Fuse/Getty Images)

(a) By pushing on the board, the man displaces the end of the board a small distance downwards. The man and the board then oscillate with approximate simple harmonic motion.

State the conditions for simple harmonic motion.

(2)

....

....

....

....

(b) The man stands at the end of the board. The board is in equilibrium when the end of the board has a vertical displacement of 18 cm.

mass of man = 75 kg

(i) The board obeys Hooke's law as it deforms.

Show that the stiffness of the diving board is about 4000 $N\,m^{-1}$.

(2)

....

....

....

....

(ii) Calculate the frequency of oscillation of the man on the board. Ignore the mass of the board.

(3)

Frequency of oscillation = ...

(c) If the amplitude of oscillation is large enough, the man will lose contact with the board at a point above the equilibrium position.

Explain why.

(3)

(Total for Question 17 = 10 marks)

BLANK PAGE

18 Wolf 359 is a red dwarf star. The distance of the star from Earth was first determined from parallax measurements made by the astronomer Max Wolf.

(a) (i) The parallax angle was 2.01×10^{-6} rad.

Calculate the distance, in metres, of Wolf 359 from Earth.

mean distance from Earth to Sun = 1.50×10^{11} m

(2)

....

....

....

....

....

....

Distance of Wolf 359 from Earth = ... m

(ii) Explain why parallax measurements can only be used to determine the distances to a relatively small number of stars.

(2)

....

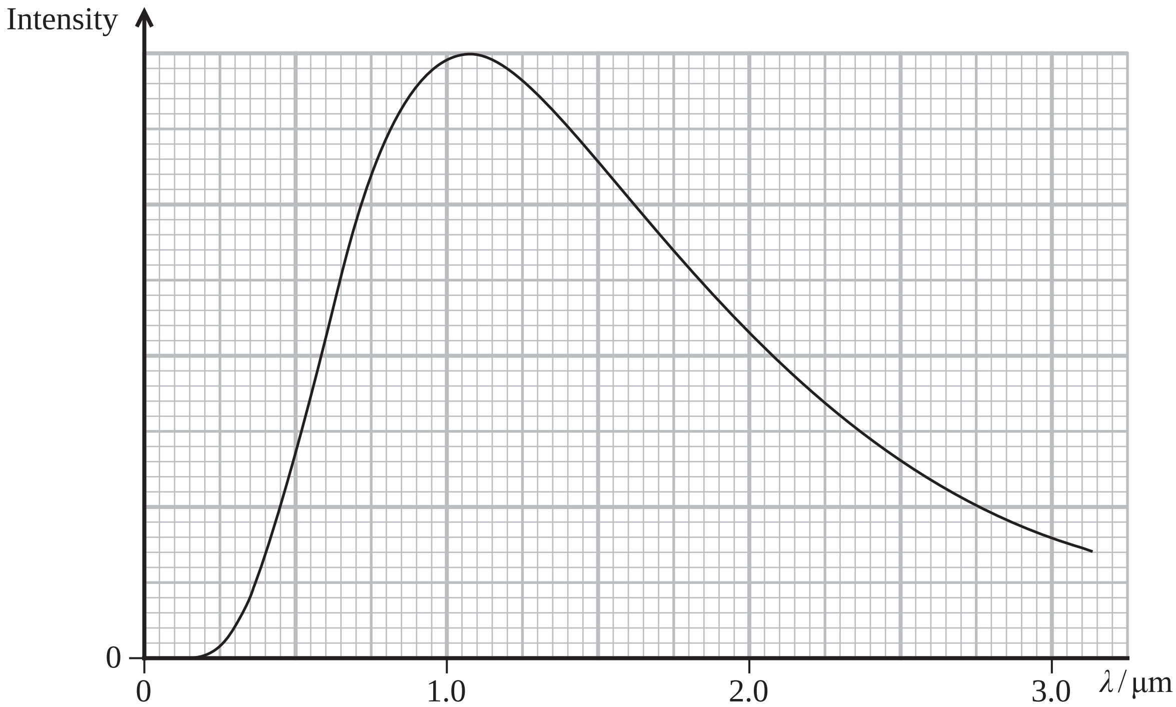
....

....

....

....

(b) The graph shows how the intensity of radiation from the star Wolf 359 varies with wavelength.



(i) Show that the surface temperature of Wolf 359 is about 2700 K.

(3)

....

....

....

....

(ii) The radius of the Sun is R_{Sun}. The radius of Wolf 359 is $0.16\,R_{Sun}$.

It is claimed that the luminosity of Wolf 359 is less than 0.1% of the luminosity of the Sun, L_{Sun}.

Deduce whether this claim is correct.

$R_{Sun} = 6.96 \times 10^{8}\,\text{m}$
$L_{Sun} = 3.83 \times 10^{26}\,\text{W}$
$T = 2700\,\text{K}$

(3)

....

....

....

....

....

....

(Total for Question 18 = 10 marks)

19 The spectrum of light emitted by the star Chi Lupi provides evidence of mercury atoms in the outer layers of the star. The light emitted from the star is compared with light emitted from a mercury lamp on Earth.

(a) The lamp contains 1.65×10^{19} mercury atoms in a volume of $1.50 \times 10^{-5}\,\text{m}^3$. The pressure of the mercury vapour is $4.25 \times 10^4\,\text{Pa}$.

Calculate the mean kinetic energy of the mercury atoms.

(3)

....

....

....

....

....

....

Mean kinetic energy of mercury atoms = ...

(b) One line in the spectrum of light from Chi Lupi has a wavelength of 576.933 nm. The equivalent line in a mercury spectrum produced on Earth is 576.959 nm.

A student concluded from this data that Chi Lupi is moving towards the Earth, and that the relative velocity of Chi Lupi is about $1400\,\text{m}\,\text{s}^{-1}$.

Deduce whether the student's conclusions are correct.

(4)

....

....

....

....

....

....

....

....

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(c) The surface temperature of Chi Lupi is twice the surface temperature of the Sun.
The radius of Chi Lupi is three times the radius of the Sun.

State where Chi Lupi would be located on the Hertzsprung-Russell diagram.

(1)

....

....

(Total for Question 19 = 8 marks)

BLANK PAGE

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

20 Lead shot consists of small lead spheres.

Originally lead shot was made by dripping molten lead through a copper sieve from the top of a 'shot tower'. The lead cooled as it fell, before landing in water and producing solid lead spheres. Figure 1 shows a shot tower, and figure 2 shows the process of making lead shot in a shot tower.

(Source: © Espresso Addict)

Figure 1

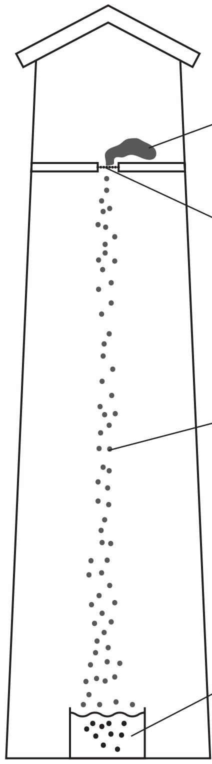


Figure 2

To avoid producing steam, the temperature of a lead sphere was below 100 °C as it reached the cold water.

(a) (i) A lead sphere falls through a distance of 41.5 m.

Show that it takes about 3 s for the lead sphere to fall through this distance. Assume that resistive forces are negligible.

(2)

....

....

....

....

....

(ii) The lead sphere has a radius of 1.2 mm. As it falls it cools from 615 K to 370 K. The molten lead solidifies at 601 K.

Calculate the mean rate at which energy is transferred from the lead sphere to the surroundings. You should assume that the specific heat capacities of liquid lead and solid lead are the same.

density of lead = $1.13 \times 10^4\,\mathrm{kg\,m^{-3}}$
specific latent heat of lead = $2.47 \times 10^4\,\mathrm{J\,kg^{-1}}$
specific heat capacity of lead = $130\,\mathrm{J\,kg^{-1}\,K^{-1}}$

(6)

....

....

....

....

....

....

....

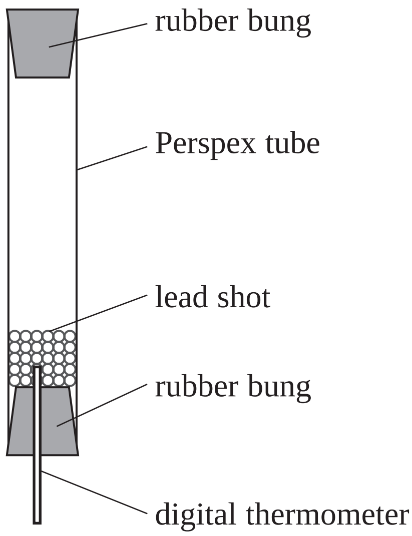
....

....

....

Mean rate of energy transfer from lead = ...

(b) A teacher demonstrates a mechanical method to determine the specific heat capacity of lead. Some lead shot at room temperature is placed in a Perspex tube.



The teacher turns the tube upside down, and the lead shot falls through a distance d.

The teacher repeats this N times and measures the final temperature of the lead shot. The change in temperature $\Delta\theta$ of the lead shot is calculated.

The teacher uses the values of d, N and $\Delta\theta$ to determine a value for the specific heat capacity c of the lead.

(i) Explain why the mass of lead shot in the tube should not affect the value of $\Delta\theta$.

(2)

....

....

....

....

....

(ii) Assess whether this method would produce an accurate value for c.

(2)

....

....

....

....

....

(Total for Question 20 = 12 marks)

TOTAL FOR SECTION B = 80 MARKS

TOTAL FOR PAPER = 90 MARKS

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9} \text{ N m}^{2} \text{ C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19} \text{ C}$	
Electron mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$	
Electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	
Gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^{2} \text{ kg}^{-2}$	
Gravitational field strength	$g = 9.81 \text{ N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27} \text{ kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8} \text{ m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27} \text{ kg}$	

Unit 1

Mechanics

Kinematic equations of motion

$$s = \frac{(u+v)t}{2}$$

$$v = u + at$$

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

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

Momentum

$$p = mv$$

Moment of force

$$\text{moment} = Fx$$

Work and energy

$$\Delta W = F\Delta s$$

$$E_k = \frac{1}{2}mv^2$$

$$\Delta E_{grav} = mg\Delta h$$

Power

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

Efficiency

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Materials

Density $\rho = \dfrac{m}{V}$

Stokes' law $F = 6\pi\eta rv$

Hooke's law $\Delta F = k\Delta x$

Elastic strain energy $\Delta E_{el} = \dfrac{1}{2}F\Delta x$

Young modulus $E = \dfrac{\sigma}{\varepsilon}$ where

Stress $\sigma = \dfrac{F}{A}$

Strain $\varepsilon = \dfrac{\Delta x}{x}$

Unit 2

Waves

Wave speed $v = f\lambda$

Speed of a transverse wave on a string $v = \sqrt{\frac{T}{\mu}}$

Intensity of radiation $I = \frac{P}{A}$

Refractive index $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n = \frac{c}{v}$

Critical angle $\sin C = \frac{1}{n}$

Diffraction grating $n\lambda = d\sin\theta$

Electricity

Potential difference $V = \frac{W}{Q}$

Resistance $R = \frac{V}{I}$

Electrical power, energy $P = VI$

$P = I^2R$

$P = \frac{V^2}{R}$

$W = VIt$

Resistivity $R = \frac{\rho l}{A}$

Current $I = \frac{\Delta Q}{\Delta t}$

$I = nqvA$

Resistors in series $R = R_1 + R_2 + R_3$

Resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Particle nature of light

Photon model $E = hf$

Einstein's photoelectric equation $hf = \phi + \frac{1}{2}mv^2_{max}$

de Broglie wavelength $\lambda = \frac{h}{p}$

Unit 4

Further mechanics

Impulse	$F\Delta t = \Delta p$
Kinetic energy of a non-relativistic particle	$E_k = \dfrac{p^2}{2m}$
Motion in a circle	$v = \omega r$
	$T = \dfrac{2\pi}{\omega}$
	$a = \dfrac{v^2}{r}$
	$a = r\omega^2$
Centripetal force	$F = ma = \dfrac{mv^2}{r}$
	$F = mr\omega^2$

Electric and magnetic fields

Electric field	$E = \dfrac{F}{Q}$
Coulomb's law	$F = \dfrac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$
	$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \dfrac{V}{d}$
Electrical potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
Capacitance	$C = \dfrac{Q}{V}$
Energy stored in capacitor	$W = \frac{1}{2}QV$
	$W = \frac{1}{2}CV^2$
	$W = \frac{1}{2}\dfrac{Q^2}{C}$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$

Resistor-capacitor discharge $I = I_0 e^{-t/RC}$

$V = V_0 e^{-t/RC}$

$\ln Q = \ln Q_0 - \dfrac{t}{RC}$

$\ln I = \ln I_0 - \dfrac{t}{RC}$

$\ln V = \ln V_0 - \dfrac{t}{RC}$

In a magnetic field $F = Bqv \sin \theta$

$F = BIl \sin \theta$

Faraday's and Lenz's laws $\mathscr{E} = \dfrac{-\mathrm{d}(N\phi)}{\mathrm{d}t}$

Nuclear and particle physics

In a magnetic field $r = \dfrac{p}{BQ}$

Mass-energy $\Delta E = c^2 \Delta m$

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

Unit 5

Thermodynamics

Heating	$\Delta E = mc\Delta\theta$
	$\Delta E = L\Delta m$
Ideal gas equation	$pV = NkT$
Molecular kinetic theory	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

Nuclear decay

Mass-energy	$\Delta E = c^2\Delta m$
Radioactive decay	$A = \lambda N$
	$\frac{dN}{dt} = -\lambda N$
	$\lambda = \frac{\ln 2}{t_{1/2}}$
	$N = N_0 e^{-\lambda t}$
	$A = A_0 e^{-\lambda t}$

Oscillations

Simple harmonic motion	$F = -kx$
	$a = -\omega^2 x$
	$x = A\cos\omega t$
	$v = -A\omega\sin\omega t$
	$a = -A\omega^2\cos\omega t$
	$T = \frac{1}{f} = \frac{2\pi}{\omega}$
	$\omega = 2\pi f$
Simple harmonic oscillator	$T = 2\pi\sqrt{\frac{m}{k}}$
	$T = 2\pi\sqrt{\frac{l}{g}}$

Astrophysics and cosmology

Gravitational field strength	$g = \dfrac{F}{m}$
Gravitational force	$F = \dfrac{Gm_1m_2}{r^2}$
Gravitational field	$g = \dfrac{Gm}{r^2}$
Gravitational potential	$V_{\text{grav}} = \dfrac{-Gm}{r}$
Stefan-Boltzmann law	$L = \sigma AT^4$
Wien's law	$\lambda_{\text{max}}T = 2.898 \times 10^{-3}\,\text{m K}$
Intensity of radiation	$I = \dfrac{L}{4\pi d^2}$
Redshift of electromagnetic radiation	$z = \dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$
Cosmological expansion	$v = H_0 d$

BLANK PAGE

BLANK PAGE