

Define the *radian*.

angle (subtended) where arc (length) is equal to radius	M1
(angle subtended) at the centre of a circle	A1

With reference to velocity and acceleration, describe uniform circular motion.

constant speed or constant magnitude of velocity	B1
acceleration (always) perpendicular to velocity	B1

State what is meant by *centripetal* acceleration.

acceleration perpendicular to velocity	B1
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State what is meant by a *field of force*.

region (of space)	B1
where a particle experiences a force	B1

State what is meant by a line of force in a gravitational field.

<i>either</i> direction of force on a (small test) mass	B1
<i>or</i> direction of acceleration of a (small test) mass	

By reference to the pattern of the lines of gravitational force near to the surface of the Earth, explain why the acceleration of free fall near to the Earth's surface is approximately constant.

Any three from: - the lines are radial - near the surface the lines are (approximately) parallel - parallel lines so constant field strength - constant field strength hence constant acceleration of free fall	B3
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State what is meant by a *gravitational force*.

force acting between two masses or force on mass due to another mass or force on mass in a gravitational field	B1
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State the equation for the gravitational force F between two point masses m_1 and m_2 that are separated by a distance r . State the meaning of any other symbols you use.

$F = (Gm_1m_2) / r^2$	M1
where G is the gravitational constant	A1

Define gravitational field.

force per unit mass	B1
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Define *gravitational field strength*.

(gravitational) force per unit mass	B1
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Explain why, at the surface of a planet, gravitational field strength is numerically equal to the acceleration of free fall.

acceleration = F/m , field strength = F/m , so equal	B1
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Explain how it is possible for the gravitational field strength to be zero despite the presence of two large masses nearby.

(gravitational) fields from the Earth and Moon are in opposite directions	B1
(resultant is zero where gravitational) fields are equal (in magnitude)	B1

Explain how a satellite may be in a circular orbit around a planet.

gravitational force (of attraction between satellite and planet)	B1
<u>provides / is</u> centripetal force (on satellite about the planet)	B1

A geostationary satellite orbits the Earth. The orbit of the satellite is circular and the period of the orbit is 24 hours.

(i) State **two** other features of this orbit.

above the equator	B1
from west to east	B1

Each planet orbits at constant speed.
Explain whether the planets are in equilibrium.

velocity changes/direction of motion changes/there is an acceleration/there is a resultant force so not in equilibrium	B1
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Define *gravitational potential*.

work done per unit mass	B1
(work done in) moving mass from infinity	B1

State the relationship between gravitational potential and gravitational field strength.

(gravitational) field strength equals (gravitational) potential gradient	M1
reference to minus sign	A1

Explain why ϕ is negative throughout

potential is zero at infinity	B1
(gravitational) force is attractive	B1
(test) mass getting closer (from infinity) loses potential energy	B1

State **one** similarity and **one** difference between the electric field lines and the gravitational field lines around an isolated positively charged metal sphere.

similarity: lines are radial / greater separation of lines with increased distance from the sphere	B1
difference: gravitational lines directed towards sphere <u>and</u> electric lines directed away from sphere	B1

what may be deduced from the difference in the temperatures of two objects,

direction or rate of transfer of (thermal) energy or (if different,) not in thermal equilibrium/energy is transferred	B1
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the basic principle by which temperature is measured.

uses a property (of a substance) that changes with temperature	B1
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explain why two thermometers may not give the same temperature reading for an object.

- temperature scale assumes linear change of property with temperature - physical properties may not vary linearly with temperature - agrees only at fixed points Any 2 points.	B2
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Explain what is meant by the statement that two bodies are in *thermal equilibrium*.

no net energy transfer between the bodies

or

bodies are at the same temperature

B1 [1]

Define specific heat capacity.

(thermal) energy per unit mass (to cause temperature change)	B1
(thermal) energy per unit change in temperature	B1

State what is meant by *specific latent heat*.

(thermal) energy per (unit) mass (to change state)	B1
(heat transfer during) change of state at constant temperature	B1

Define *specific latent heat of fusion*.

(thermal) energy per unit mass (to cause change of state)	B1
(energy transfer during) change of state between solid and liquid at constant temperature	B1

Define specific latent heat of vaporisation.

(thermal) energy per unit mass	B1
energy to change state between liquid and gas at constant temperature	B1

Explain why, although the power of the heater is changed, the rate of loss of thermal energy to the surroundings may be assumed to be constant.

temperature difference (between liquid and surroundings) does not change	B1
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State what is observed by the student that shows that the ice is melting at a constant rate.

Any one from: - rate of increase in mass (of beaker and water) is constant - level of water rises at a constant rate - volume of water (in beaker) increases at a constant rate - constant time between drops - constant rate of dripping	B1
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During melting, a solid becomes liquid with little or no change in volume.

Use kinetic theory to explain why, during the melting process, thermal energy is required although there is no change in temperature.

(during melting,) bonds between atoms/molecules are broken	B1
potential energy of atoms/molecules is increased	B1
no/little work done so required input of energy is thermal	B1

the Avogadro constant N_A ,

number of atoms/nuclei in 12 g of carbon-12 B1 [1]

the mole.

amount of substance M1

containing N_A (or 6.02×10^{23}) particles/molecules/atoms
or

which contains the same number of particles/atoms/molecules as there are atoms in 12g of carbon-12 A1 [2]

State what is meant by an *ideal gas*.

gas that obeys equation $pV = \text{constant} \times T$	M1
symbols p , V and T explained	A1

The equation of state for an ideal gas can be written as

$$pV = NkT.$$

State the meaning of each of the symbols in this equation.

p = pressure (of gas), V = volume (of gas) and k = Boltzmann constant	B1
N = number of molecules	B1
T = thermodynamic temperature	B1

assumptions of the kinetic theory of gases.

• <u>molecules</u> have negligible volume (compared with gas/container) • no forces between <u>molecules</u> (except during collisions) • <u>molecules</u> are in random motion • collisions are instantaneous	B2
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e.g. time of collisions negligible compared to time between collisions

no intermolecular forces (except during collisions)

random motion (of molecules)

large numbers of molecules

(total) volume of molecules negligible compared to volume of containing vessel
or

average/mean separation large compared with size of molecules

Describe the motion of molecules in a gas, according to the kinetic theory of gases.

random/haphazard	B1
constant velocity or speed in a straight line between collisions or distribution of speeds/different directions	B1

State what is meant by an *elastic* collision.

no loss of <u>kinetic</u> energy	B1
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Explain how movement of the gas molecules causes pressure in the container.

Any 3 from: - molecule collides with wall - momentum of molecule changes during collision (with wall) - force on molecule so force on wall - many forces act over surface area of container exerting a pressure	B3
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State what is meant by the *internal energy* of a system.

total potential energy and kinetic energy (of molecules/atoms)	M1
reference to <u>random</u> motion of molecules/atoms	A1

By reference to intermolecular forces, explain why the change in internal energy of an ideal gas is equal to the change in total kinetic energy of its molecules.

internal energy = ΣE_K (of molecules) + ΣE_P (of molecules) or no forces between molecules	B1
potential energy of molecules is zero	B1

The first law of thermodynamics may be expressed as

$$\Delta U = (+q) + (+w)$$

where ΔU is the increase in internal energy of the system.

State the meaning of:

+q: thermal energy transfer to system	B1
+w: work done on system	B1

State what is represented by a negative value of ΔU .

<u>decrease</u> in internal energy	B1
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State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

no (total) change (in internal energy)	B1
gas returns to its original temperature	B1

Explain what is meant by the *natural frequency of vibration* of a system.

frequency at which body will vibrate when there is no (resultant external) resistive force acting on it OR frequency at which body will vibrate when there is no driving force / external force acting on it	B1
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forced frequency,

frequency at which object is made to vibrate/oscillate

B1 [1]

State, by reference to simple harmonic motion, what is meant by *angular frequency*.

(angular frequency =) $2\pi \times \text{frequency}$ or $2\pi/\text{period}$	B1
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State what is meant by *simple harmonic motion*.

acceleration (directly) proportional to displacement	B1
acceleration in opposite <u>direction</u> to displacement or acceleration (directed) towards equilibrium position	B1

State the defining equation for simple harmonic motion. Identify the meaning of each of the symbols used to represent physical quantities.

$a = -\omega^2 x$	M1
a = acceleration, x = displacement from equilibrium position and ω = angular frequency	A1

State what is meant by damping.

loss of (total) energy (of system)	B1
due to resistive forces	B1

resonance.

maximum amplitude of vibration of oscillating body	B1	
when forced frequency equals natural frequency (of vibration)	B1	[2]

State what is indicated by the direction of an electric field line.

(field line indicates) direction of force	B1
force on a positive charge	B1

For any point outside a spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre. By reference to electric field lines, explain this.

electric field lines are radial/normal to surface (of sphere)	B1
electric field lines <u>appear</u> to originate from centre (of sphere)	B1

State Coulomb's law.

force proportional to product of charges and inversely proportional to the square of the separation	M1
reference to point charges	A1

State what is meant by *electric field strength*.

force per unit charge	B1
(force on) positive charge	B1

State an expression for the electric field strength E at a distance r from a point charge Q in a vacuum.

State the name of any other symbol used.

$(E =) Q / 4\pi\epsilon_0 r^2$	M1
where ϵ_0 is permittivity (of free space)	A1

State **one** similarity and **one** difference between the electric field due to a point charge and the gravitational field due to a point mass.

similarity – any one point from: • both have an inverse square variation • both decrease with distance • both are radial	B1
difference – any one point from: • gravitational field always towards (the mass) • electric field can be towards or away from (the charge)	B1

Define electric potential at a point.

work done per unit charge	B1
work done (on charge) in moving positive charge from infinity (to the point)	B1

State the relationship between electric potential and electric field strength at a point.

field strength = potential gradient	M1
'–' sign included or directions discussed	A1

State what is meant by the *capacitance* of a parallel plate capacitor.

charge / potential	M1
charge is on one plate, potential is p.d. between the plates	A1

Suggest why, when the capacitor is connected across the terminals of a battery, the capacitor stores energy, not charge.

equal and opposite charges on the plates so no resultant charge	B1
+ve and –ve charges separated so energy stored	B1

State **three** functions of capacitors in electrical circuits.

any three points from:	B3
- smoothing - timing/(time) delay - tuning - oscillator - blocking d.c. - surge protection - temporary power supply	

Show that the combined capacitance C of the capacitors is given by

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

$$V = V_1 + V_2 + V_3$$

B1

$$\text{either } Q/C = Q/C_1 + Q/C_2 + Q/C_3 \text{ or } V/Q = V_1/Q + V_2/Q + V_3/Q$$

$$\text{and so } 1/C = 1/C_1 + 1/C_2 + 1/C_3$$

B1 [2]

Show that the combined capacitance C_T of the two capacitors is given by

$$C_T = C_1 + C_2.$$

p.d. across both capacitors = E	B1
$Q_T = Q_1 + Q_2$	B1
$C_T E = C_1 E + C_2 E$ hence $C_T = C_1 + C_2$	B1

State what is meant by a *magnetic field*.

region where there is a force exerted on	M1
a current-carrying conductor or a <u>moving</u> charge or a magnetic material/magnetic pole	A1

Define magnetic flux density.

force per unit current	M1
force per unit length	M1
current / wire is perpendicular to (magnetic) field (lines)	A1

Define the *tesla*.

newton per ampere per metre	M1
where current/wire is perpendicular to magnetic field	A1

State what is meant by a *field of force*.

region (of space)	B1
where an object/particle experiences a force	B1

State the **two** conditions that must be satisfied for a copper wire, placed in a magnetic field, to experience a magnetic force.

there must be a current (in the wire)	B1
(wire) must be at a non-zero angle to the magnetic field	B1

State **two** situations in which a charged particle in a magnetic field does **not** experience a force.

(particle is) stationary/not moving	B1
(particle is) moving parallel to the (magnetic) field	B1

Explain why the electrons follow a circular path when inside the region of the magnetic field.

force is (always) perpendicular to the velocity / direction of motion	B1
magnetic force provides the centripetal force or force perpendicular to motion causes circular motion	B1
magnitude of force (due to the magnetic field) is constant or no work done by force or the force does not change the speed	B1

Explain the use of a uniform magnetic field and a uniform electric field for the selection of the velocity of charged particles. You may draw a diagram if you wish.

electric and magnetic fields normal to each other	B1
velocity of particle normal to both fields	B1
forces (on particle) due to fields are in opposite directions	B1
<u>forces are equal</u> for particles with a particular speed/for a selected speed/for speed given by $v = E(q)/B(q)$	B1

Explain why a constant voltage V_H is developed between the faces

charge carriers moving normal to (magnetic) field	B1
<u>charge carriers</u> experience a <u>force</u> normal to I (and B)	B1
charge build-up sets up electric field across the slice or build-up of charges results in a p.d. across the slice	B1
charge stops building up/ V_H becomes constant when $F_B = F_E$	B1

Define *magnetic flux*.

flux density $\times$ area	M1
where flux is normal to area	A1
or	
flux density $\times$ area $\times \sin \theta$	(M1)
where θ is angle between flux direction and (plane of) area	(A1)

State what is meant by the *magnetic flux linkage* of a coil.

(magnetic) flux density $\times$ area	B1
magnetic flux density normal to area or reference to cross-sectional area or $\times \sin$ (angle between B and A)	B1
$\times$ number of turns on coil	B1

State Faraday's law of electromagnetic induction.

(induced) e.m.f. proportional to rate	M1
of change of (magnetic) flux (linkage)	A1

State Lenz's law of electromagnetic induction.

direction of induced e.m.f.	M1
such as to (produce effects that) oppose the change that caused it	A1

By reference to heating effect, explain what is meant by the *root-mean-square (r.m.s.)* value of an alternating current.

the steady current or the direct current	M1
that produces the same heating effect (as the alternating current)	A1

State what is meant by rectification.

conversion (from a.c.) to d.c.	B1
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Smoothing

- *The reduction in the variation of the output voltage or current by adding a single capacitor with capacitance C is connected in parallel with a load resistor of resistance R*

State what is meant by a *photon*.

quantum of energy	M1
of electromagnetic radiation	A1

the *photoelectric effect*

emission of electrons (from a metal surface)	B1
when electromagnetic radiation is incident (on electrons)	B1

With reference to the photoelectric effect, state what is meant by the *threshold frequency*.

minimum frequency for electron(s) to be emitted (from surface) M1
reference to frequency of electromagnetic radiation/ photon A1

or

frequency causing emission of electron(s)
from surface with zero kinetic energy (M1)
reference to frequency of electromagnetic radiation/ photon (A1) [2]

State what is meant by the work function energy of a metal.

photon energy (to remove electron)	B1
minimum energy to remove electron or energy to remove electron from surface or energy to remove electron with zero kinetic energy	B1

State **three** pieces of evidence provided by the photoelectric effect for a particulate nature of electromagnetic radiation.

Any three points from: • (max) energy of emitted electrons depends on frequency • (max) energy of emitted electrons does not depend on intensity • rate of emission of electrons depends on intensity (at constant frequency) • existence of frequency below which no emission of electrons • instantaneous emission of electrons • increasing the frequency at constant intensity decreases the rate of emission of electrons	B3
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Describe **two** phenomena associated with the photoelectric effect that cannot be explained using a wave theory of light.

two from: - there is a frequency below which electrons are not ejected <u>maximum</u> energy of electron depends on frequency <u>maximum</u> energy of electrons does not depend on intensity - emission of electrons is instantaneous	B2
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Electromagnetic radiation of a single constant frequency is incident on a metal surface. This causes an electron to be emitted.

Explain why the maximum kinetic energy of the electron is independent of the intensity of the incident radiation.

- frequency determines energy of photon - intensity determines number of photons (per unit time) - intensity does not determine energy of a photon <i>Any two points, 1 mark each</i>	B2
kinetic energy (of the electron) depends on the energy of one photon	B1

Describe the appearance of a visible line emission spectrum, as seen using a diffraction grating.

mostly dark/dark background	B1
coloured lines	B1

The spectrum of the light emerging from the cloud of cool gas is viewed using a diffraction grating.

Explain why this spectrum contains a number of dark lines.

electrons (in gas atoms/molecules) interact with photons	B1
photon energy causes electron to move to higher energy level/to be excited	B1
photon energy = difference in energy of (electron) energy levels	B1
when electrons de-excite, photons emitted in all directions (so dark line)	B1

Explain how the emission spectrum provides evidence for the existence of discrete energy levels for the electron in a hydrogen atom.

- energy of photon has a corresponding frequency - change in electron energy level emits a single photon - photon energy = difference in energy levels - discrete frequencies must have come from discrete energy gaps - discrete energy changes imply discrete energy levels Any three points, 1 mark each	B3
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State what is meant by the *de Broglie wavelength*.

particle/electron has a wavelength (associated with it)	B1
dependent on its momentum or when/because particle is moving	B1

State what is meant by *radioactive decay*.

unstable nucleus	B1
emission of particles/photons	B1
emission is spontaneous or (particles/radiation) are ionising	B1

Radioactive decay is both a random and a spontaneous process.

(a) State what is meant by:

(i) random

(ii) spontaneous.

(i)	cannot predict when a (particular) nucleus will decay or cannot predict which nucleus will decay next	B1
(ii)	not affected by external / environmental factors	B1

Explain what is meant by the *binding energy* of a nucleus.

(minimum) energy required to separate the nucleons	M1
to infinity	A1

Define radioactive *decay constant*.

probability of decay (of a nucleus)	M1
per unit time	A1

Define radioactive *half-life*.

time for number of atoms/nuclei or activity to be reduced to one half M1

reference to (number of...) original nuclide/single isotope
or

reference to half of original value/initial activity A1 [2]

State what is meant by *nuclear fusion* and *nuclear fission*.

fusion: two nuclei <u>combine</u> to form a (single) nucleus	B1
fission: a (single) large nucleus <u>divides</u> to form (smaller) nuclei	B1
Any one from: - fusion is initiated by (very) high temperatures - fission is initiated by neutron bombardment - resulting nuclei in fission are of similar size (both processes) release energy - binding energy per nucleon increases - total binding energy increases - fission involves release of neutrons	B1

Explain what is meant by *gamma radiation* (γ -radiation).

(photons of) electromagnetic radiation M1

emitted from nuclei A1 [2]

Explain what is meant by a tracer.

substance containing radioactive nuclei that is introduced into the body or substance containing radioactive nuclei that is absorbed by the tissue being studied	B1
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Explain what is meant by annihilation.

a particle interacting with its antiparticle so that mass is converted into energy	B1
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State the names of the particles involved in the annihilation process.

electron(s) and positron(s)	B1
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Positrons are not naturally present in the body.

Explain how positrons come to be present in the body during PET scanning.

introduction of tracer (into the body)	M1
containing a β^+ emitter	A1

Explain how positrons cause the emission of gamma-radiation from the body during PET scanning.

positron interacts with electron	B1
(pair) annihilation occurs	B1
mass of particles converted into gamma photons	B1

Explain how the gamma photons are used to produce an image.

Any 3 from: - the two gamma photons travel in opposite directions - gamma photons detected (outside body / by detectors) - gamma photons arrive (at detector) at different times - determine location of production (of gamma) - image of tracer concentration in tissue produced	B3
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Explain how X-rays are produced for use in medical diagnosis.

electrons are accelerated (by an applied p.d.)	B1
electrons hit target	B1
X-rays produced when electrons decelerate	B1

State, for an X-ray image, what is meant by:

contrast.

difference in degrees of blackening	B1
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State how, in a modern X-ray tube, the intensity of the X-ray beam and its hardness are controlled.

intensity: vary filament current/p.d. across filament	B1
hardness: vary accelerating potential difference	B1

State the purpose of computed tomography (CT scanning).

to produce a 3-dimensional image of structure/body	B1
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Outline the principles of CT scanning.

X-rays (are used)	B1
scanning in sections	B1
scanning from many angles	B1
image of each section is 2-dimensional	B1
scanning repeated for many sections or images of many sections combined together	B1

Explain the principles of the **generation** of ultrasound waves for use in medical diagnosis.

quartz crystal	B1
alternating p.d. across crystal causes it to vibrate	B1
resonance occurs when frequency of p.d. matches natural frequency of crystal	B1
natural frequency of crystal is in ultrasound range	B1

Outline the **use** of ultrasound to obtain diagnostic information about internal body structures.

(ultrasound) pulse	B1
reflected at boundaries	B1
gel is used to minimise reflection at skin or generated <u>and</u> detected by quartz crystal	B1
time delay between generation and detection gives information about depth	B1
intensity (of reflected wave) gives information about nature of boundary	B1

Describe the function of the quartz crystal.

generates <u>ultrasound</u>	B1
detects <u>reflected</u> ultrasound	B1
applied p.d. causes crystal to vibrate or vibrations cause crystal to generate an e.m.f.	B1

Explain why ultrasound used in medical diagnosis is emitted in pulses.

Any 2 from: - allows the reflected signal to be distinguished from the emitted signal - detection occurs in the time between emitted pulses (reflection of ultrasound) detected by same probe / transducer / crystal - cannot emit and detect at same time (hence pulses)	B2
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Define *specific acoustic impedance*.

product of density and speed	M1
speed of ultrasound in medium	A1

Describe, qualitatively, how the specific acoustic impedances of two materials affect the intensity reflection coefficient at a boundary between the materials.

difference between (the specific acoustic impedances)	C1
- if similar/same then reflection coefficient is zero/very low - if very different then reflection coefficient is (nearly) 1 - the lower the difference means lower the reflection coefficient (any one point)	A1

Explain the principles of the **detection** of ultrasound waves used in medical diagnosis.

piezo-electric crystal	B1
ultrasound makes crystal vibrate / resonate	B1
vibration produces (alternating) e.m.f. / p.d. across crystal	B1

State what is meant by luminosity of a star.

total power of radiation emitted (by the star)	B1
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State Wien's displacement law.

wavelength of maximum intensity is inversely proportional to (thermodynamic) temperature	B1
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State what is meant by redshift.

apparent wavelength is greater or wavelength is greater than known value	B1
(due to) movement of star away (from observer)	B1

Explain how cosmologists are able to determine that light from a distant star has undergone redshift.

by examining the (lines in the) spectrum (of light from the star)	B1
and comparing with known spectrum	B1

State Hubble's law.

speed is (directly) proportional to distance	M1
where speed is speed of recession of galaxy (from observer) and distance is distance of galaxy away from observer	A1

Explain how cosmologists use observations of emission spectra from stars in distant galaxies to determine that the Universe is expanding.

wavelengths (of spectral lines) are greater (than their known values)	B1
redshift shows stars (in distant galaxies) moving away from Earth	B1

Explain how Hubble's law and the idea of the expanding Universe lead to the Big Bang theory of the origin of the Universe.

(all) parts of Universe moving away from each other	B1
more distant objects are moving away faster	B1
matter must have been close together / very dense in the past	B1